THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

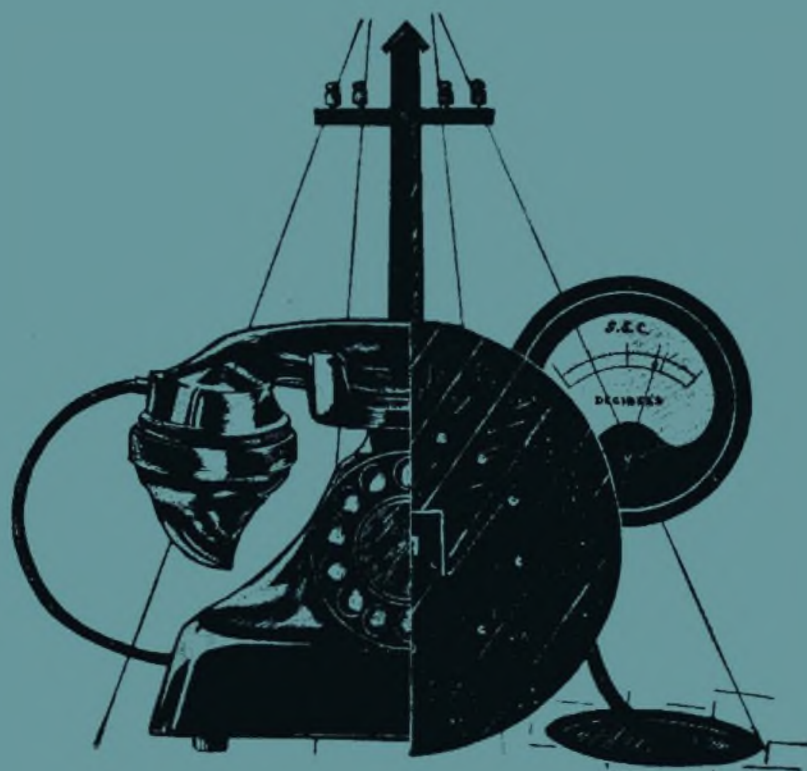
VOL. 41 JANUARY 1949 PART 4

CONTENTS

	PAGE
THE LONDON-BIRMINGHAM TELEVISION CABLE—Part 1—General System and Electrical Requirements—H. Stanesby, M.I.E.E. (Post Office), and W. K. Weston, B.Sc.(Eng.), M.I.E.E. (Standard Telephones and Cables Ltd.)	183
A SPEECH SPECTRUM ANALYSER	188
THE POST OFFICE PHOTOTELEGRAPH SERVICE TO EUROPE—A. Wilcock, A.M.I.E.E.	189
THE BRITISH TELEPHONE TECHNICAL DEVELOPMENT COMMITTEE—R. W. Palmer, M.I.E.E., and W. L. Brimmer	193
VACUUM TECHNIQUE—SOME GENERAL PRINCIPLES AND POST OFFICE APPLICATIONS—J. E. Thwaites, A.M.I.E.E., and H. E. Pearson, B.Sc.(Eng.), A.M.I.Mech.E.	199
POISONING EFFECTS IN OXIDE-CATHODE VALVES—G. H. Metson, M.C., Ph.D., M.Sc.(Eng.), A.M.I.E.E.	204
PNEUMATIC TUBES—C. A. R. Pearce, M.Sc.(Eng.), A.C.G.I., A.M.I.E.E.	206
TUNGSTEN CARBIDE TIPPED TOOLS—F. S. Lewis	213
MECHANICAL TRUNK FEE ACCOUNTING—Part 1—Principles of Punched Card Accounting—K. M. Heron, A.M.I.E.E,. and D. L. Benson, Grad.I.E.E.	216
AN ELECTRONIC REGENERATIVE REPEATER FOR 7½-UNIT START-STOP TELEGRAPH SIGNALS—R. O. Carter, M.Sc., A.C.G.I., D.I.C., A.M.I.E.E., L. K. Wheeler, B.Sc.(Eng.), A.M.I.E.E., and A. C. Frost	222
A MINIATURE AUDIO-FREQUENCY AMPLIFIER—W. T. Duerdoth, B.Sc., A.M.I.E.E., and J. Garlick, B.Sc., A.M.I.E.E.	228
NOTES AND COMMENTS	234
INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS	234
REGIONAL NOTES	235
STAFF CHANGES	240
INDEX TO VOL. 41	243
BOOK REVIEWS	192, 212, 221, 227, 233

Price 1/6 net

THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS



THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

Vol. 41 | January, 1949 | Part 4

The London-Birmingham Television Cable

H. STANESBY, M.I.E.E. (Post Office) and
W. K. WESTON, B.Sc.(Eng.), M.I.E.E.
(Standard Telephones and Cables Ltd.)

Part I.—General System and Electrical Requirements

U.D.C. 621.315.212 : 621.397.5

A cable is being laid between London and Birmingham incorporating two 0·975 inch and four 0·375 inch coaxial tubes. The cable is designed to transmit very-high-definition or colour television, 405-line television and broad-band telephony simultaneously. The large tubes may ultimately transmit frequencies up to 30 Mc/s or more with repeaters at 3-mile intervals. Details are given of the performance requirements, the cable design, and the results obtained on repeater sections. Part 1 discusses the general requirements of the system and details the electrical performance necessary. Part 2 will give details of the cable design, construction and test results.

Introduction.

SOUND broadcasting depends largely on items that are relayed from one part of the country to another over landlines, and there is little doubt that television broadcasting will evolve in the same way. Moreover, the cost of providing a full and satisfying television programme is so high that as television extends to other parts of the country it will be necessary to transmit major items to as many centres as possible.

All development of the transmission of television signals over long distances stopped in Great Britain between 1939 and 1945 because of the war, and most of the equipment and cables that had previously been used for development work were absorbed in providing additional trunk telephone circuits. Meanwhile, however, ideas were maturing and work was proceeding in the United States, and in 1943, H.M. Government appointed a committee under the Chairmanship of Lord Hankey, " To prepare plans for the reinstatement and development of the television service after the war. . ." In its report[1], published in 1945, this Committee recommended that after the war, the 405-line system be reinstated in London and extended first to Birmingham and then to other provincial centres, and that the new stations relay the studio programme from London. It also recommended, among other things, that developments be planned on the assumption that a higher definition system, perhaps incorporating colour, would for some time be operated side by side with the present system. These recommendations form the framework within which the Post Office has planned the transmission by cable of television signals to Birmingham.*

[1] " Report of the Television Committee 1943." Published by H.M. Stationery Office, 1945.

* The Postmaster-General has more recently proposed that the present number of lines, 405, should not be altered for a number of years; and has indicated that the development of a substantially improved system, which might include colour, would take several years, and would be prejudiced if the very slight improvement that would result from increasing the number of lines by 100 or 200 were introduced.

General Arrangement of Cable Connection.

The link between the existing B.B.C. television transmitter and studios at Alexandra Palace, London, and the new transmitter being installed near Sutton Coldfield, Birmingham, will consist of three parts: the main cable between London and Birmingham and a short tail cable at each end. Because it would be uneconomic to provide long-distance wide-band cables exclusively for television, the main cable will form part of the Post Office trunk network and terminate at Museum exchange, London, and Telephone House, Birmingham. Referring to Fig. 1, the end connections to the transmitters will be provided by tail cables between Museum exchange and Alexandra Palace and between Telephone House and Sutton Coldfield.

At present all studio items originate at Alexandra Palace ; but the B.B.C. include in their programmes a considerable number of outside broadcasts, i.e. " O.B.s," which are transmitted to B.B.C. premises by the Post Office over its television O.B. network or over specially equalised telephone pairs, or by the B.B.C. over their O.B. radio link. The B.B.C. therefore propose to set up a position at Broadcasting House, London, a few hundred yards from Museum exchange, where they can control the routing of programme material, and a similar B.B.C. switching position is being provided at Broad Street, Birmingham, near Telephone House. The Post Office terminals will therefore be connected to the B.B.C. switching positions by short cables which can be regarded as providing extensions of the main and tail cables ; in other words, there will be three cable links in tandem between the London and Birmingham transmitters : Alexandra Palace—Museum ; Museum —Telephone House ; Telephone House—Sutton Coldfield ; and for engineering purposes the Post Office will control them from Museum and Telephone House while the B.B.C. will have access to them at their near-by switching positions and, of course, at the television transmitters. Museum and Telephone House will also be the terminals of a radio circuit that is being provided as an alternative, 405-line television, link between London and Birmingham[2]; and the tail cables, including the short extensions to Broadcasting House and Broad Street, will be used with the radio link or the main cable as required.

Initially, the cable system will transmit vision signals of 405-line definition only and the video bandwidth will be approximately 3 Mc/s, nearly 50 per cent. greater than is necessary for equal horizontal and vertical definition on the picture,† but in accordance with the 1943 Television Committee's recommendation the whole system is being planned so that it can ultimately be equipped to handle culty would be increased if attempts were made to transmit low- and high-definition signals alongside each other over the same conductors. Separate pairs are, therefore, being provided for the two sets of signals. Coaxial tubes, i.e. coaxial pairs, are used for the same reason that led to their adoption for wide-band carrier telephony: because the frequency at which the loss rises to a given value per unit length is roughly twice as high on a coaxial tube as it is on a balanced pair of the same cross-section, and because the design of the line equipment is much simpler if unbalanced circuits are used with terminal equipment

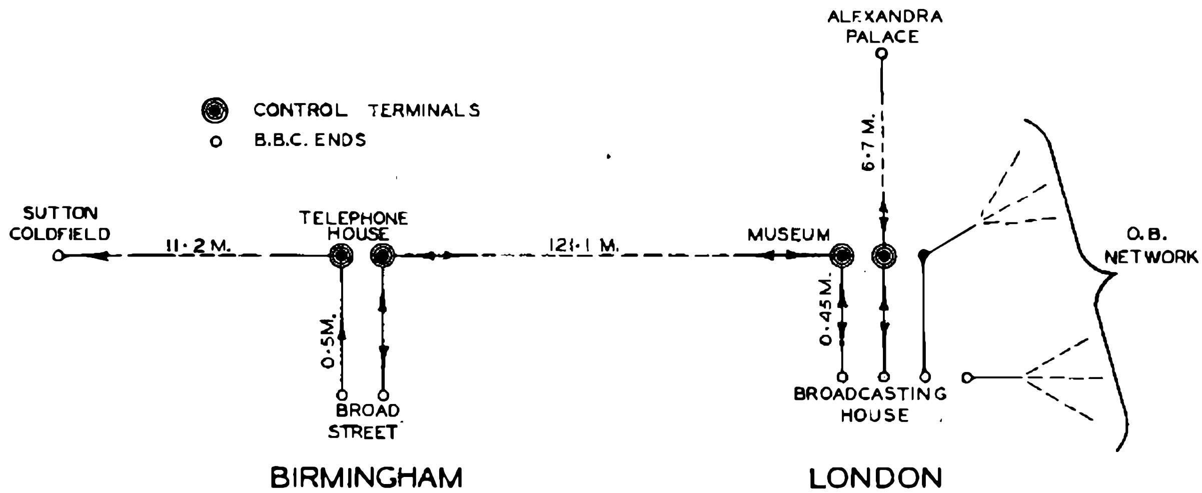


FIG. 1.—GENERAL ARRANGEMENT OF LONDON-BIRMINGHAM TELEVISION CABLE AND TAIL CABLES.

very-high-definition monochrome or colour television at the same time as 405-line signals.

It seems likely that for some time most programme material will pass from Alexandra Palace or the London O.B. cable network to Birmingham; but items will no doubt be transmitted in the other direction to an increasing extent as television becomes more firmly established in other parts of the country; the cables from Telephone House to Museum and Alexandra Palace will therefore provide for two-way transmission.

GENERAL SYSTEM REQUIREMENTS

Number of Television Tubes.

The cable system must ultimately be capable of transmitting 405-line and high-definition signals simultaneously. There is fairly general agreement that a video band-width of the order of 3 Mc/s is adequate for 405-line 50 frames/second television; but for very-high-definition television, or colour television, bandwidths of 10 Mc/s or more will be necessary. Up to the present, limitations in valves have made it very difficult to design repeaters for such wide bands, free from harmonic and intermodulation distortion, and sufficiently immune to the effects of supply variations, valve ageing, etc.; and the difficulty would be increased if attempts were made to transmit low- and high-definition signals alongside each other over the same conductors.

of a type that makes it unnecessary to transmit very low frequencies along the cable.

Except for the tail cable to the Birmingham transmitter the system will provide for simultaneous transmission in both directions. There are objections to using the same tube for both directions, either (*a*) simultaneously, by using half the frequency band for each direction, or (*b*) on a reversible basis by switching line and terminal equipment. Alternative (*a*) would involve the use of filters to separate the "go" and "return" channels, which would introduce prohibitive delay distortion, and (*b*) would be complicated, and would lack operating flexibility. Two tubes are therefore being provided for 405-line television and two for high definition.

Size of Television Tubes.

The most economical method of transmitting television signals over coaxial cable is by the asymmetric or vestigial sideband system, which needs a bandwidth rather wider than the video frequency band. For a reasonable compromise between the various factors involved it is perhaps 15 per cent. larger. This means that the channels used for transmitting 405-line television will be called upon to handle a band of approximately 3·5 Mc/s. This can just be accommodated comfortably on coaxial tubes in which the outer conductor has an inside diameter of 0·375 in., with repeaters at 6-mile intervals, transmitting frequencies up to 4 Mc/s; indeed, the C.C.I.F. have

[2] *P.O.E.E.J.*, Vol. 41, pp. 111 and 112.

† On the assumption that the image on a television screen of a very narrow nearly horizontal line, has an average width of 1·4 times the line spacing (see *Proc.I.R.E.*, Vol. 26, p. 540 *et seq.*).

recently recommended that a European broad-band system be planned on such a basis. The 405-line television tubes will therefore be of this size.

It has not been so easy to determine the best diameter and the other requirements for the high-definition tubes because, of course, the precise form of the signals that will ultimately be transmitted is not yet known. However, there is no doubt that wide bands will have to be handled and frequencies up to perhaps 30 or even 40 Mc/s may be employed, which makes it desirable to use as large a tube as possible to reduce attenuation. Bearing in mind the size limitation imposed by Post Office ducts* and the need to accommodate two high-definition tubes and two 405-line television tubes in the cable, it appeared that the former should have an overall diameter of about 1 in.

To confirm that such a tube diameter would be satisfactory, certain assumptions have been made about the signals that will be transmitted and the results that could be obtained on very-wide-band repeaters with present-day valves. It has been assumed that:

(*a*) A video band of 12 Mc/s is desirable, which, with a vestigial sideband system, leads to a cable bandwidth of about 14 Mc/s.

(*b*) It is difficult to avoid appreciable second order modulation in repeaters covering very wide bands, which makes it desirable to avoid bands much exceeding a 2 : 1 frequency ratio, i.e. say, 12-26 Mc/s for a 14-Mc/s bandwidth.

(*c*) With present-day technique it would be very inconvenient to employ repeater sections with a loss at 26 Mc/s much above 30 db; this is because the sending level would be limited by the overload point of the repeaters and the receiving level should not fall to the point at which noise becomes troublesome.

(*d*) The repeater spacing should be equal to, or a submultiple of, that used for the 0·375-in. tubes, i.e. 6/N miles where N is an integer.

The attenuation, A, of a coaxial tube of the type used for long distance transmission is given approximately by:

$$A = 1{\cdot}52 \sqrt{f}/D \text{ decibels/mile} \quad \ldots(1)$$

where f is the frequency in megacycles per second and D is the inner diameter of the outer conductor in inches. If D is just less than 1 in., say, 0·975 in., which is in fact the value that has been adopted, the loss at 26 Mc/s will be 8 db/mile, i.e. 48 db for the 6-mile repeater sections planned for the 0·375-in. tubes. Requirements (*c*) and (*d*), above, therefore indicate that a nominal 3-mile spacing would be needed for the high-definition tubes, correspondin to a loss of approximately 24 db at 26 Mc/s. As it i desirable to leave margins for (i) some longer sectior where there is difficulty in finding repeater statio sites, (ii) the basic loss of equalisers, 24 db is a cor venient figure; it is moreover one that is convenier from the point of view of repeater design. The larg tubes therefore have an outer conductor of inne diameter 0·975 in., and provision is being made fc repeaters at 3-mile intervals.

Cable Lay-up.

In considering the cable lay-up it became apparer that two more 0·375-in. tubes could be incorporate without affecting the diameter of the complete cabl or the large tubes appreciably. As the extra cost :

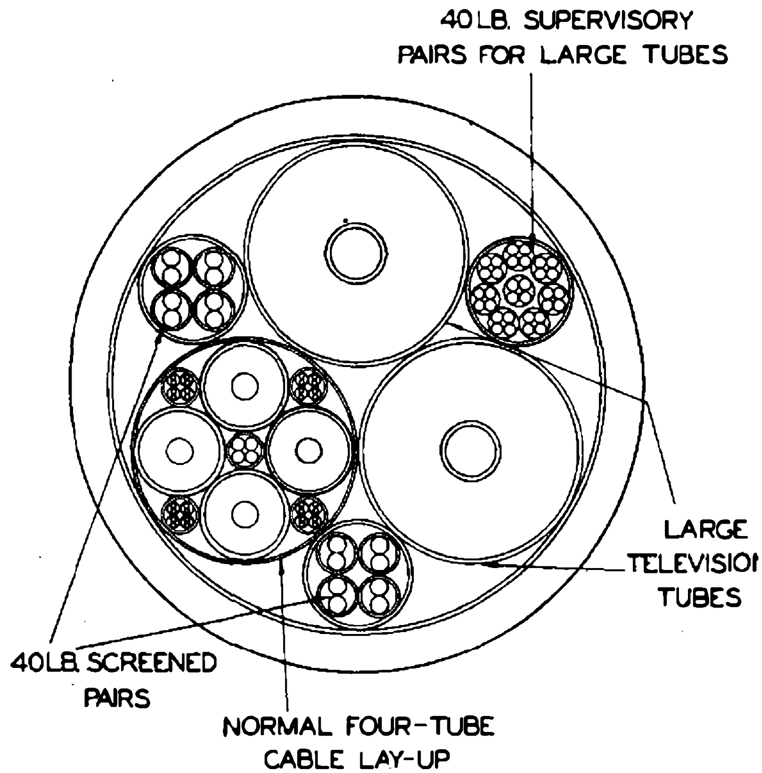


FIG. 2.—LAY-UP OF TELEVISION CABLE.

comparatively small they have been included an will be used for a multi-channel telephone systen Referring to Fig. 2, in which the lay-up is shown, th eight 40-lb. quads between the two large tubes wi be associated with these tubes for control and supe visory purposes; the two sets of four 40-lb. screene pairs will provide ordinary sound broadcast channe as well as those for the television channels; and th other pairs, which are laid up with the 0·375-in. tub in the same way as they are for standard four-tub coaxial cables, will be used for controlling and supe vising the systems operating over the 0·375-in. tube

The tail cable between Birmingham and the Sutto Coldfield transmitter need only provide for one-wa transmission of television and therefore contains onl

* The internal diameter of Post Office multiple-way ducts used on main trunk routes is 3½ in., and it is desirable to limit the overall diameter of trunk cables to 2¾ in.

two coaxial tubes. To make a practicable lay-up, both are 0·975-in. tubes. The cable also contains eight 40-lb. screened pairs, and a number of unscreened 40-lb. quads for miscellaneous purposes including control and supervision.

Electrical Requirements

In considering the other requirements that affect the design and manufacture of the cable, attention will be confined almost entirely to the 0·975-in. coaxial tubes. because the smaller tubes and the balanced pairs conform substantially with established practice.

Characteristic Impedance.

For coaxial tubes in which both conductors are of the same material and D, the inside diameter of the outer conductor, is fixed, the attenuation is a minimum when d, the outside diameter of the inner conductor, is D/3·59. When the permittivity of the space between the conductors is unity, i.e. the dielectric is wholly gaseous, this yields a characteristic impedance of 77 ohms. For a permittivity of 1·2, which is on the high side for tubes of the type used in trunk cables, the impedance would be 70 ohms, and to raise it to 75 ohms d would have to be reduced to D/3·94, which would increase the attenuation by less than 0·5 per cent. Such a minute increase is trivial compared with the advantage of maintaining a standard impedance value. The Post Office has always adhered to 75 ohms as the nominal characteristic impedance for coaxial tubes and has retained that value for the present cable. The specification calls for the characteristic impedance of the large tubes averaged over a small interval centred on 20 Mc/s to be between 74 and 76 ohms.

It is inevitable that the characteristic impedance of a coaxial tube or any other form of transmission line will vary slightly from point to point. These variations can occur within drum lengths, from drum length to drum length, or may be introduced by the joints themselves ; but unless they are very gradual and only become appreciable over very long lengths of cable they give rise to significant internal reflections. Reflections also arise at the ends of repeater sections unless the terminations match the characteristic impedance accurately. If reflections occur at two or more points in a repeater section part of the signal energy reflected backwards from a point nearer the receiving end will be reflected forward again at a point nearer the sending end and give rise to an echo that arrives after the main signal. In television this may result in a picture in which the main outlines are followed by faint and distorted ghosts. So many factors are involved in considering these echoes and their effects on a television picture that it must suffice here to indicate the way in which the impedance irregularities are assessed and the limits that have been adopted.

Reflections at the ends of repeater sections, although very difficult to eliminate, are determined by the repeater equipment, but irregularities within the cable must as far as possible be avoided during the manufacture, laying and jointing of the cable. As viewed from the end of a section, with the other end terminated in its characteristic impedance, each irregularity gives rise to a roughly sinusoidal variation of the input impedance with frequency. The amplitude of this variation is proportional to the irregularity modified by the attenuation of the intervening length of cable, and the net effect of a considerable number of irregularities randomly distributed is to cause the input impedance to vary more or less at random about the mean characteristic impedance. Although perhaps not the best from a theoretical point of view, this variation of input impedance is a convenient index of the variation of characteristic impedance along the cable, and the criterion adopted is that for the large tubes the sum of the six largest variations of the resistive component of the input impedance between 3 and 26 Mc/s at each end of a 3-mile repeater length shall not exceed 26·5 ohms.* It has been shown from an analysis of the results on a number of lengths of cable that this limit corresponds to an R.M.S. variation of impedance about the mean value of one per cent.

Attenuation.

The attenuation in nepers, A_n, per unit length of any transmission line in which the conductor resistance, R, and dielectric conductance, G, per unit length are small compared with ωL, the series reactance, and ωC, the shunt susceptance, is given by :

$$A_n \doteqdot \frac{R}{2}\sqrt{\frac{C}{L}} + \frac{G}{2}\sqrt{\frac{L}{C}} \quad \ldots\ldots\ldots\ldots (2)$$

At high frequencies, where skin effect is fully developed, R is closely proportional to $\sqrt{f}$, and G for any good quality non-dispersive insulating material is proportional to f ; and it can be shown that small variations in the distribution of the inductance and capacitance have negligible effect on the attenuation provided the values averaged over the whole of the length in question are constant. Equation (2) can therefore be rewritten as :

$$A = K_1 \sqrt{f} + K_2 f \text{ decibels/mile} \quad \ldots\ldots\ldots (3)$$

where K_1 and K_2 are constants determined by the resistance and conductance loss components, respectively. To ensure that neither component contributes unduly to the loss and that the loss/frequency characteristic approximates reasonably closely to a given law, on the large tubes, between 1 and 40 Mc/s, the attenuation per mile corresponding to 15°C., measured on complete 3-mile repeater sections, is required to be within $\pm$ 4 per cent. of the values given by the following expression

$$A = 1{\cdot}56 \sqrt{f} + 0{\cdot}01 f \text{ decibels/mile} \quad \ldots\ldots\ldots (4)$$

In general the measurements are made at temperatures differing from 15°C., which can be determined from D.C. resistance measurements, and they are corrected to 15°C., using temperature coefficients of loss determined on drum lengths before laying. To ensure that the cable will not be subject to secular

* In determining this quantity the highest and lowest turning points in the impedance characteristic are combined in pairs such that the six largest differences are obtained, using each turning point once only. This index is used rather than the R.M.S. deviation because it is more easily determined.

change, the attenuation atter one year is required to remain within 1 per cent. of the values determined during acceptance tests, due allowance being made for differences in temperature.

Crosstalk.

The crosstalk attenuation between coaxial tubes may be expected to increase rapidly with frequency if, as is usual, there is complete longitudinal continuity of the outer conductors. Thus, although the tubes of the present cable, particularly the 0·975-in. tubes, may ultimately be used over very wide frequency ranges, crosstalk at frequencies above about 1,000 kc/s is unlikely to cause any difficulty and need not be considered here.

It is not possible at this stage to decide exactly how all the 0·375-in. and 0·975-in. tubes will finally be used below 1,000 kc/s ; it is nevertheless important that crosstalk shall not be a limiting factor. It is therefore assumed that broad-band telephony, on frequencies of 60 kc/s and above, will be transmitted over some, at least, of the 0·375-in. tubes, with a repeater spacing of 6 miles, and may even be transmitted over the 0·975-in. tubes with a 12-mile repeater spacing. It is also assumed that 405-line television might be transmitted over either type of tube, with the above repeater spacings, using an asymmetric sideband system involving frequencies from 300 kc/s upwards, with the carrier frequency not lower than 500 kc/s.

Where television and telephone channels pass over tubes in the same cable, crosstalk from the former to the latter is likely to be more serious than in the reverse direction, because of the high energy concencentrations at, and relatively near, the television carrier. It is therefore sufficient to consider the requirements in terms of the signal/crosstalk ratio in the telephone channels. The C.C.I.F. have recommended that this ratio should be at least 58 db[3].

In testing the cable, it is convenient to make all crosstalk measurements on 6-mile sections, the 0·975-in. tubes being connected through at the 3-mile points. It is thus necessary to find a relation between the values so measured and the overall signal/crosstalk ratio for a complete route, for specified combinations of tubes and repeater spacings. It is assumed that the route might ultimately be 600 miles long, but that there would be frequency-translating equipment, e.g. to bring the telephone channels down to the range 60-108 kc/s, every 150 miles. Over the whole route the near-end crosstalk contributions from successive repeater sections will tend to add on a power basis, because the total lengths of cable that they traverse differ in a non-systematic way on account of the slight differences in length of the repeater sections. For far-end crosstalk the components from successive repeater sections add on a voltage basis* between the 150-mile terminal points. The contributions of the four 150-mile lengths will, however, add, or can be made to add, on a power basis because approximately random phase-changes can be introduced in the frequency translating equipment.

Making these assumptions the expressions given in Table 1 have been derived for the minimum crosstalk attenuation that must be realised on individual 6-mile lengths, to obtain an overall signal/crosstalk ratio of 58 db for a 600-mile route.

TABLE

MINIMUM CROSSTALK ATTENUATION REQUIRED ON 6-MILE LENGTHS OF CABLE

Conditions	Attenuation in Decibels	
	Near-end	Far-end
Between 0·375-in. tubes with 6-mile repeater spacing	$N_1 = 78+p+0{\cdot}72\sqrt{f_k}$	$F_1 = 92+p+0{\cdot}72\sqrt{f_k}$
Between 0·975-in. tubes with 12-mile repeater spacing	$N_2 = 76+p+0{\cdot}60\sqrt{f_k}$	$F_2 = 92+p+0{\cdot}30\sqrt{f_k}$
From 0·975-in. tubes with repeaters at 12-mile spacing to 0·375-in. tubes with repeaters at 6-mile spacing	$N_3 = 77+p+0{\cdot}72\sqrt{f_k}$	$F_3 = 91+p+0{\cdot}72\sqrt{}$

Symbols used

f_k : Frequency in kc/s.
N_1, N_2, N_3 : Near-end crosstalk attenuation measured on a 6-mile section.
F_1, F_2, F_3 : Far-end crosstalk attenuation measured on a 6-mile section.
p : Ratio in decibels of output in any 4 kc/s band from repeater on an interfering tube to output from repeater on disturbed tube.

Note.—In some cases it has been necessary to make certain approximations to obtain a simple formula covering the whole frequency band. All the formulæ are strictly correct at 60 kc/s but some give crosstalk requirements erring slightly on the side of stringency at higher frequencies.

The above expressions contain a term " p " to take account of any difference in repeater output level between the two tubes in any 4 kc/s band. At 60 kc/s, where telephony only is of interest, it is assumed that there will be no systematic differences in level and p is fixed at zero.

For the transmission of television, carrier levels as much as 35 db higher than the levels used in testing the telephone channels might conceivably be employed, which would involve an increase of 35 db in the crosstalk attenuation required at all possible television carrier frequencies. In the neighbourhood of 500 kc/s this would be a stringent requirement. It should, however, be practicable to make the television carrier frequency correspond to a gap between supergroups in the telephone spectrum, so that the margin need only cover the levels corresponding to concentrations of energy in the television sidebands. This margin will be taken as 20 db, and the requirements at 500 kc/s and above are, therefore, given by the expressions in the table with p equal to 20. To allow for television signal components on the cable down to 300 kc/s, the factor p is specified as increasing uniformly with frequency from zero at 300 kc/s to 20 db at 500 kc/s.

As it is very unlikely that all the adverse conditions assumed will be encountered together no allowance has been made for crosstalk contributions from several tubes simultaneously.

Test Voltage.

It is inconvenient and expensive to provide a separate connection to the mains at each repeater

[3] Programme Général d'Interconnexion Téléphonique en Europe (1947-1952), C.C.I.F. Montreux, 1946.

* This is strictly true only if both tubes have the same velocity of propagation ; where the velocities differ, as they will for the 0·375-in. and 0·975-in. tubes, the components will not all add in phase, and the conditions will be less stringent. This advantage is neglected here.

station on a coaxial cable to supply power for the repeater equipment ; moreover, such an arrangement would introduce a large number of points at which the supply might fail, with a greater likelihood of interruption when power is derived from a rural network, and would involve the extensive provision of emergency supplies. It is therefore normal practice to supply power to a coaxial cable at selected points only, and transmit it over the cable itself to intermediate stations.

When the present cable was first planned it seemed likely that power for as many as five intermediate stations, at 3-mile intervals, might have to be fed over the large tubes in some sections of the cable.† Assuming that the equipment for each tube at each station might require 400 watts of power and that the conductor resistance would be approximately 7 ohms per mile, it appeared that the large tubes at a power feeding point might have to operate at about 640 volts R.M.S. To be sure of a substantial factor of safety the large tubes are required to withstand a two minutes application of 2,000 volts R.M.S. at 50 c/s.

† Later it turned out that only four stations need be catered for.

A Speech Spectrum Analyser

U.D.C. 534.41 : 534.78 : 621.396.615.17

A CONVENIENT method of analysing a speech spectrum is to divide the frequency range into narrow bands and to measure the total energy present in each band over a specified time period. This time period must be long enough to ensure that a representative speech sample is included, i.e. 15 seconds at least. An analyser has recently been developed at the Post Office Research Station which enables times of up to one minute to be employed, and which possesses some novel features, particularly with regard to the technique used for performing the energy summation.

In this apparatus the signal is passed to 21 filters which divide the spectrum into bands ½ octave wide from 75 c/s to 850 c/s and ¼ octave wide from 850 c/s to 9,600 c/s. These bandwidths represent a useful compromise between the ideal of an infinite number of very narrow bands and the practical consideration of simplicity of apparatus. Each filter is followed by a square-law rectifier circuit the output of which is connected to an integrator for an automatically timed period of 15, 30 or 60 seconds. The integrator stores the energy from the filter in the form of electric charge on a condenser, the voltage across the condenser at the end of the integration time being a measure of the total energy supplied. The time-constant of such a circuit must obviously be very much greater than the time over which the integration is performed or the accumulated charge will leak away ; thus, if the integration time is 60 seconds a time-constant of about 2,000 seconds is required. The Miller integrator, well known in its applications as a linear time base,[1,2] enables a long time-constant to be obtained with ordinary component values.

The Miller Integrator.

In the Miller integrator a condenser of capacitance C is connected between the grid and anode of a valve which has a stage gain of A ; this is equivalent to a condenser of capacitance (A + 1) C connected between the grid and cathode of the same valve (The " Miller effect "). Thus, in the practical design, a 2 μF condenser is connected across a valve which has a stage gain of 300 times ; it is charged via a resistance which has a value of 4 megohms (when the integration time is 60 seconds) and has therefore a resultant time-constant of 2,400 seconds. For other integration times the charging resistance is changed in proportion. Also it may be shown that the anode current of the valve is proportional to the charge on the condenser ; a meter measuring this current, therefore, provides the necessary indication. An additional advantage of this particular integrating circuit is that disconnection of the charging resistance at the end of the integration time increases the time-constant to a very high value, so that the condenser charge, and therefore the meter reading, is held constant almost indefinitely. This enables an operator to note at leisure the readings of the 21 meters, each recording the energy of its particular frequency band. Operation of a key then resets all the meters instantaneously by discharging the condensers. A complete spectrum analysis of a sample of speech of up to one minute's duration may therefore be performed in a few minutes.

Some Applications.

In addition to the direct study of voice characteristics the apparatus has a number of possible important applications. For example, a pure tone frequency-response characteristic of any non-linear element (e.g. a carbon microphone) cannot be readily interpreted in terms of its performance under working conditions. It is hoped that a " real voice " technique for microphone calibration using the analyser may lead to a wholly objective method of rating the transmission performance of telephone systems.

Another application of the energy integrator may be expected to arise in the design of equipment for acceptance-testing of telephone instruments.

G. P. H.

[1] Ranging circuits, linear time base generators and associated circuits, F. C. Williams and N. F. Moody, *J.I.E.E.*, Part IIIA 93, No. 7, p. 1188.

[2] " The Miller Integrator." B. H. Briggs, *Electron Eng.*, August 1948, Vol. 20, No. 246, p. 243.

The Post Office Phototelegraph Service to Europe

A. WILCOCK, A.M.I.E.E.

U.D.C. 621.397.3

The equipment provided to reopen the Post Office phototelegraph service to Europe is described in this article which also covers, in broad outline, the circuit arrangements employed and the methods adopted for high-speed photographic processing.

Introduction.

JULY 15th, 1948, marked the reintroduction of a phototelegraph service to the continent of Europe by the British Post Office. The original equipment was of German (Siemens & Halske) manufacture and has been described in an earlier article[1]; it was partly destroyed in the fire raid of December, 1940, although service had terminated earlier with the overrunning of the continent. To reopen the service, modern equipment manufactured by the British firm of Muirhead & Co., has been installed in the Central Telegraph Office, London, and service is already available to official terminals in Paris, Brussels, Oslo, Copenhagen, Stockholm and Rome; it will be extended to other centres as they acquire equipment. The service will also operate to recognised private installations.

Equipment Standards.

The equipment conforms with the C.C.I.T. (Comité Consultatif International Télégraphique) standards as follows:—

- Drum diameter, 66 mm.
- Drum speed, 1 r.p.s.
- Scanning, $5\frac{1}{3}$ lines per mm.
- Control frequency for drum speed, 1,020 c/s.
- Line frequency, 1,300 c/s (amplitude modulated).
- Maximum picture size, 130 × 180 mm.

The degree of perfection attainable in pictures transmitted telegraphically is ultimately a product of the standards adopted, and of these, the fineness of scanning (i.e. lines per inch or millimeter) and speed of scanning (i.e. inches or millimeters per second) are of fundamental importance. The standards adopted must always offer a compromise between the time needed for reception of a picture that is just acceptable as a reproduction and the time that would be required for the transmission of sufficient detail to obtain a nearly perfect picture.

The standards quoted above have now been in use many years and were those employed in the design of the pre-war equipment; nevertheless, sufficient progress has been made in the utilisation of those standards to enable it to be said that pictures received on the present equipment are far more faithful reproductions than it was possible to obtain with the earlier equipment. Some indication of the processes now employed may, therefore, be of interest.

The Transmitter.

A block schematic diagram of the transmitter is shown in Fig. 1, from which the following description will be more readily understood. The picture to be transmitted is wrapped around the transmitting drum and secured to it by clips. The drum is driven by a phonic motor whose supply, for a drum speed of 1 r.p.s., is controlled by a 1,020 c/s oscillator via a frequency divider. To complete the scanning motion, the drum assembly with motor drive (the carriage) is traversed in steps of $\frac{3}{16}$ mm. per revolution of the drum by a pawl and ratchet driving a lead-screw, the whole moving in front of a fixed optical system.

The drum is illuminated by two lamps whose filaments are focused through lenses to an image in the form of a cross at the surface of the picture on the drum. Light from the centre of this "light cross" is reflected through the object lens to a focus on a small screen in a position equivalent to that of the film or plate in a camera. In the centre of this screen is the true scanning aperture whose size is determined by the fineness of the scanning used; for the Post Office equipment this is 0·35 mm. by 0·28 mm. Situated immediately behind the scanning aperture is the chopper disc, which interrupts the light beam before it falls on a photo-electric cell (P.E.C.) thus producing an output from the cell which is handled by electronic circuits of conventional design. In this case the output has a frequency of 7,200 c/s and varies in amplitude according to the light reflected from the picture. After initial amplification, the signal is filtered through a high-pass filter passing frequencies above 5,000 c/s to eliminate any spurious frequencies. The signal is then fed to the control grid of a mixing valve of the triode-hexode type, a frequency of 8,500 c/s from a local oscillator being fed to the triode grid. The

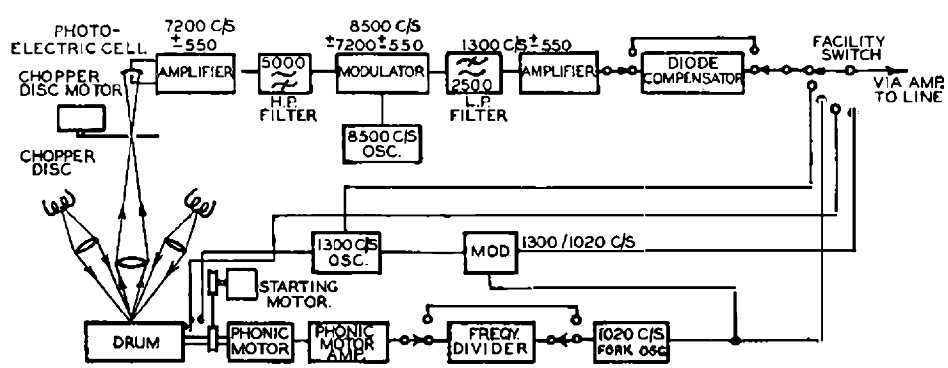


FIG. 1.—BLOCK SCHEMATIC DIAGRAM OF PHOTOTELEGRAPH TRANSMITTER.

[1] *P.O.E.E.J.*, Vol. 23. p. 1.

anode circuit of this valve carries the sum and difference products of the modulated 7,200 c/s carrier and modulating frequency of 8,500 c/s. The insertion of a low-pass filter enables the lower sideband frequencies of 1,300 $\pm$ picture modulation (calculated to be between 0 and 550 c/s) to be filtered out for further amplification and transmission to line. To produce the non-linear responses (compensation) a diode peak chopper provided at the transmitter could be used, but since there is some advantage in transmitting the original P.E.C. signal and carrying out this compensation at the receiver, this is the internationally agreed practice.

Other facilities provided at the transmitter include: artificial white signal from a local 1,300 c/s oscillator; artificial black, which is merely the artificial white signal attenuated by 31 db. (a figure found by experience to represent a picture-black of average intensity); 1,020 c/s fork tone for synchronisation of the drive oscillators; 1,300 c/s modulated with 1,020 c/s for synchronisation over carrier telephone channels where the carriers frequencies are not locked; and a phasing signal to ensure that the picture edge, or join, is in the same relative position on both transmitter and receiver drums. This phasing signal consists of a pulse of 1,300 c/s tone, from the local oscillator, of approximately 30 mS duration once per revolution of the transmitter drum drive and is controlled by a cam and contacts on the drum driving head. The phasing signal is only sent for lining-up the drums prior to the transmission of a picture, after which the line-up of the picture is dependent on the stability of the valve-maintained tuning fork oscillators at both transmitter and receiver.

The Receiver.

A block schematic diagram of the receiver is shown in Fig. 2. Here the facilities required are means for (*a*) synchronising the local 1,020 c/s fork oscillator to that of the transmitting station; (*b*) phasing the receiving drum to the same relative position as that at the transmitter; and (*c*) demodulating the line picture signal and converting it into light of varying intensity for projection on to the photographic material mounted on the receiving drum.

The signal from line is always first amplified to enable it to be controlled to a level suitable for subsequent operations. For synchronisation of the 1,020 c/s control or drive oscillator, the 1,020 c/s line signal is passed, after this pre-amplification, to a cathode-ray oscilloscope (C.R.O.). When a 1,300/1,020 c/s modulated signal is sent—as required for working over carrier telephone lines—the signal is demodulated and the 1,020 c/s product filtered out before passing to the C.R.O. The C.R.O. is arranged for the local 1,020 c/s oscillator to give a circular trace by connection to R-C components on the deflector plates, while the incoming 1,020 c/s signal is fed to the modulating grid. Under these conditions half the circular trace is suppressed and that left is stationary when the two 1,020 c/s supplies have exactly the same frequency. Differences of one part in 10^6 can be readily seen and the form of trace is particularly suitable for the relatively non-technical operator. A tolerance of 10 parts in 10^6 is the international limit. The phasing signal after pre-amplification is fed, under the control of a relay operated by press button, to an anode-bend detector in whose anode circuit is a Siemens high-speed relay. This, in turn, closes a circuit for the release of the electromagnetic pawl clutch on the receiving drum.

The picture signal is subject to compensation by a diode peak chopper so that the variations in the signal after demodulation in a subsequent stage are more nearly proportional to the light values as sensed by the eye, and are more suitable for manipulation by the following " light valve". After further amplification, demodulation of the received picture signal is carried out by a bridge metal rectifier, followed by a low-pass filter for smoothing out the products of the rectification of the carrier frequency while maintaining the characteristics of the picture modulation. The signal so obtained is passed directly through the loop of a Dudell oscillograph which also has applied to it a local bias current to enable the most sensitive part of its range to be used, as well as to provide continuous control.

The optical system of the receiver includes a single projector lamp, and an image of a single filament coil is brought to a focus on the mirror of the Dudell

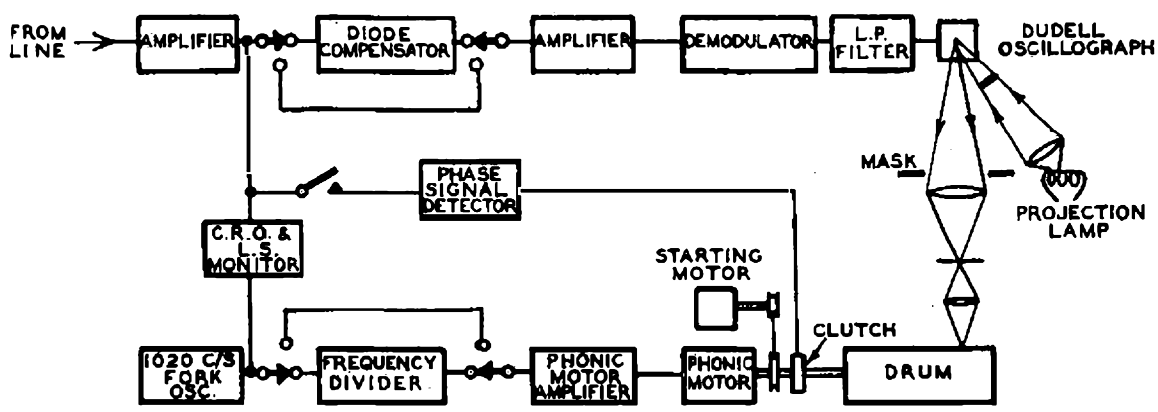


FIG. 2.—BLOCK SCHEMATIC DIAGRAM OF PHOTOTELEGRAPH RECEIVER.

oscillograph. As the oscillograph responds to the incoming line signals the light reflected from its mirror is made to sweep over a shaped mask, the light passing through being finally brought to a focus on the receiving drum as a spot comparable in size to the scanning aperture in the transmitter. The intensity of illumination of the spot varies according to the amplitude of the incoming signal as modified by the mask.

As the picture is received on photographic paper or film highly sensitive to light, the receiving drum is mounted in a light-tight container having a longitudinal shutter which can only be opened when the drum is in place in the receiver and the cover closed and locked, the shutter and cover being mechanically linked by the lock.

The mechanism driving and traversing the receiver drum is similar to that on the transmitter.

Fig. 3.—Phototelegraph Equipment.

The two compensating or non-linear features are required to facilitate the projection of the correct light intensity (which requires to follow a logarithmic law) on to the photographic material. The first consists of a diode-chopper in the amplifying stages feeding the oscillograph and reduces the deflection of the light beam on the higher level signals. This enables the mask, placed in the light beam to complete the compensation, to have practical proportions and shape. Three interchangeable masks are in fact provided, one for positive reception on bromide paper, another for negative reception on film and a third for documentary work (i.e. without half-tones). In documentary reception where maximum contrast between black and white is required, it is usual also to switch out the diode-chopper to increase the light beam deflection for any change in signal level. At the transmitter and in the line the maximum signal always represents white, the selection of positive or negative reception being performed at the receiver by reversing the line signal through the oscillograph loop and by changing the light mask.

Layout of the Equipment.

Fig. 3 shows a general view of the phototelegraph equipment, the console in the left foreground is the transmitter; that on the right is the receiver. Two racks of equipment are associated with each console and can be seen in the centre.

Although the equipment shown forms the complete installation of transmitter and receiver, the two are quite independent and, apart from interconnection of line circuits for convenience of operating (possibly under "duplex" conditions) over the go and return pairs of a four-wire circuit, are not in any way connected. The equipment is designed for mains operation.

The right-hand rack of each pair is similar and comprises the main drive panels namely: power input with voltage stabilisers, 6V projection lamp supplies (with generous smoothing, since any 50 or 100 c/s ripple would show very prominently on the picture), valve-maintained tuning fork, frequency divider, and amplifier for the phonic motor drive. The left-hand rack of each pair mounts the transmission circuit panels, and their power pack supplies, namely:—

Transmitter. Transmitter amplifier, monitoring loudspeaker, 8,500 c/s oscillator and line panel.

Receiver. Receiver amplifier, C.R.O. and loudspeaker monitor and line panel.

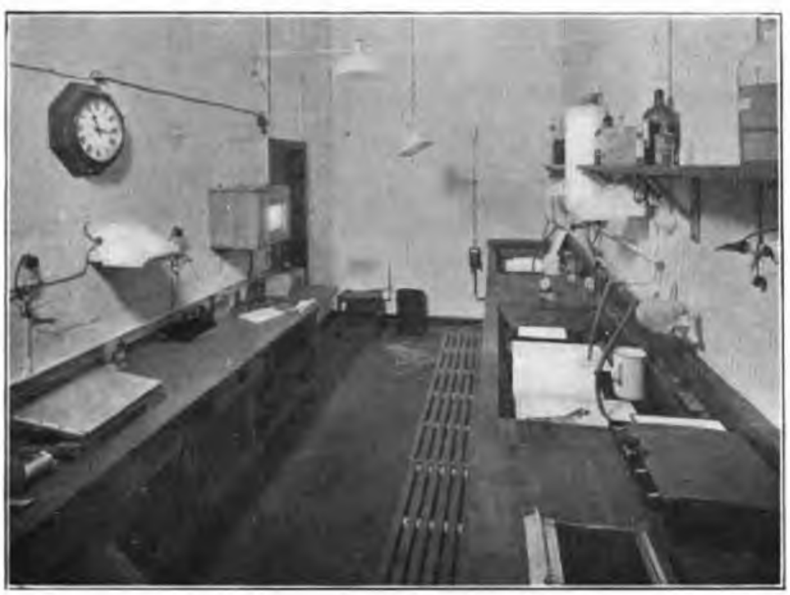


Fig. 4.—Dark Room.

The lines, which are four-wire, are connected direct to the "Continental Test" at Faraday Building where the Continental line (terminating two-wire on the Continental switchboard) over which the call is first made, may be intercepted and extended four-wire to the equipment.

Photographic Processing.

While picture quality is naturally a first requirement of the service, speed of service is a very close second. The picture can be marred in the processing just as readily as it can in transmission, and for prints of high quality dark room organisation must be of a high order. Such are the considerations which have decided the equipment of the dark room shown in Fig. **4**. The photographic processing takes quite as long as the transmission over the circuit when using the standards previously quoted, and all possible steps are taken to keep it to a minimum. Quick acting developer is used followed by what may be called extra-quick drying. Films can be dried in two minutes by a drier designed specially for this job, which compares very favourably with 20 to 30 minutes by commercial drying cupboards; the time required for drying and glazing prints has been reduced to half that required by the commercial glazer provided.

In addition to obtaining good quality negatives and prints, largely by following closely time and temperature methods, it is also necessary to be able to produce a number of virtually identical prints from one negative for despatch to different press agencies. This is considerably assisted by the use of a precision exposure control (a product of the Research Branch) associated with the printing box. Apart from these aids for speeding the processes the darkroom follows conventional design and layout for dish development, generous in working space but arranged so that all facilities required are close at hand.

Acknowledgments.

In conclusion, the author wishes to thank numerous colleagues for assistance and advice in respect of darkroom arrangements incorporated in the installation and also Mr. E. Jones, of Muirhead & Co. Ltd., for much information on the equipment and for advice on the "teething troubles" encountered in setting up the installation.

Book Reviews

"Ionospheric Radio Propagation." U.S. Department of Commerce, National Bureau of Standards, Circular 462. Superintendent of Documents, U.S. Government Printing Office, Washington 25. D.C. 209 pp. 205 ill. $1.00.

This book is a successor to the well-known I.R.P.L. Radio Propagation Handbook, and it is chiefly concerned with H.F. ionospheric propagation. It includes a considerable amount of new and revised material, particularly in connection with propagation over short distances (less than 4,000 km.).

The book is intended primarily for the solution of practical ionospheric communication problems—such as the determination of M.U.F.s and L.U.H.F.s—not as a text-book, although the various chapters do give an excellent outline of the phenomena concerned. Lack of space, unfortunately, frequently puts "further discussion beyond the scope of this book"; additional references might, with advantage, have been added to the general references given at the end of each chapter. The noise data, and the methods for calculating received field intensities, follow very closely Reports already issued by the U.S. Signal Corps Radio Propagation Unit.

The bases and assumptions used in the preparation of the various nomograms and charts are adequately set out and this makes it possible to modify them where necessary for application to other conditions. The techniques follow American practice, but references are made to some of those developed in other countries.

The determination of M.U.F.s and ionospheric absorption and a knowledge of the atmospheric radio noise at the receiving site are the three most important factors in H.F. communications problems. It is a curious fact that in spite of the great advances in our knowledge of the ionosphere, the calculation (from observations at vertical incidence) of M.U.F.s and ionospheric absorption for long-distance communication is still largely of an empirical nature, while the subjective measurements which are now being made at certain places throughout the world are also showing how sketchy is our knowledge of atmospheric radio noise. Although some of the empirical techniques, etc., described in the book may not fully satisfy the theoretical ionospherist, they are among the best that have yet been put forward from the engineering point of view for the application of ionospheric data to the practical problems of radio communication. The book, therefore, can be well recommended to those concerned with planning H.F. radio services. There is, however, a need for comparisons to be made between observed circuit performance and calculation made by the methods given in the circular.

G. H. M. G.

"Fundamentals of Electrical Engineering." V. P. Hessler, Ph.D., and John J. Carey. McGraw-Hill Publishing Co. 241 pp. 190 ill. 21s.

This work is a companion volume to Terman's "Radio Engineering" and Spangenberg's "Vacuum Tubes" in the McGraw-Hill Electrical and Electronic Engineering Series. It is, in effect, an introductory book to the other two.

The scope and method of presentation of the subject are very similar to those of Mueller's "Introduction to Electrical Engineering," reviewed in the July 1948 issue of this Journal, though some sections, particularly those on Ohm's and Kirchchoff's laws, are not quite so extensively treated. The emphasis is on basic theory rather than on the more practical aspects of electrical engineering and the importance of understanding units, particularly the M.K.S. system, is stressed throughout.

It follows that the book will appeal more to the university student than to the junior engineer, but the latter must appreciate that, without a thorough knowledge of the fundamental concepts as presented by this and other similar works, he will not be able to master the more complex problems of modern electronic engineering.

H. L.

The British Telephone Technical Development Committee

R. W. PALMER, M.I.E.E., and W. L. BRIMMER

U.D.C. 061.24 : 384

The function of this committee, together with the continuous co-operative effort which it represents, is important in its effect on the technical and economic efficiency of the British Post Office telephone exchange system. It also leads to a new outlook on the daily relations between supplier and consumer, far beyond the actual committee work.

Introduction.

BEFORE 1923, the telephone exchange contracts for the British Post Office were placed as the result of competitive tendering, each of the telephone manufacturers in Great Britain negotiating with the Post Office individually. This method gave rise to a fairly wide diversity in the products of the various manufacturers as there was no co-operation between the manufacturers in development, and latitude was necessary in the interpretation of the Post Office requirements to meet individual manufacturing practices. Moreover, the unsuccessful tenderers expended very considerable time and effort in vain for every contract placed.

In 1923, when the wholesale conversion of the telephone system in London to automatic working was seriously considered by the Post Office, and the step-by-step system was to be standardised, it was obvious that there would be grave disadvantages in the competitive system, so the Post Office called together the four manufacturers then in the automatic field and made an agreement with them to co-ordinate the supply of equipment at a satisfactory price level for the standard components. By 1928, a fifth manufacturer was available and a fresh agreement was drawn up for a period of five years based on the competitive quotations submitted by each of the five parties. The administration of this agreement, and those which have succeeded it, necessitated the formation of the manufacturers' Bulk Contract Committee (B.C.C.) to decide production policy and distribution of contracts, and to negotiate prices. The five firms represented are :—

Automatic Telephone & Electric Co. Ltd., Liverpool.
Ericsson Telephones Ltd., Beeston.
General Electric Co. Ltd., Coventry.
Siemens Bros & Co. Ltd., Woolwich.
Standard Telephones & Cables Ltd., New Southgate.

This rational sharing of contracts and of responsibility made possible the establishment of a highly technical organisation which, under the auspices of the British Post Office, could influence telephone technical development in this country to a degree hitherto not attempted, and promote standardisation on sound practical lines. A joint technical committee was therefore formed in 1933 under the chairmanship of an Assistant Engineer-in-Chief to the Post Office, and this was named the " British Telephone Technical Development Committee " (B.T.T.D.C.). The manufacturers' complement of this committee is known as the Manufacturers' Technical Development Committee " (M.T.D.C.) which meets under the chairmanship of the Manufacturers' Secretary to exercise control on technical policy, development and technical routine so far as the manufacturers are concerned. Devolution of work to specialist committees was also necessary to cover the detail of apparatus, circuits, equipment, etc., as the range and complexity of automatic telephony expanded.

Subscribers' telephone instruments and the many common components of telephone plant such as switchboard jacks, tag blocks and the like were also made the subject of a supply agreement in 1936, but in this case three additional manufacturers (making eight in all) were parties to the " Telephone Apparatus Agreement " (T.A.A.) :—

Phoenix Telephone & Electric Works Ltd., London, N.W.
Plessey Co. Ltd., Ilford.
Telephone Manufacturing Co. Ltd., London, S.E.

A corresponding joint technical committee for this class of plant was formed and for convenience was linked with the B.T.T.D.C. so far as general direction is concerned.

It was recently decided to systematise the many subsidiary bodies that had been added in the course of years, and it is now possible to define the activities and responsibilities of all the various constituent bodies shown in Fig. 1.

Functions of the Main Committee.

The fundamental procedure for all major developments is to table in the first instance a Committee Paper setting out clearly the intentions of each new development, and the case is then known by that " C.P." number until the item is completed. For efficient execution of that work without overlapping of effort, the next operation is to define which manufacturer or P.O. Branch is to carry out the work, one liaison officer being named as the sole representative of the developing organisation and one as the representative of the P.O. The stage is then set for the development to proceed as a planned programme, and the quarterly meetings of the B.T.T.D.C. enable progress to be directed by means of the reports from liaison officers.

To quote a small but typical example of a new development, the P.O. presented in the form of a " development " committee paper (C.P.187) a request for improved facilities on trunk timing, involving a new item to supersede Key No. 292. Design was allocated to firm " A " on behalf of all parties, but firm " B " followed this almost immediately with a further committee paper (C.P.190) reporting some work they were already considering for improvements to the Clock No. 44 itself to facilitate its use and readability by operators. These two committee papers were discussed and agreed in principle and the whole development was co-ordinated and allocated to firm

" A." The other firm willingly handed over all its ideas and experience to the common cause, and by inference agreed to manufacture whatever was developed by firm " A " under this B.T.T.D.C. procedure. All manufacturers were kept informed of the technical development as it proceeded, so that they could make contributions at any stage, thus ensuring that the necessary research and development work was not multiplied 5 times over by unnecessary parallel effort. When all parties had recorded their agreement to the technical features of the new design,

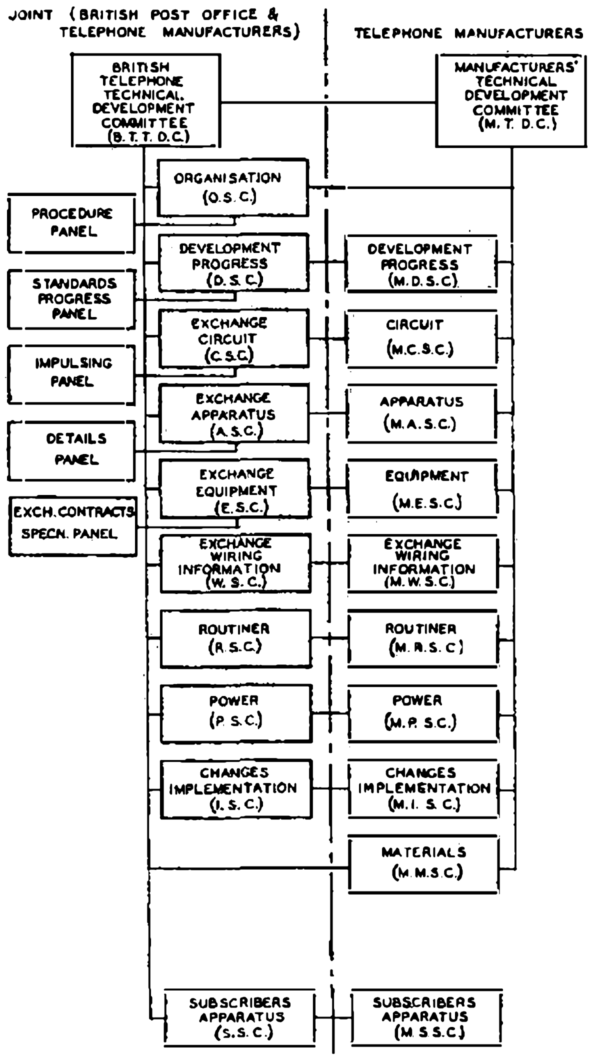


Fig. 1.—Structure of Telephone Development Committees.

and a model had been approved, the main development stage was declared by the B.T.T.D.C. to be complete and arrangements were then made for the production of full manufacturing drawings with a view to manufacture by all firms as a new standard.

Apart from specific development such as this, the B.T.T.D.C. is a most valuable clearing house for technical information having a direct or indirect bearing on telephone exchange practice. For example, the Post Office may advise the manufacturers of some problem or idea which it has decided to study before embarking on an actual design for inclusion in th telephone system. Similarly, any information fror one or more manufacturers on developments likely t be of interest to the Post Office is submitted, an experience on overseas contracts may also give rise t an " Informative C.P." when production for the hom and export markets is inter-related.

There is yet a third class of Committee Pape known as " Exploratory C.P.s" for the general guic ance of future development. An example is the contr bution of data and opinions on the operating efficienc of V.F. signalling systems, and there are also othe important contributions such as on alternativ materials and the impact of international discussion on the trend of national developments.

The whole of this C.P. procedure, including th duties and responsibilities of the liaison office appointed for each C.P. case, is agreed jointly an defined as a " Technical Procedure " to be followe continuously, quite independently of the meetings c any committee or sub-committee.

In addition to the regular business of " C.P. developments, the agenda of the main committe naturally includes discussions of a more gener nature, particularly in relation to the present problem of production. In this category is the attempt a unification of overseas practices where technic variations in specifications affect the overall produc tion capacity of the industry. The B.T.T.D.C. has n executive authority in this field, but encouragemer is being given to the standardisation of types c enamelled wire and finishes of apparatus.

Manufacturers' Technical Development Committ (M.T.D.C.).

This is the manufacturers' counterpart of the joir B.T.T.D.C. and is an important clearing house fc questions of technical policy affecting the manufa turing side only, or for discussion to produce an agre ment among firms prior to joint committee meeting There are also similar counterparts of most of the joir sub-committees as indicated in Fig. 1. On the man facturing side, there is a permanent secretary of tl B.C.C. and M.T.D.C., and another for all the man facturers' sub-committees. Although seconded fro the technical staffs of individual firms they a responsible to all, and have offices and duties qui independent of any one manufacturer. They a closely linked with the Post Office, and the sul committee secretary was for convenience provid with office accommodation on Post Office premis during the recent war.

Sub-Committees on Technical Development.

Since no single committee could handle alone tl detail of so vast a subject as a complete telepho system, the devolution of a great deal of work is bo deliberate and logical. Sub-committees usually me at intervals of not less than 2-3 months, and for tl purposes of this article are classified under thr headings—Technical Development, Technical Det and Procedure. The first classification is intended embrace the two which handle complete ne developments within specialised fields.

The Subscribers' Apparatus Sub-Committee (*S.S.C.*) has the distinction of representing the eight manufacturers under the Telephone Apparatus Agreement, and therefore is not wholly subsidiary to the B.T.T.D.C. which is representative of only five. Nevertheless, there are many standard items such as dials, fuse mountings, connection strips and the like which are purchased by the Post Office in large quantities under both the Bulk Supplies Agreement and the Telephone Apparatus Agreement, and it has been accepted that all such dual cases should be handled by this sub-committee whose primary concern is the subscriber's telephone instrument. The standardisation of P.B.X. switchboards is also very important, as Private Branch Exchanges, both manual and automatic types, are becoming more and more analogous to public exchange practice and this imposes a severe test on the flexibility and unity of the B.T.T.D.C. structure. The nature of the terms of reference make the work of this sub-committee very similar to that of the B.T.T.D.C. itself. Thus, there is a system of active and informative committee papers (S.C.P.s) to define the business in hand, together with the appointment of development contractors and liaison officers for each case.

The Routiner Sub-Committee (*R.S.C.*) is required to consider and reach agreement upon all questions affecting automatic routiners, and the main business is again conducted on the lines of the main committee. For this purpose it operates a system of Routiner Committee Papers (R.C.P.s) to define the detailed design of particular routiners within the requirements of the Development C.P.s of the main committee.

This overall responsibility for particular items of exchange equipment involves technical detail such as circuit design, apparatus development and exchange equipment practice, for which specialist sub-committees are also responsible, but the Routiner Sub-Committee observes the limits of current standard practice on exchange equipment as agreed by other bodies, and where a departure from standard practice is considered necessary, the liaison officers automatically refer the matter direct to the technical sub-committee concerned or, in the case of major policy, to the B.T.T.D.C. In fact, as many problems as possible are settled by standing procedures, and the Routiner Sub-Committee has referred to it only such questions as are not resolvable between its liaison officers either because of the broad nature of the question or because of a difference of opinion.

Sub-Committees on Technical Detail.

The development of new designs of plant by one party to the B.T.T.D.C. on behalf of all is accompanied by adequate opportunities for others to observe and comment on particular designs and models, but there is still a need for detailed discussion of general aspects such as circuit principles, standard apparatus components, cabling arrangements and the like. Four specialist sub-committees provide a clearing house for such discussions and they are normally more concerned with progressive changes to existing plant, or repercussions of new developments on existing equipment, than with complete new designs individually.

The Exchange Circuit Sub-Committee (*C.S.C.*) which meets three times a year, deals with circuit principles and the usage of particular apparatus items. It is therefore required to consider any problem in the design of circuits or groups of associated circuits which are of general interest or application (e.g. impulsing, cut drive, etc.), to arrive at the best solution of the problem from both the technical and the economic points of view.

Related to this basic requirement, the committee is required to consider also the electrical characteristics, performance and limitations of all apparatus used in exchange circuits, and to agree on performance limits for acceptance and maintenance testing of the equipment so composed. This requires a very detailed study and culminates in the determination of impulsing and signalling limits for all combinations of automatic equipment and particularly of new signalling systems being developed under C.P. cases. This latter work is performed by a joint Impulsing Panel.

The characteristics and performance of individual relay designs are a major factor in this work and, in fact, this committee was originally set up solely for study of this aspect. It is therefore vitally concerned with the approval of the basic design data for electromagnetic relays standardised by the P.O., and it arranges for the approval of all individual relays according to an established Technical Procedure, examining the circuit design when necessary to check the suitability of the relay proposed.

The Exchange Apparatus Sub-Committee (*A.S.C.*) is concerned with the physical components comprising a piece of switching equipment, and it embraces pieceparts, mechanisms, relay components, mountings and all the mechanical details involved. Electrical considerations are largely overshadowed by the mechanical and physical features in the design of apparatus, and this committee is therefore attended by specialists who are competent to discuss design for economical manufacture, choice of materials, methods of assembly and adjustment, tolerances and interchangeability, and the prevention of wear, breakage or other failure in normal use. The committee meets quarterly to resolve differences of opinion or to decide principles, and in this category have been the discussions on bank aligning gauges for 2,000-type selectors and improvements to uniselector wipers. It will be appreciated that great care is necessary before basic items of apparatus are put into mass production, and when a particular piece of plant requires discussion in great detail, a " Details Panel " is appointed to handle the particular case.

The Exchange Equipment Sub-Committee (*E.S.C.*) appears to have a title that is all-embracing, but, in the language of the telephone industry, the title " equipment " is restricted to racks and switchboards, and the mounting, cabling and installation of the standard selectors, etc., to constitute a telephone exchange. Thus, the design and manufacture of selectors and relay sets is outside its scope, but the way in which these items are used to build up a complete telephone exchange installation or extension is the primary concern.

The policy of extending obsolescent exchanges with modern 2,000-type equipment is largely a product of this committee, and any queries on the interworking of old and new equipment are answered from the pool of experience represented by this co-operation of manufacturer and customer.

The detailed work on the form of exchange contract specifications, as standardised in the " draft sheets " issued to Regions by the Engineer-in-Chief's Office is also the responsibility of this sub-committee, with the assistance of an Exchange Contract Specification Panel who examine all major alterations to ensure that P.O. requirements are expressed in the simplest form consistent with clarity, avoiding unnecessary work for its translation into a production order in the contractor's works. The Panel also resolves any major difficulties of interpretation that may be raised by Regions or manufacturers in particular cases.

The approval of contractors' equivalents to P.O. standard drawings and diagrams is a matter specifically required by the Bulk Supplies Agreement, and the E.S.C. is responsible for the routine procedure by which this requirement is met.

The Power Sub-Committee (*P.S.C.*) deals with power supplies for telephone exchanges, and, although the manufacture of heavy electrical machinery and batteries may, in practice, be sub-let to other firms by the telephone equipment contractors, the suppliers from the P.O. point of view are those represented on the B.T.T.D.C. The items most frequently requiring discussion and agreement relate to the development of charging systems, float schemes, tone and pulse machines, etc., rather than to detailed design of generators or secondary cells.

Problems arising in both circuit and apparatus design, and also mounting and cabling, all come under review if concerned mainly with power plant. In respect of distribution of power, tones or pulses, the line of demarcation between " power plant " and " exchange equipment " is normally the output terminal on the power switchboard, but it is only to be expected that adequate co-operation is necessary between this and other sub-committees if the power plant is to serve the many special requirements of telephone exchange switching and to follow similar standards of technical design.

Sub-Committees on Procedure.

In a separate class from the foregoing are the four sub-committees which have a controlling interest in particular phases of all other sub-committee work. They are not concerned directly with technical design but are required to co-ordinate technical development to a controlled programme or to determine organisation or general procedure from a " documentary " point of view.

The Development Progress Sub-Committee (*D.S.C.*) meets just before, and again just after, each meeting of the main committee, and exists mainly for routine sifting of reports on C.P. cases from which it extracts and submits the important matters requiring discussion and decision at a higher level. In its rather broad terms of reference it is required to consider technical detail only in so far as it may be affecting completion of developments by the date required and to give directions to liaison officers for reference to the technical sub-committees as considered necessary. It is also authorised to represent the need for action direct to individual manufacturers or P.O. Branches in cases of urgency.

The D.S.C. is also required to keep under review the requirements of standard manufacturing information in relation to technical developments and it controls a Standards Progress Panel who prepare, maintain and publish lists and other documents to manufacturers and P.O. Branches to facilitate the final stages of all technical developments. This is a phase which is often overlooked, or perhaps even resented, as an unnecessary delay between the availability of a working model and its inclusion in a public telephone exchange, but experience has shown the futility of including in an exchange contract an item which may hold up execution of the whole installation because of unexpected difficulties in manufacturing details for mass production. This is not to imply that exceptions to the rule are prohibited entirely, but the expediency has to be agreed by manufacturers—or may even be initiated by manufacturers. The decision to include a new development in the Equipment Master List (denoting authority to include in exchange contracts) rests with this sub-committee, or its panel. It has been agreed that the P.O. will refrain from introducing new or changed designs for telephone exchange equipment without the agreement of the contractors who will be required to make it. This is not as magnanimous as it might seem, because an early knowledge of proposed new designs enables the manufacturer to plan his shop production with the maximum efficiency in respect of both costs and delivery programme, and also permits the advance ordering of the necessary materials and standard components.

The Changes Implementation Sub-Committee (*I.S.C.*) is very closely related to the D.S.C. described above, but meets every two months to deal with minor improvements and changes to existing circuits and apparatus. These changes may be quite independent of one another or inter-related to some small degree, and some may arise from the introduction of a major C.P. development and be linked with the D.S.C. and its Standards Progress Panel.

The work of the I.S.C. is in two phases, the first of which is the routine submission of proposed changes, whether originated to implement a major development, to overcome local maintenance defects or to facilitate manufacture. Each suggestion is distributed to all parties for technical examination outside committee and agreement that the change is necessary and practicable ; the committee has only to see that this continuous procedure is operated on agreed lines, and to discuss items which cannot be agreed by routine methods. The technical work in committee is limited to a general appreciation of the engineering requirements and to the routing of technical problems to the Sub-Committee or Branch of the Post Office who may be concerned.

The second phase is the implementation of the agreed change, involving a decision on whether it shall be made retrospectively or not, or made a " departure"

THE MANUFACTURER. THE POST OFFICE.

DEVELOPMENT LABORATORY.

ENGINEER-IN-CHIEF'S CIRCUIT LABORATORY.

ENGINEERING AND DRAWING OFFICE.

ENGINEER-IN-CHIEF'S OFFICE.

ASSEMBLY AND WIRING SHOP.

COMPLETED AUTOMATIC EXCHANGE IN SERVICE.

TYPICAL SCENES IN POST OFFICE ENGINEERING DEPARTMENT AND MANUFACTURERS' WORKS.

on a temporary and optional basis without amendment of standard documents during the present production difficulties. Retrospective changes require a decision to define on which current contracts the change shall be incorporated and on which contracts the manufacture shall proceed without disturbance, leaving the change to be made after installation on site. This work has an important bearing on the manufacturers' mass production programme, because every change involves a great deal of hidden documentary work. For example, every selector must be represented in the form of a Stock List of all the sub-assemblies and standard components which it comprises, and each exchange contract must be translated by means of the Stock Lists into many "shop" orders for components. These shop orders are sent out with copies to planning executives, costing experts, shop foremen and so on, to cover all manufacturing operations from the purchase of the correct raw material to the calculation of the production costs, so the number of documents prepared for just one batch of selectors may run into hundreds. It follows that to carry even a single change of component into a current contract after this ordering machinery has been set in motion is a very serious and complex matter, and the date of implementation of changes is a matter for a balance between the operational needs of the administration and the production needs in respect of time and cost.

The Exchange Wiring Information Sub-Committee (W.S.C.) provides a discussion ground to deal with the principles of conversion of schematic circuit diagrams into standardised wiring diagrams and other wiring information for mounting and interconnection of selectors, relay sets and the like. Its function is classed as "procedure" rather than "technical detail" because it is more concerned with the preparation of documents than with physical design or with types of wire.

The "derived" documents concerned are those usually referred to as the W, U and X diagrams (e.g. ATW., ATU., etc.), which are prepared by an allocated manufacturer on behalf of all, to define relay plate wiring, shelf jack wiring and cross-connection wiring, respectively. The W.S.C. is therefore responsible for that comprehensive document known as "ATW 22000" which defines the wiring rules, nomenclature, symbols and conventions to be followed in such wiring diagrams, and this in turn must be related to the British Standard terminology and graphical symbols. The routine procedure for preparation, amendment, circulation and general approval of individual documents in this series is also defined by this committee.

The Organisation Sub-Committee (O.S.C.) is the final co-ordinating link for the whole structure. With the growth of the B.T.T.D.C. responsibilities, including the many activities which it controls outside the actual committee work, it has been necessary to devolve on to this sub-committee the definition of the procedure and organisation applicable to all joint operations of the Post Office and manufacturers under the B.T.T.D.C. This includes the determination of the constitution and terms of reference of all committees and the publication of a loose-leaf volume of "B.T.T.D.C. Procedures" on the lines of P.O. Engineering Instructions, but with limited circulation and having the authority of both Post Office and manufacturers. The detail of production of these procedures is devolved largely on a small Procedure Panel, and the main work is that of editing and co-ordinating the drafts presented by the other specialist committees for their particular aspects of the work. The range of subject matter is illustrated by these four divisions:-

General Division, covering the history, structure and operations of the B.T.T.D.C. as a whole.

Constitution Division, which includes terms of reference and personnel of every committee and panel.

Committee Procedure Division, defining the conduct of business in committee.

Technical Procedure Division, covering joint operations outside committee.

The nature of such documents implies that they cannot be amended without the consent of all parties and this includes the agreement of all sub-committees affected. When once settled, however, the definition of the obligations of all parties is of immense value in the day-to-day work of technical development and the illustrations showing typical views of a few parts of the manufacturers' and the Post Office work may serve as a reminder of the many parties concerned.

Conclusions.

It is hoped that the conclusion will have been reached from this description of the B.T.T.D.C. that organised technical development as a continuous process outside the conference room has rightly been considered more important than the committee work itself, and that the efficiency of the British telephone exchange system could not have been achieved by any other organisation.

By the removal of patronage and distrust the Post Office has been able to facilitate mass production, and the manufacturers have been able to contribute usefully to the technical problems of the administration. The indirect advantages in the field of economics will be obvious, but, in addition, it has enabled manufacturers to originate many technical developments which have led to direct reductions in plant cost. Moreover, from the point of view of the engineer at headquarters, in the field, or in the factory, the partnership of the B.T.T.D.C. has given freedom for those fierce technical battles which are the only true basis of technical progress.

As a final remark, it seems almost superfluous to acknowledge that this article is just another example of the anonymous co-operation of all parties concerned.

Vacuum Technique — Some General Principles and Post Office Applications

J. E. THWAITES, A.M.I.E.E., and
H. E. PEARSON, B.Sc.(Eng.)., A.M.I.Mech.E.

U.D.C. 621.52

Equipment as commonly used in producing vacua down to 10^{-6} mm. mercury is described. The applications mentioned include the evacuation of demountable valves, certain metal plating processes, and the mounting of components in vacuo or in inert gases.

Introduction.

MANY dictionaries define a vacuum as a place devoid of matter and then describe that place as one from which nearly all the air has been removed. In the seventeenth century Torricelli discovered that atmospheric pressure would support a column of mercury some 760 mm. in height, and before the end of that century other workers succeeded in removing all but about the last thousandth part of air from a vessel, thus reducing the pressure of the air remaining until it would support less than one mm. of mercury. Not until the nineteenth century was any substantial improvement in vacuum recorded, but more recently progress towards that interesting objective the perfect vacuum, or absolute zero of pressure, has reached the stage when all the air except the last part in several hundred million can be removed from a container, not only in laboratories but also in factory production processes. This achievement would seem to approach the ultimate were it not for the fact that those who have made it possible have stated that this last remaining part still contains several thousand million air molecules per cubic centimetre of space in the container. It would perhaps be unwise to quote a figure for the best vacuum attainable at the present time even if such a figure were readily available, and for present purposes a limit of interest of 10^{-6} mm. mercury will be taken.

There is no precise distinction between low or rough vacuum and high or fine vacuum, but it is usual to apply the former term when reduction of pressure is obtained by means of a mechanical pump exhausting to the atmosphere and the latter when other means are employed to reduce the pressure still further after the mechanical pump has reached its limit. On this basis the division occurs at about 10^{-3} mm. mercury with an economic limit for the mechanical pump of about 10^{-2} mm. in many cases. Pumps have been devised which exhaust from atmospheric pressure down to 10^{-5} mm., but these are usually slow or difficult to operate or expensive and hence find little application. Vacuum technique as here discussed will cover the production of low pressures in two stages, the first of which is mechanical.

Mechanical Pumps.

Mechanical air pumps are devices in which moving metal parts are made to build up an increase in pressure between inlet and outlet. If the inlet is open to the atmosphere and the outlet is connected to a closed container, a pressure greater than that of the atmosphere is built up in the container and the pump is called a compressor. If the inlet is connected to a closed container and the outlet is open to the atmosphere, a pressure less than atmospheric is produced in the container and the pump is called a vacuum pump. Where the required difference in pressure between inlet and outlet is not very great, the same device can be used either as a compressor or a vacuum pump. One such general purpose type commonly used in laboratories will reduce the pressure in a vessel from atmospheric to about 10^{-1} mm. or will increase it to about 1,300 mm. mercury. A larger version such as that used in the pneumatic tube system at the Central Telegraph Office produces operating pressures at inlet and outlet of 530 and 1,400 mm. of mercury respectively, or expressed as gauge pressures, a vacuum of 9 inches mercury and a pressure of 12 lb/sq. in.[1]. When pressures much beyond these orders are required the machines are designed for single-purpose operation.

The Geryk pump shown schematically in Fig. 1 is an example of the reciprocating type of mechanical vacuum pump. Air from the vessel to be evacuated enters the cylinder through the inlet. When the piston rises it traps the air in the cylinder and compresses it against the valve which forms the end of the cylinder. When the pressure above the piston has been raised above atmospheric by an amount exceeding the weight of the parts and the load of the spring, the valve lifts and air is driven through the exhaust or outlet port. Finally, the piston overruns the cylinder and comes into close contact with the valve. Oil in the upper compartment wets the exposed portion of the piston to ensure lubrication and give a film seal between the high and low pressure parts of the cylinder. The limit of the low pressure obtainable is fixed by the accuracy of manufacture of the parts and the sealing properties

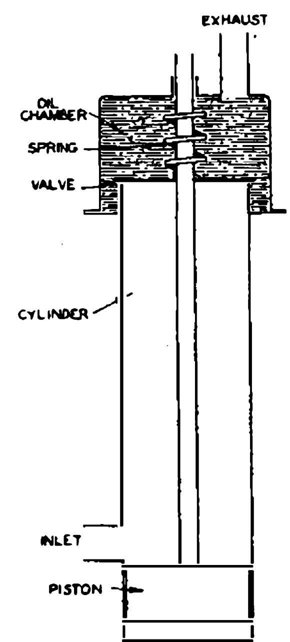


FIG. 1.—GERYK PUMP.

[1] *P.O.E.E.J.*, Vol. 40, p. 166.

of the oil film and is usually about 10^{-2} mm. for the single stage.

The same order of vacuum can be obtained with less costly mechanical pumps having oil film seals, by substituting rotary for reciprocating motion in an arrangement such as that of the Gaede pump shown in Fig. 2.

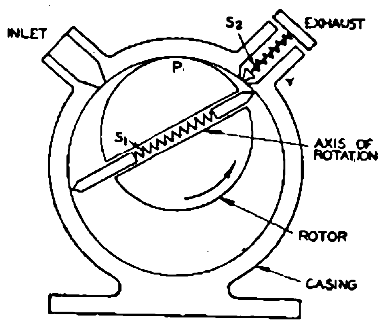


FIG. 2.—GAEDE PUMP.

Air enters through the inlet into the crescent-shaped space between the casing and the off-centre rotor. A diametral slot in the rotor carries vanes whose outer edges are kept in contact with the inside of the casing during rotation, by spring S_1. As the vane approaches the exhaust valve V the air becomes compressed into a continually diminishing space and if the pressure built up in this space exceeds that of the atmosphere and the load of spring S_2 exhaust takes place. Oil films separate the high- and low-pressure sides at the vane tips as well as at P and the same factors determine the limit of operation as with the Geryk pump.

In another design of scraping vane pump, the Hyvac shown in Fig. 3, the rotor is mounted eccen-

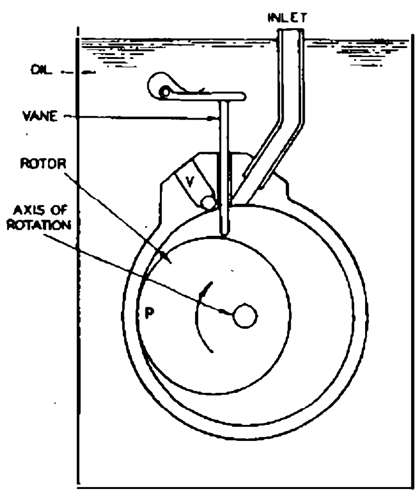


FIG. 3.—HYVAC PUMP.

trically on a spindle passing through the centre of the casing and air entering the inlet is compressed against a spring-loaded vane which is free to slide in a slot in the casing and so follow the movement of the rotor. As before, when the pressure built up in the space between the vane, the valve V, and the oil sealing point P exceeds that of the atmosphere and the load of the ball-valve, the pump exhausts to the atmosphere through the oil in which it is immersed. At the expense of the more accurate machining necessary to maintain the seal at point P, where the rotor makes near contact with the casing, a rather better vacuum of the order of 10^{-3} mm. is claimed.

No mechanical pump can reduce pressure beyond the limit imposed by the vapour pressure of the most volatile constituent of the oil in the pump, and with clean moisture-free oil this is usually between 10^{-3} and 10^{-4} mm. at 20°C. The vapour pressure of water at this temperature is 17·5 mm., hence it is necessary in all cases to prevent admission of moisture, and a trap containing a drying agent, such as silica gel or phosphorous pentoxide, is inserted in the system between the inlet to the pump and the vessel to be evacuated. In laboratory pumps it is practicable to change oil which has become contaminated with water, but in some industrial plants where moisture absorption is continuous, the oil on the exhaust side of the pump is cleaned by heating to 130° C to boil off the water, and then re-enters the pump.

Diffusion Pumps.

Diffusion pumps are so called because they depend for their action upon the ability of gas molecules to diffuse into a stream of heavier vapour molecules under certain conditions. Within the stream the gas molecules are trapped and carried along to be released again by condensation of the vapour at the cold surfaces on to which the stream is directed. It is a condition of operation that the initial pressure in the diffusion pump should be of the order of 10^{-1} mm. or less and when this condition has been produced by a mechanical pump (in this connection referred to as a "backing" pump) the pressure in the vessel being evacuated may be reduced a hundredfold by a single stage of diffusion pumping.

In appearance, diffusion pumps vary considerably according to the many designs which have been produced. The two main types are those which use mercury to provide the heavy vapour, and those using special oil having a low vapour pressure ; both types are operated in the Radio Development Branch laboratories. The operation is more readily understood by reference to the schematic diagram,

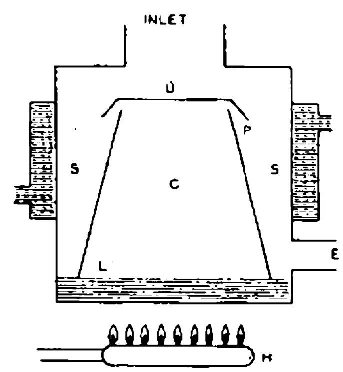


FIG. 4.—PRINCIPLE OF DIFFUSION PUMP.

Fig. 4. At the backing pressure of say 10^{-2} mm. the liquid L is boiled by the heater H and vapour

ascending the chimney C is deflected by the umbrella U and streams down the annular space S. The outer walls of this space are water-cooled and vapour condensing on the walls runs back into the boiler. Gas molecules from the chamber being pumped pass through the inlet and enter the vapour stream at points such as P whence they are carried down the annular space and out through the exhaust port E to the backing pump. They are prevented from re-entering the chamber by the vapour stream itself.

By using two or more stages of diffusion pumping the pressure at the inlet to the pumping system can be reduced to the order of 10^{-6} mm.

Measurement of Vacuum.

In the foregoing, different degrees of vacuum have been expressed to the nearest order. It is rarely necessary in applied vacuum work to know the value to any greater accuracy, which is perhaps fortunate in view of the difficulty of making absolute measurements of pressure over the range of interest. The fundamental method of measuring vacuum, which is to measure the height of the mercury column which the gas pressure will support, was elaborated by McLeod in the 1870's, and the direct-reading McLeod gauge, which may be constructed to read down to 10^{-6} mm. of mercury, remains the reference standard. Other types of gauge depend for their operation on some physical property of the residual gas, such as its ability to conduct different amounts of heat or electricity at different pressures (Pirani and Ionisation gauges). Auxiliary equipment is required to make these indirect measurements and with one exception the gauges must be calibrated against a McLeod gauge. The exception is the Knudsen gauge which is an absolute manometer in that its response to given pressures can be calculated. It is, however, a very delicate instrument as it contains a lightly suspended vane on which heated gas molecules impinge, and it is little used outside vacuum research laboratories.

One simple form of vacuum indicator, the discharge tube, deserves special mention. It consists of two electrodes in a glass tube which is sealed at one end and is open to the vacuum system at the other end. When the pressure in the system lies between about 10 and 10^{-2} mm., the application of a high potential to the electrodes causes ionisation of the residual gas and there appears in the tube a glow whose characteristics can be related approximately to particular pressures. When the pressure falls below about 10^{-2} mm. the glow disappears, and the device finds its greatest use as an indicator that this point has been reached. Thus the discharge tube may he used to indicate when the pressure in a pumping system has reached a sufficiently low value for the diffusion pumps to be started.

Post Office Applications

Demountable Valves and Tubes.

Probably the biggest application of high vacuum technique in the Engineering Department, in terms of quantity of equipment in regular use, is at the radio stations Rugby, Criggion and Leafield. The final amplifiers of some of the high-power radio transmitters at these stations contain valves which are demountable for filament replacement, and separate pump installations in each transmitter provide and maintain the high vacuum necessary for operation of the valves. A typical pump installation consists of a manifold serving two valves, pumped by two oil diffusion pumps in series to a reservoir backed by a two-stage mechanical pump of the Gaede type. No measuring gauges are fitted, but gauge elements of the Pirani type control the backing pump motor and thus a satisfactory backing pressure for the first diffusion pump is maintained in the reservoir. Discharge tubes in the rough vacuum line on either side of the reservoir serve to indicate that the Pirani elements are adjusted to operate at the correct pressures, and also assist in the location of leaks. The presence of the reservoir enables the apparatus to be maintained under vacuum conditions for short periods even with the backing pump disconnected, thus facilitating maintenance attention to the pump or replacement of phosphorus pentoxide in the vapour trap. The demountable valve filaments cannot be heated until a flow switch in the cooling water line to the diffusion pumps and thermal switches attached to the pump oil boilers have been operated. Thus, the whole system can be brought into use by people having little knowledge of vacuum physics. In this application the high vacuum chamber, i.e., the valve itself, is only opened at intervals averaging perhaps 2,000 hours.

In certain X-ray work it is necessary to use radiation having a wavelength suited to the investigation in hand. Some X-ray tubes are made demountable to facilitate the introduction of the target to produce radiation of the wavelength desired. In use the tube is continuously pumped by two oil diffusion pumps backed by a mechanical pump but less automatic control gear is provided than in the transmitting valve example, and consequently more knowledge of the subject is required. A calibrated Pirani gauge is fitted to the instrument panel and the pump heaters are switched on when a satisfactory backing pressure is indicated.

Metal Plating Processes.

Similar pumping installations are used in the production of quartz crystal oscillator and resonator units, but here the application is somewhat different in that the vacuum chamber is frequently opened to the atmosphere to receive the items to be processed. The processes involved are the deposition of metal electrodes on to the surfaces of the quartz plates and the sealing of the mounted quartz elements into evacuated envelopes. The two processes mainly employed for deposition of electrodes are the evaporation of metal in vacuo and the cathode sputtering process.

In the evaporation process the metal to be used as plating, in the form of wire, is wound round a suitable metal filament connected at its ends to massive metal terminals, and is located, together with the specimens to be plated, inside a glass bell-jar or other chamber which can be evacuated. When a sufficiently high vacuum has been produced in the chamber, the filament is heated by the passage of current and the wire melts and then boils. Vapour streams away from the boiling metal and condenses on any cool surface exposed to it. The filament material must be chosen to suit the metal to be evaporated, since it is essential that the molten metal should wet and adhere to the filament and not drop off. Tungsten filaments are suitable for use with aluminium, and nickel filaments have been found satisfactory with silver. The arrangement is shown schematically in Fig. 5. To obtain uniformity of

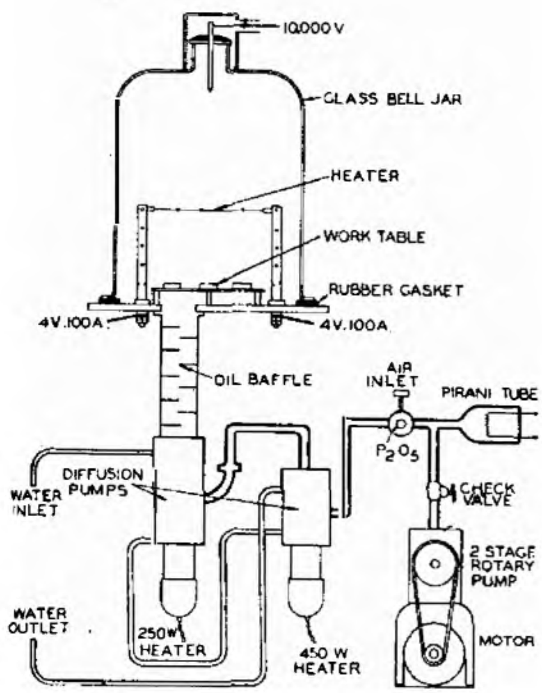


Fig. 5.—Principle of Evaporation Equipment.

coating the quartz elements to be plated are disposed round the inner surface of a cylindrical holder having the filament as axis. In a simple form of apparatus only one side of the specimen is plated at one operation and so the chamber must be opened, the specimen turned over, and a second evaporation carried out, to complete the plating. At the commencement of the process, and after reopening for the second operation, a film of air adheres to all the exposed surfaces of the chamber. The backing pump finds difficulty in removing this layer to an extent sufficient for the diffusion pumps to be brought into use. Assistance is provided by a high tension electrode in the chamber which ionises the residual gas and dislodges the "adsorbed layer" as it is called. With this arrangement the whole chamber constitutes a discharge tube indicating its own vacuum condition. Generally speaking the better the vacuum the better are the results in the evaporation process.

In the cathode sputtering process, which has been extensively used for the deposition of gold electrodes on quartz crystal elements, a much lower order of vacuum is required and diffusion pumps are unnecessary. Indeed, the process requires the presence of a certain amount of gas within the chamber for its operation. As shown in Fig. 6, the work to be plated stands on a platform between a gold cathode mounted in the vacuum chamber and the anode which forms

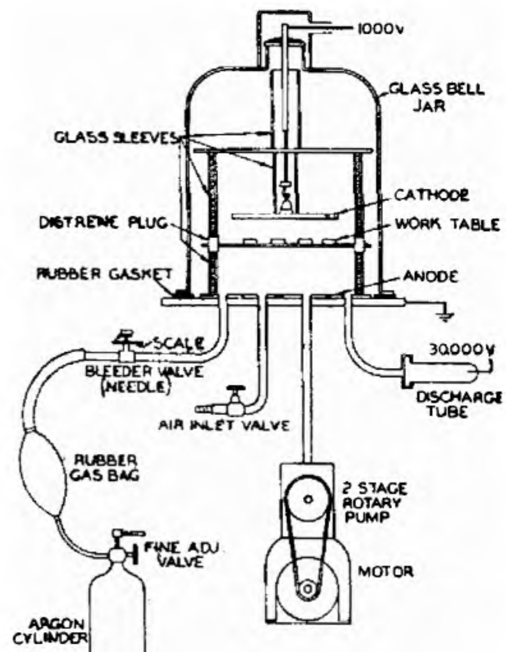


Fig. 6.—Principle of Sputtering Equipment.

the base. The chamber is pumped against a slow leak of argon admitted through a needle valve to an equilibrium pressure at which the glow discharge produced by 1,000 volts shows a cathode dark space extending to within about ¼ in. of the crystals. Under these conditions gold from the cathode is sputtered on to the crystal surfaces and in about half an hour an opaque conducting film is produced. The exact mechanism of sputtering is not completely understood but one explanation suggests that when the electrical discharge takes place the intervening space becomes conductive and positive ions are attracted to the cathode. The momentum of these relatively heavy ions is such as to cause the disintegration of the cathode surface, and some of the particles removed therefrom fall on the crystals which thus receive a metal coating. It is a more easily controlled process than evaporation and can be carried out by semi-skilled operators.

Both plating methods described are directly applicable to mirror-making by substituting polished glass for quartz surfaces, and front surface reflectors have been produced for use as viewing mirrors associated with cathode-ray tubes, galvanometer mirrors have been replated and other small jobs have been done with the laboratory equipment. Special precautions must be taken, however, when making good permanent mirrors, and the protective coatings which are desirable involve technique not normal to crystal production.

Quartz Crystal Holders.

The first type of evacuated crystal holder used by the Post Office was made of stainless steel and was exhausted by a hand-operated piston pump to a pressure corresponding to about 5 centimetres of mercury; air damping on the vibrating crystal was thus reduced sufficiently to improve the "Q" of the crystal by about 50–100 per cent. The holder was expensive because of the high quality of workmanship required and because the vacuum seal was made between two surfaces machined to a high order of flatness, but its performance was very satisfactory. Crystals in these holders were used as master oscillators in the original carrier generating equipment fitted to the London-Birmingham coaxial cable system[2] and in an early frequency standard[3]. Many others have been supplied to the B.B.C. for medium-wave transmitter control. A second type in the form of a copper can sealed with solder, was exhausted by a motor-driven rotary pump to about 10^{-1} mm. The result of reducing the pressure to this lower value was to improve the Q of the crystal five or six times. Some trouble was experienced in sealing but it was found that leaks usually showed up in the first few days after sealing and during the period of laboratory testing before despatch. Several hundred crystals in these holders have been made for precision applications such as primary standards of frequency[4] and quartz clocks[5] as supplied to the Astronomer Royal and the cost of the holders for comparable quantities was about one-tenth that of the earlier stainless steel type.

A further substantial reduction in cost, a useful improvement in vacuum, and a guaranteed gas-tight seal resulted from the introduction, in 1944, of evacuated glass envelope crystal holders, and in current practice these are used whenever possible. The glass envelopes are made from standard components as used in thermionic valve manufacture and allied industries, sealed together in gas flames and exhausted by a diffusion pump and backing pump. It has been shown that little improvement in crystal performance is to be expected by evacuation beyond 10^{-2} mm. and this pressure could be reached at the inlet to a rotary pump alone. A diffusion pump is used to ensure that a sufficiently good vacuum will be produced in the envelope without keeping a careful watch on the performance of the backing pump.

Miscellaneous Applications.

The evacuated glass envelope technique is, of course applicable to work other than crystal production. It is sometimes desirable for tests to be made to determine the characteristics in a vacuum of components such as rectifier elements, and samples for test have been prepared on the normal crystal production equipment. Another application was the mounting of high speed relays in glass envelopes. In their original form the relays (H96D) did not present a sufficiently high impedance across the break contacts in operating conditions of high humidity. The relays were, therefore, stripped of all wrappings and mounted in glass envelopes with connections to the break contacts brought out at opposite ends, one through a valve top cap and the other through one pin of an international octal base. During pumping to remove air liable to cause contamination of contacts, there was visible evidence that gases and/or vapours came off the lacquers and varnishes on the essential parts of the relay. It would have been unwise to leave the envelopes evacuated as further "outgassing" would have occurred during the life of the relay, which might have brought about the very contamination it was wished to avoid. To prevent this the envelopes were refilled with nitrogen up to atmospheric pressure before sealing off. The complete unit, which has been coded "Relay 330A", is shown in Fig. 7.

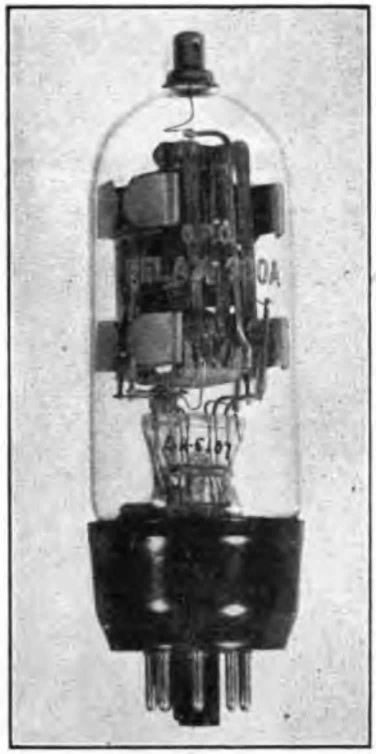


FIG. 7.—RELAY 330A.

In the development and production of thermionic valves, pumps and gauges such as those described are "tools of the trade", but additional methods must be employed to obtain the higher degree of vacuum (10^{-7} mm. or better) required in sealed-off valves. This subject is outside the scope of the present brief review.

[2] *P.O.E.E.J.*, Vol. 30, p. 274.
[3] *J.I.E.E.*, Vol. 88, Part III, p. 107.
[4] *J.I.E.E.*, Vol. 93, Part III, p. 223.
[5] *P.O.E.E.J.*, Vol. 39, p. 33.

Poisoning Effects in Oxide-Cathode Valves

G. H. METSON, M.C., Ph.D., M.Sc.(Eng.), A.M.I.E.E.

U.D.C. 621.385.032.216 : 537.533

It is commonly supposed that residual gases left in an oxide-cathode valve during manufacture are liberated when the valve is operated, attack the cathode, and cause the emission to fall. This article refers to observations on this subject made by other workers and gives an abridged account of some recent research by the author using commercial pentode valves.

Introduction.

EMISSION failure in oxide-cathode valves is commonly supposed to be due to poisoning of the cathode by residual gases left in the valve during the manufacturing process. These gases may be left in the occluded state within the electrodes, absorbed on the glass envelope, or in the combined state on the surfaces of grids and anode. During the operation of the valve these gases may be liberated and attack the cathode causing the emission to fall.

Although cathode poisoning effects have been widely observed in the past, they are still only vaguely understood and literature on the subject is meagre and somewhat contradictory, although two papers appear in advance of others. In 1936 Headrick and Lederer[1] reported that an oxide-cathode became poisoned when the control-grid of the valve was bombarded with electrons having an energy in excess of 7 volts. In 1947, Hamaker, Bruining and Aten[2] observed a similar effect but occurring with a minimum bombarding energy of 11 volts.

In 1946 some work on such poisoning effects was carried out in the Research Branch. It is thought, therefore, that an outline of the work might be of interest, although it must be emphasised that the effects described may be only indirectly concerned with emission failure in service. Fuller details of the work will be published elsewhere.

Dissociation by Electron Bombardment.

When a metal combines with oxygen it gives rise to the oxide and evolves a definite amount of heat. Under favourable conditions the same amount of oxide supplied with the same amount of heat will decompose into the metal and oxygen. The amount of heat necessary to decompose unit mass of the oxide (or other compound) is constant and characteristic for a particular compound.

If a high-velocity electron strikes a mass of oxide, its velocity is destroyed and its kinetic energy converted into heat. If the velocity is high enough the heat produced on impact will be just sufficient to dissociate one molecule of the oxide. H. Jacobs[3] in 1946 demonstrated the truth of this statement for a number of metallic oxides and showed that the relation between the critical energy of the impacting electron and the heat of formation of the material concerned was

$$V_E = H/23 \text{ electron-volts} \quad \ldots\ldots (1)$$

where 23 kilogram calories per mole is equivalent to 1 electron-volt per molecule.

The work of Jacobs leads to an obvious method of estimating the chemical composition of thin films —too minute for chemical or spectroscopic analysis— by observing the voltage at which they dissociate under electron bombardment.

The Voltage-Dependent Poisoning Effects.

Working with ordinary commercial pentode valves, three separate and distinct poisoning effects have been noted. The method of detection is simple. The pentode is arranged as a diode with control-grid as electron collector and a volt/amp. characteristic taken. The characteristic follows a 3/2 power law so long as the emission of the oxide-cathode is adequate to meet the space-charge requirement of the diode and the emitting area of the cathode remains constant. If the cathode is subject to poisoning during the recording of the characteristic then the 3/2 law characteristic ceases to apply. Furthermore, if the poisoning occurs at discrete voltages, the characteristic may show discrete deviations at these voltages, as, for example, in Fig. 1.

The generalised observations of Headrick and Lederer cover all three effects without apparent realisation of their individuality. The work of Hamaker, Bruining and Aten is only concerned with the 11-volt effect.

The Critical Voltages.

Of the three effects the 6-V one was found to be by far the most powerful. A typical example of the effect

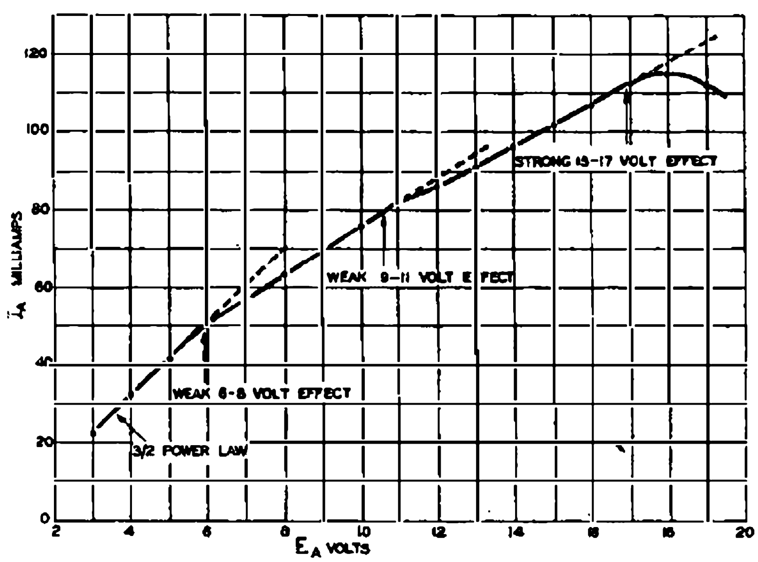


FIG. 1.—VOLTAGE-DEPENDENT DEVIATIONS FROM 3/2 POWER LAW.

[1] *Physical Review*, Vol. 50, L.1094 (1936).
[2] *Phillips Res. Reports*, Vol. 2, No. 3, 1947.
[3] *Jour. App. Physics*, Vol. 17, No. 7, 1946.

is shown in Fig. **2**, and frequent cases were observed in which the cathode emission fell by over 95 per cent. when the collector voltage was raised above 6V. In such cases it is, of course, impossible to observe

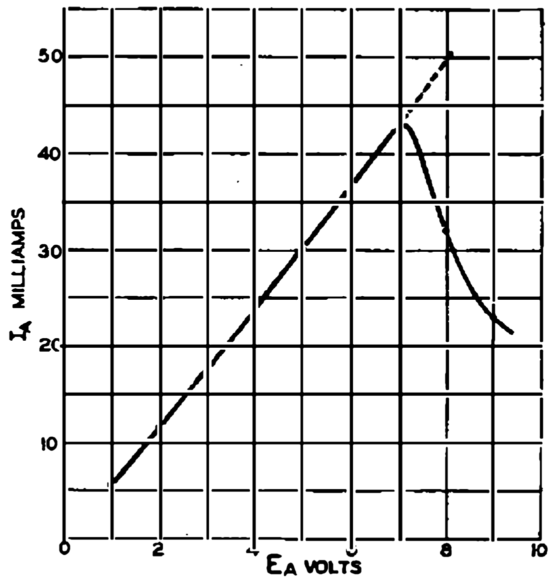


FIG. 2.—TYPICAL EXAMPLE OF 6-8 VOLT EFFECT.

the 11-V and 17-V effects. Fig. **1** shows a case in which the valve had been treated to reduce the 6-V effect to very small proportions in order to observe the higher voltage effects.

To determine the critical energy of impact for dissociation, a batch (24 samples) of pentodes from various sources was tested and a mean value of critical energy of 5·56 electron-volts observed with a standard deviation of 0·28 electron-volts.

The 9-V and 11-V effects noted were relatively slight and more difficult to measure. Mean critical energies for the three effects with values of H derived from equation (1) are tabulated below. It will be observed that the critical energies are somewhat below the value of the applied potential for breakdown —this is due to corrections applied to account for contact potential between electrodes and for thermal emission energies of the electrons from the hot cathode.

Effect	Mean Critical Energy	Derived Value of H
6-volt	5·56 electron-volt	128 kilogram cals. per mole
11-volt	9·40 electron-volt	216 kilogram cals. per mole
17-volt	15·97 electron-volt	367 kilogram cals. per mole

No effects were found between 17V and 25V and there appear to be no likely compounds with a heat of formation greater than the equivalent of 25V. It is probable, therefore, that the three effects noted are the only ones likely to be encountered in common commercial valves.

Reference to a chemical handbook shows the following barium compounds with their heats of formation : monoxide 133, chloride 205, sulphate 349.

The tentative conclusion reached from these results is that a film of mixed oxide, chloride and sulphate may exist on the surface of the control-grid of typical commercial pentodes. Experiments with valves made specially for the purpose showed that barium monoxide is evaporated from the cathode on to the control-grid during the production of the valve when the cathode is activated at relatively high temperature. Examination of a typical sample of cathode paste showed traces of both chloride and sulphate and it appears probable that these radicles are evaporated on to the control-grid at the same time as the oxide. Hamaker and his colleagues offer an alternative explanation for the appearance of the chloride on the grid and show, in their own case, that it is derived from the glass envelope of the valve which is shown to evolve HCl when it is baked at 400°C during the processing of the valve.

During the normal operation of the valve there is little likelihood of the control-grid film being disturbed as high energy electrons are excluded from the grid. The film, therefore, rests undisturbed except for possible positive ion bombardment (reverse grid current) which is extremely small. Valves of 50,000 hours' life have been examined and shown to have films of barium oxide on the control-grid comparable in magnitude to those noted on new valves of the same type. It must, however, be appreciated that the screen-grid of a pentode—which is subject to high energy bombardment throughout life—is just as likely to receive films in the same way as the control-grid.

Reversible and Irreversible Poisoning.

If the voltage on the control-grid of a pentode is raised steadily the current increases in accordance with the 3/2 power law until electrons strike the grid film with an energy in excess of 5·65 electron-volts. At this stage oxygen is evolved and the liberated gas poisons the cathode with consequent fall of emission. If the bombardment is continued for a long period (say 100 hours or more) all of the oxide on the grid is dissociated and the supply of poisoning gas ceases. At this stage the cathode begins to recover by ejecting the poisoning oxygen atoms or ions and the emission ultimately re-establishes itself at the value it had before poisoning started. Careful quantitative measurements of total emission seem to indicate that recovery is complete. Such poisoning effects are described as " reversible " and oxygen, at the pressures examined, is shown to be completely reversible in action.

Normal emission failure of valves in service is due to a form of " irreversible " poisoning. There is almost no published information on this subject, but work in the Research Branch appears to indicate that it is closely allied to the reversible form. Reversible poisoning—simultaneous poisoning and reactivation —is probably a continuous feature of the cathode throughout its life in a pentode valve. Superimposed on this is a progressive failure of minute areas of the cathode to reactivate. The total effective emitting area of the cathode, therefore, shrinks with time and the common phenomena of falling anode current and mutual conductance are observed.

Pneumatic Tubes

C. A. R. PEARCE, M.Sc.(Eng.), A.C.G.I., A.M.I.E.E.

U.D.C. 621.867.8

A description is given of some tests which had for their object the proof of a more precise statement of the mechanics of a carrier in a pneumatic tube than had hitherto been published. The author claims that whilst the theories advanced in the article are not conclusively proved they at least offer a consistent explanation of the subject and are supported by the results obtained.

Introduction.

ALTHOUGH pneumatic street tubes have been used to convey telegrams for almost a century and the method must now be considered to be approaching obsolescence, little has been published about its basic theory. This is probably due in part to the inherent simplicity of the method which does not invite the attention of the research worker. Despite this simplicity, however, certain features of the subject may profitably be enlarged upon and some of the history of street tubes is not without interest.

The London pneumatic street tube system was out of use after the destruction of the Central Telegraph Office in 1940 and the damage, by enemy action, which it sustained during the years that followed accumulated, until in 1943 it was found that it would be a major task to make the tubes fit to carry traffic. Before reconditioning and repair work could be started a complete survey and considerable testing was essential and the opportunity was taken to include some tests of a fundamental character. The results of some of these tests are included in this article.

Historical.

The first street tube to be laid in London was put into service in 1853 by the International Telegraph Company through their engineer, Mr. Latimer Clark. It ran from the Telegraph Centre to the Stock Exchange. In 1870, Dr. C. Siemens completed work for the Post Office on tubes to Charing Cross and Temple Bar and Mr. Varley, whose name was given to the standard test for line faults, was responsible for the introduction, in 1858, of compressed air working.

By 1875 the Post Office was operating in London 25 tubes totalling nearly 18 miles in length and all except those installed by Siemens were of lead. Siemens used iron, but the rust problem seems to have been serious and eventually to have caused lead to be adopted as the standard material.

An unusual sidelight on the faulting practice of the 1870's is provided by two methods advocated for dealing with carriers which had jammed. In Paris the position of such carriers was determined by firing a pistol near the mouth of the tube and timing the period that elapsed before the echo was heard. Half this time multiplied by the velocity of sound gave the distance to the fault. The excitement of the method was doubtless one of its attractions for the volatile Parisians. In this country the method was even more drastic. Each tube was provided with a connection to the water main and when a blockage occurred it was cleared by flooding the tube and using the mains pressure to force the carrier past the obstruction. No details are available of the use made of the device, but it is not difficult to imagine some amusing repercussions.

It is also interesting to note in passing that in 1893 the United States Post Office Department put into service the first of a number of 6-in. diameter tubes for the transmission of mails. Prior to this, pneumatic street tubes had only been used successfully for telegrams and the like. By 1908, 150 tons of mail (or 17 per cent. of the total weight) was moved each day by U.S. tubes at a speed of about 30 miles per hour, and by 1918 8-in. diameter tubes were in use and were favourably reported upon.

Almost from the beginning two sizes of street tube were standard in this country, viz. 2¼ in. and 3 in. diameter and there is little difference between the standard construction methods employed to-day and those of 50 years ago. In fact some of the tubes installed under the City streets about 1880 are still in use. The system working from the Central Telegraph Office now comprises some 70 tubes with lengths up to 2½ miles.

Symbols Employed.

In the sections which follow, v, p, ρ and l are used to represent mean velocity across a section, absolute pressure, density, and distance along the tube from the high pressure end, respectively.

Where symbols for velocity refer specifically to the carrier and the air and the context does not make clear which, the respective prefixes "c" and "a" are added, e.g. ${}_{c}v$ represents the velocity of the carrier. For the terminal conditions capital letters P and V are used. The suffix "1" indicates the high pressure end and "2" the low pressure end; thus ${}_{a}V_1$ represents the mean velocity of the air at the high pressure end. L and D are the length and diameter of the tube. h_c is the pressure drop across the carrier. Except in equation (9) where it is specifically indicated otherwise, equations are in f.p.s. units, but for general convenience the pressures in the curves are all, as stated, in inches of mercury.

Early Theories and Formulæ.

The paucity of literature on the subject has been mentioned already and it is necessary to go back to 1875 to find the only real attempt to derive formulæ to express the transit time for a carrier in terms of the air pressure on a tube and its physical dimensions. In a paper read to the Institute of Civil Engineers,[1] Messrs. Culley and Sabine derived the following formula for the average velocity of a carrier in ft./sec. in tubes having a length exceeding 5,000 diameters :—

$$56{\cdot}7\left(\frac{D}{L}\right)^{\frac{1}{3}}\left(\frac{f}{\rho}\right)^{\frac{1}{2}}\left(\frac{P_1+P_2}{2P_1}\right)^{\frac{1}{2n}}\text{ (f.p.s. units)......(1)}$$

in which f = work performed by 1 cu. ft. of air in expanding from P_1 to P_2, ρ is the mean density and n is the ratio of the specific heats of air.

[1] *Proc. I.C.E.*, 1875. "The Pneumatic Transmission of Telegrams."

The formula is based on the assumption that the expansion of the air in the tube takes place adiabatically, and the authors claimed that it gave results which agreed well with those obtained in practice.

During the discussion, which incidentally seems to have extended over three separate evenings, Professor Unwin produced a second formula based on isothermal expansion of the air, viz. :—

$$1{,}416\sqrt{\frac{D}{\alpha L}}\cdot\frac{(P_1^2-P_2^2)^{\frac{3}{2}}}{P_1^3-P_2^3} \quad \text{(f.p.s. units)} \ldots\ldots\ldots (2)$$

where α is the coefficient of friction between the air and the wall of the tube. The mean value quoted is 0·028 for smooth lead.

Formulæ (1) and (2) are derived from total energy considerations and assumptions that the carrier has negligible effect on the motion of the air and that the air slides over the tube surface. Later work and some of the tests described in this article have shown both assumptions to be invalid and in Fig. 1 the predictions

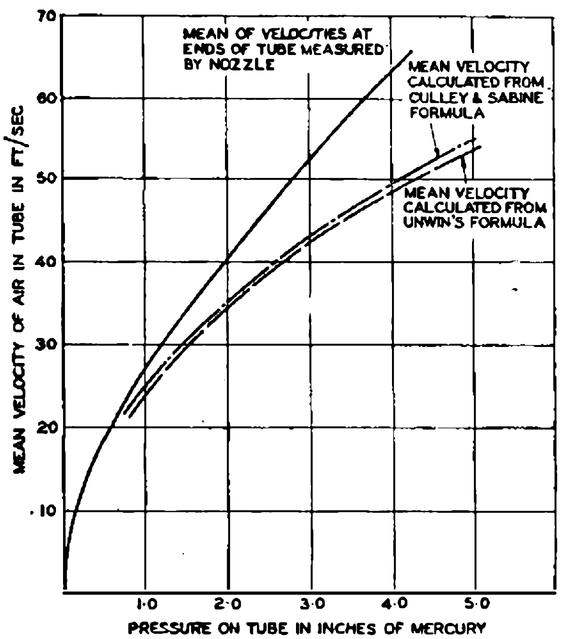


FIG. 1.—COMPARISON OF ACTUAL AIRFLOW WITH PREDICTIONS BY CULLEY-SABINE AND UNWIN.

of the formulæ are compared with the results of air flow tests on a tube.

In 1874, the year previous to the meeting at the Institute of Civil Engineers, Osborne Reynolds had published a paper on fluid flow[2], but presumably this was unknown or unappreciated by those at the meeting as it was not mentioned. His classic researches were published in 1883.[3]

Theory of Air Flow in Pipes.

It would be out of place in an article of this type to recapitulate the complete theory of the flow of air in pipes, but a brief outline is perhaps permissible.[4]

At air speeds below the critical value for the pipe the distribution of the air velocities across a section is parabolic (see Fig. 2). In such a case the flow is known as "laminar" or "streamlined", although even with this class of flow irregularities are present. In a 3-in. diameter tube laminar flow is present only for velocities of less than about 1¼ ft./sec. and for a 2¼-in. diameter tube the critical velocity, according to Ower, is about 1¾ ft./sec. The streamline condition

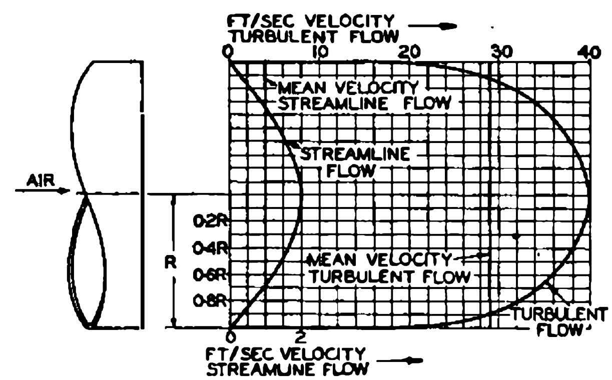


FIG. 2.—DISTRIBUTION OF AIR VELOCITY ACROSS TUBE.

is therefore of only passing interest in connection with pneumatic tubes where the air velocities are of the order of 30 ft./sec.

At velocities greater than the critical, the flow is "turbulent" and eddies are continuously present, i.e. the motion of the air ceases to be parallel with the axis of the tube across the whole section and the velocity distribution takes on the form indicated in Fig. 2. Laminar flow still persists in the boundary layers near the tube walls and as in the streamline condition the air velocity at the wall approaches zero.

For an incompressible fluid the equivalent of the friction force per unit area of tube wall is, according to Ower, approximately proportional to v^m where

$$m = 2 - \frac{29{\cdot}7}{85 + \left(\frac{vD}{\gamma}\right)^{\cdot 85}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

and γ is the kinematic viscosity of the fluid.

The term "friction force" used above is convenient but inaccurate. The pressure difference δp (Fig. 3) is

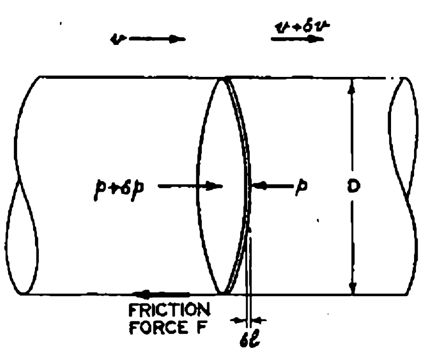


FIG. 3.—CONDITIONS FOR ELEMENTAL DISC OF AIR IN TUBE.

[2] *Proc. Manchester Lit. and Phil. Soc.*

[3] *Phil. Trans. Roy. Soc.*

[4] For detailed treatment see *Proc. Roy. Soc.*, Vol. 85, *Phil. Trans. Roy. Soc.*, Vol. 215 (Stanton and Pannell) and "Measurement of Air Flow" (Ower).

balanced by the viscous forces, due to the velocity gradients across the section (Fig. **2**), i.e. it causes the layers of air to slide one over another. A fair average value for "m" for tubes of the diameter of pneumatic tubes and at velocities and temperatures normally encountered is **1**·75.

Individual values of m at 20°C are :—

1·77 for a 3-in. tube at 30 ft./sec.
1·76 for a $2\frac{1}{4}$-in. tube at 30 ft./sec.
1·73 for a 3-in. tube at 15 ft./sec.
1·72 for a $2\frac{1}{4}$-in. tube at 15 ft./sec.

The effect of a lower temperature is small but 20°C was chosen because it is near the mean temperature of the air in the first group of tests to be described.

Thus for the elemental disc of air shown in Fig. **3**

$$\frac{\delta p}{\delta l} \propto v^{1 \cdot 75} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

The relevance of the prescribed quality of "incompressibility" is that if the fluid is compressible it will expand whilst flowing in the direction of decreasing pressure and this expansion will of itself increase the velocity. This effect becomes appreciable in a long pneumatic tube where the pressure to work the tube may be 10 lb./sq. in. or more, so that the absolute pressure of the air falls by about one-third during its passage through the tube and there is a corresponding increase in velocity.

Although all this is in accordance with the present accepted theories it is not in agreement with the assumptions of Unwin or Culley and Sabine, and the first tests to be described were aimed at checking expression (4) and ascertaining whether it was justified to consider the carrier as carried along at the mean velocity of the air with negligible effect on the air flow.

Measurement of Air Velocity.

To those familiar with the subject there is nothing noteworthy in the method employed to measure the air velocities in the tests described in the sections which follow. It was based on the nozzle described in B.S.S. No. 726. This nozzle is illustrated in Figs. **4** and **5** and depends for its operation on the " Venturi effect. Thus a constriction in a pipe through which fluid is passing will cause a temporary increase in tl velocity (and consequently the velocity head) and corresponding decrease in the static head or pressu

FIG. **4**.—NOZZLE.

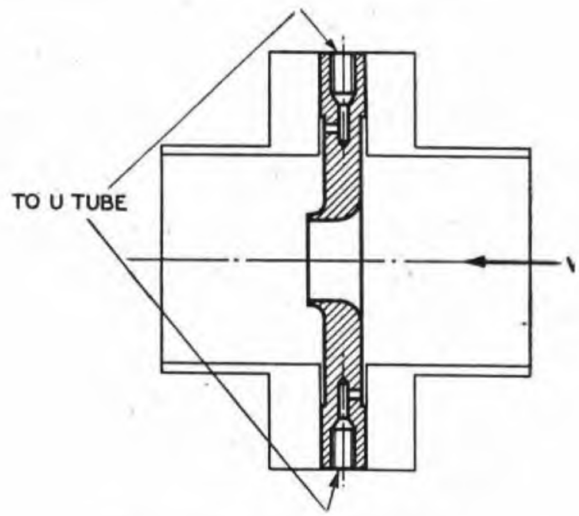


FIG. **5**.—SECTIONAL VIEW OF NOZZLE.

The pressure drop across the nozzle may be measur by a "U" tube and from a simple formula tl quantity of air passing can be determined.

The beauty of the nozzle method is that calibration is required if the plates are constructed the limits quoted in the specifications and the limits are realisable without difficulty.

The nozzles used had a $1\frac{1}{2}$-in. throat diameter a were mounted in a length of 3 in. pipe, the wh being connected to the tube under test irrespective whether it was a $2\frac{1}{4}$-in. or 3-in. diameter tube. accord precisely with the specified conditions for use the nozzle should have been used in a tube of n smaller diameter than $3\frac{1}{4}$ in., but allowance was ma for this fact by recalculating the nozzle constant.

Air Flow and the Effect of Carriers in a Short Tube.

A $2\frac{1}{4}$ in. diameter tube 660 ft. long was available the basement of the Central Telegraph Office and series of tests were made on this, to determine t mean air velocity resulting from various applied pressures. The curve of the results, which has be mentioned already, is given in Fig. **1**, together wi corresponding curves obtained using the formulæ Unwin and Culley and Sabine.

The agreement between the predictions of t formulæ and the results obtained is poor and althou the minimum tube length of 5,000 diameters whi was stipulated by Culley and Sabine was not availab Unwin specified no such limitation to the applicati of his very similar expression and the differen between the predicted and the actual results is t great to be explained by the short tube.

The curves of Fig. **6** were obtained using a series weighted carriers in the same 660 ft. long, $2\frac{1}{4}$-diameter tube and show that even the lightest carri are slower than the undisturbed air stream.

Fig. **6**, taken together with Fig. **1**, provides a fairly clear proof that the assumptions of the earlier workers were not well founded.

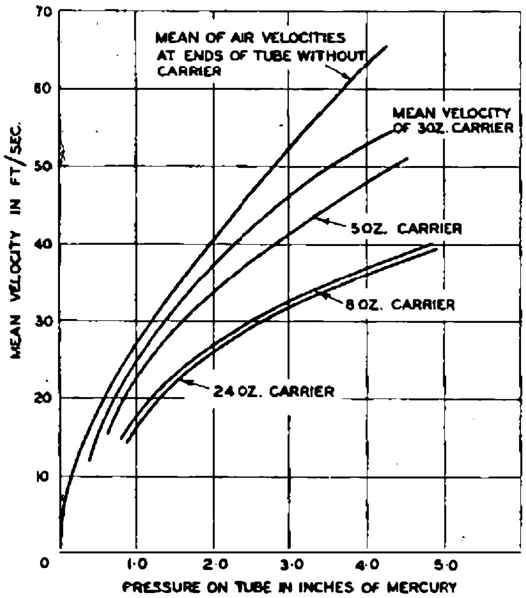


Fig. 6.—Effect of Carrier Weight on Average Speed.

The law of the air flow curve gives a general approximate expression (see Fig. **3**) :—

$$\frac{\delta p}{\delta l} = v^{1 \cdot 75} \times \frac{0 \cdot 802 \times 10^{-3}}{D} \rho \text{ (f.p.s. units) } \ldots\ldots (5)$$

The value of the index agrees exactly with the prediction of equation (3). When the pressure is measured in inches of mercury the constant becomes $1 \cdot 13 \times 10^{-5}$.

The Mechanics of the Carrier.

Having cleared the ground by showing the inadequacy of the earlier views on the subject, it is appropriate to turn to the problem of providing an alternative solution to the problem. A first step is to consider in detail the forces acting on the carrier.

Pneumatic tube carriers are of somewhat rough construction and do not fit exactly the tubes in which they work (see Fig. **7**). A clearance of about ⅛ in. on

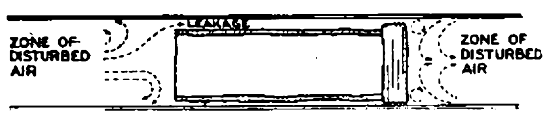


Fig. 7.—Conjectured Air-Disturbance Around Carrier.

the diameter is typical. Experience has shown that there is nothing to be gained by making the carrier fit the tube closely and in old tubes with numerous distortions such a step is likely to occasion frequent blockages. As will be seen later, the theoretical considerations confirm the practical experience.

At a steady speed it would seem that three main forces act upon a carrier, viz.:—

(i) *The friction reaction between the carrier and the tube.* This in a level straight tube is equal to $K\mu W$, where μ is the coefficient of friction, W the weight of the carrier and K depends on the fit of the carrier in the tube. If the carrier is an average fit in the tube the friction reaction may be sensibly greater than μW. Some static tests with working carriers gave $K\mu = 0 \cdot 6$.

(ii) *The air pressure on the leading face of the carrier.* This force is made up of a part represented by the head necessary to move the air in front of the carrier and a part which appears hitherto to have received no consideration, viz., a back pressure due to the motion of the carrier.

It seems clear that the presence of a carrier in a stream of air flowing through a tube must create a disturbance in the normal distribution of flow. The presence of slow-moving boundary layers has already been mentioned, and when these are disturbed by the carrier it is clear that a back pressure will be built up, and it is conjectured that immediately in front of and immediately behind the carrier zones of air will exist which are moving in a manner radically different from air elsewhere in the tube. Fig. **7** conveys a general picture of what is envisaged.

The conditions are presumably similar to those existing in front of a tube train and it happens that the clearance between a train and the wall of a tunnel is proportionately equal to that between a carrier and a tube. As a matter of interest Fig. **8** shows how the

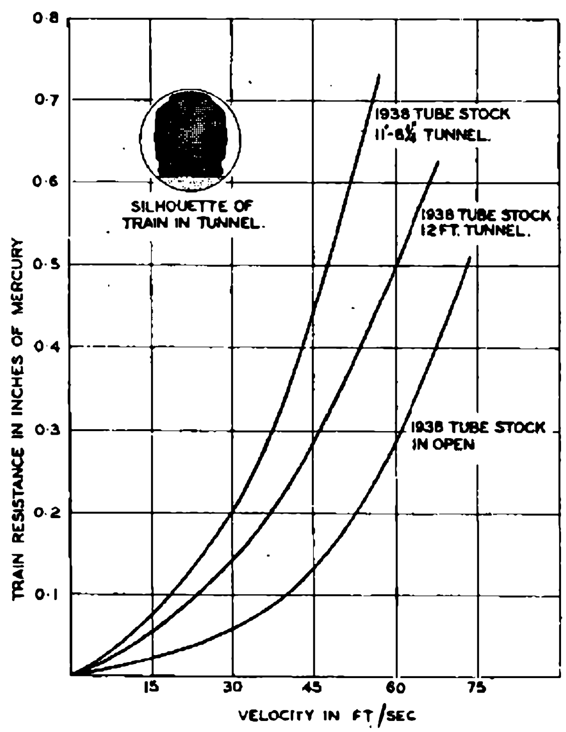


Fig. 8.—Train Resistance in Tunnel and in Open.

air resistance to a tube train varies with speed and the clearance with the tunnel walls. The resistance is converted to air pressure on the front of the train. Support for the author's theory comes mainly from the striking reduction in wind resistance which results from only a 4 in. increase in the tunnel diameter.

The part of the force on the face of the carrier which is due to the resistance of the column of air in front of it will depend on its position relative to the ends of the tube, but as a first approximation, the resistance of the whole tube without a carrier can be considered equal to the sum of the resistances of the lengths of tube up to and beyond the carrier.

The value of the back pressure occasioned by the carrier disturbing the velocity distributions (Fig. 2) can at this stage be written $f({}_{c}v)$, i.e. a function of the carrier velocity.

(iii) *A pressure difference, h_c between the rear and the front of the carrier, which maintains its motion.*

Clearly,

$$h_c \times \text{area of the end of the carrier} = K\mu W + f({}_{c}v) \quad \ldots (6)$$

Since the carrier is not an exact fit in the tube the pressure h_c will cause air to leak past, and this leak expressed as an air velocity over the whole section of the tube will presumably be equal to some function of h_c, viz., $F(h_c)$ and thus :—

$${}_{a}v = {}_{c}v + F(h_c) \quad \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Determination of h_c, $f({}_{c}v)$ *and* $F(h_c)$.

To determine the values of h_c, $f({}_{c}v)$ and $F(h_c)$, the tests already described were extended to include measurements of the mean air velocity in the tube whilst carriers were passing through it. Some of these results are given as curves with those of carrier velocity and air velocity without a carrier in Fig. 9.

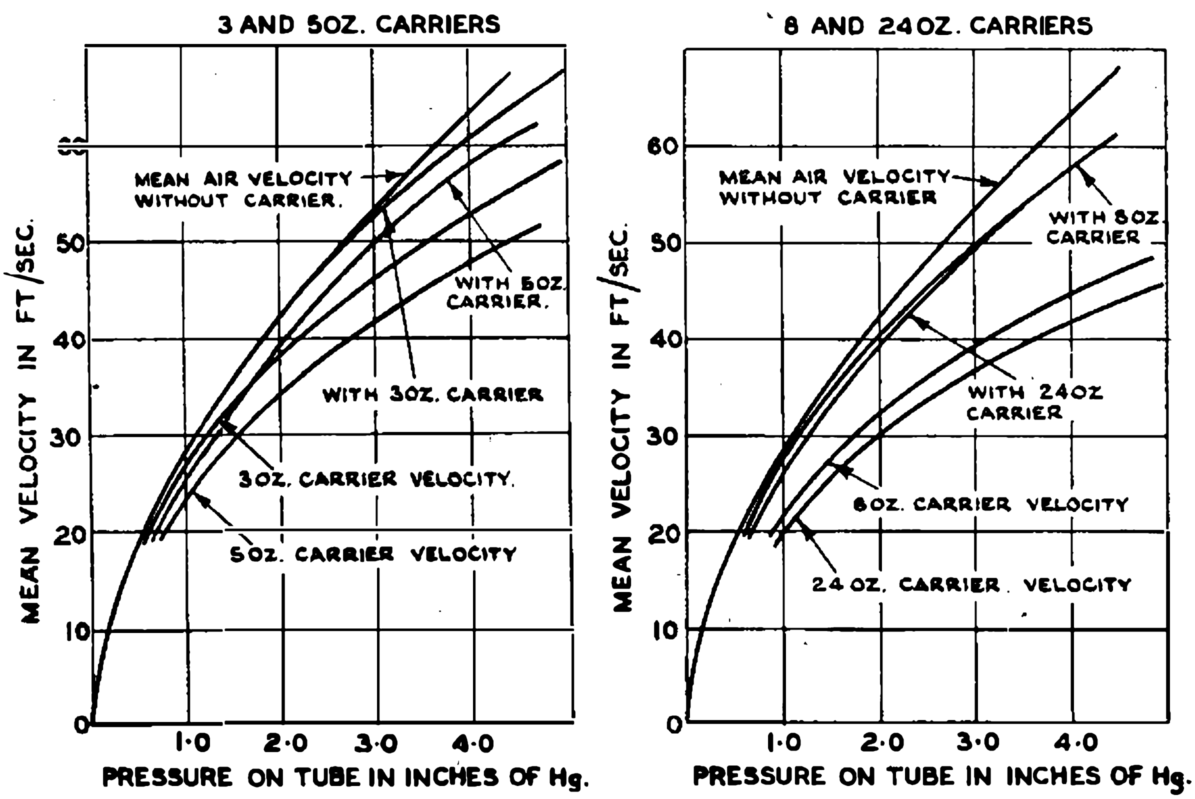


FIG. 9.—CARRIER VELOCITIES, AND MEAN AIR VELOCITIES WITH AND WITHOUT CARRIER.

By applying the equations derived in the previous section to these groups of curves as indicated in Fig. 10, the values of h_c and $F(h_c)$ can be measured and $f({}_{c}v)$ then obtained from equation (6) and the values of μ, K and W. The method can be understood by considering the conditions obtaining with a pressure head OD (Fig. 10). The carrier velocity is then DC

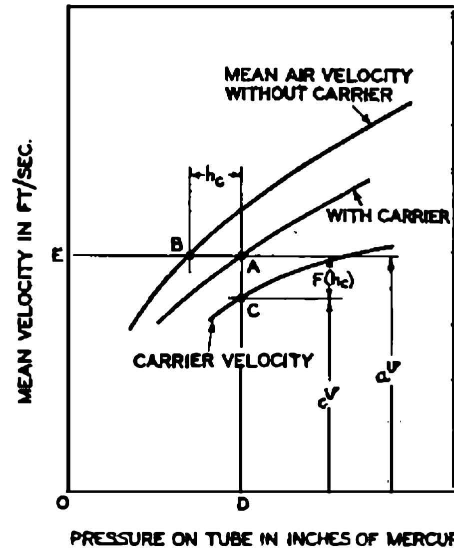


FIG. 10.—RELATION BETWEEN AIR AND CARRIER VELOCITIES.

whereas the air velocity is DA, hence the equivalent velocity of the leakage air $F(h_c)$ is AC. If the carrier were not present in the tube the pressure EB would result in an air velocity DA, hence the pressure across the carrier h_c is AB. In this way the curves of Fig. 11 were obtained and those of the pressure drop across the carrier are of the same general shape as the corresponding curves for the tube trains in Fig. 8.

Before examining the derived curves it is as well to decide how accurate they are likely to be. The testing methods used to obtain the basic curves are susceptible of an accuracy of ± 2 per cent. or better, but to realise it improved facilities and more time would be necessary than were available with this work, which was an adjunct to some purely utilitarian tests. The types of inaccuracy present in the results are such that whilst the general shapes of basic curves are likely to be fairly accurate, their placing relative to the ordinates is not so certain. This condition will of course result in a much greater inaccuracy in the derived curves.

If the theory outlined is representative of the facts, a common curve of $F(h_c)$ — h_c should result and since it represents the air leaking past the carrier relative to the pressure across the leak, and the leak is effectively a small orifice, it should conform to a square law. Fig. 11(*a*) approximately confirms these

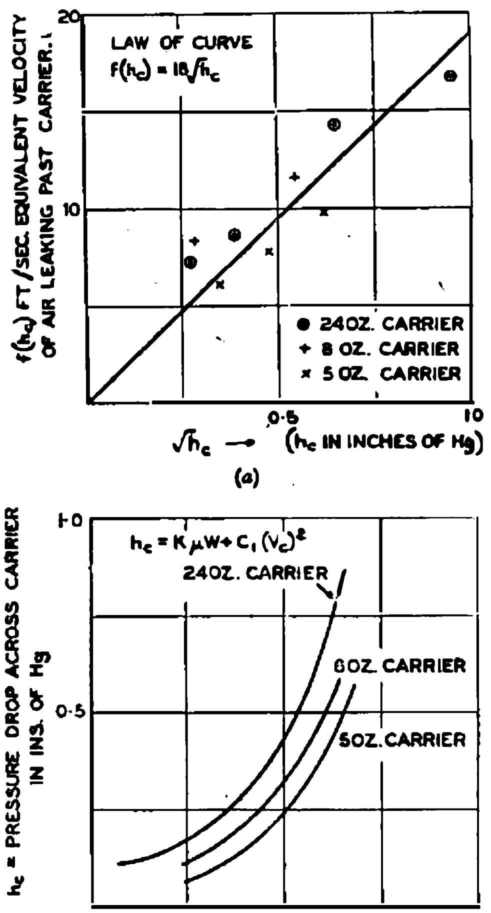


Fig. 11.—Curves Derived From Fig. 9.

expectations and is consistent with the leakage measured with a stationary carrier.

Further, since the air disturbance resulting from the motion of the carrier through the tube is independent of the weight of the carrier, the curves of h_c against ${}_sv$ for the various carrier weights (Fig. 11 (*b*)), should have a common shape and reduce to a single curve when $K\mu$ × area of carrier end is subtracted from each. The common shape is present but the second criterion is met only very approximately.

Air Flow in a Long Tube.

The increase in velocity that occurs in a long tube as the air pressure falls along its length has already been mentioned, and the factor forms a complication in estimating the transit time of such a tube. A first step towards deriving an expression for the mean velocity was to obtain formulæ for the air velocities at the ends of a long tube using equation (5). Integrating from the conditions of the elemental disc of Fig. 3, the expression

$$ {}_sV_1 = \sqrt[1.75]{\left(\frac{P_1^{1.75} - P_2^{1.75}}{P_1^{.75}}\right)\frac{D}{1.75 \times 0.802 \times 10^{-3} \rho_1 L}} $$

(f.p.s. units) .... (8)

is obtained.

The term in brackets is approximately equal to :—

$$ 1.28\ (P_1 - P_2)^{0.56} \quad \ldots\ldots\ldots\ldots (9) $$

within the relevant range when the pressures are converted to inches of mercury and $P_2 = 30$, i.e. the condition for a pressure tube open to atmosphere at the exhaust end. As before, 0.802×10^{-3} is then replaced by 1.13×10^{-3} (see equation (5)). ${}_sV_2$ is of course equal to ${}_sV_1 \frac{P_1}{P_2}$. It was impossible to check these formulæ because at the time no long tube was available which was reasonably free from leaks. An approximate check is however afforded by the curves of Fig. 12 which will be discussed later.

Tests of Long Street Tubes.

Shortly after the inspection and testing of the street tubes had commenced, it became obvious that it would be hopeless to attempt making many of the tubes even reasonably air tight. The great expense of

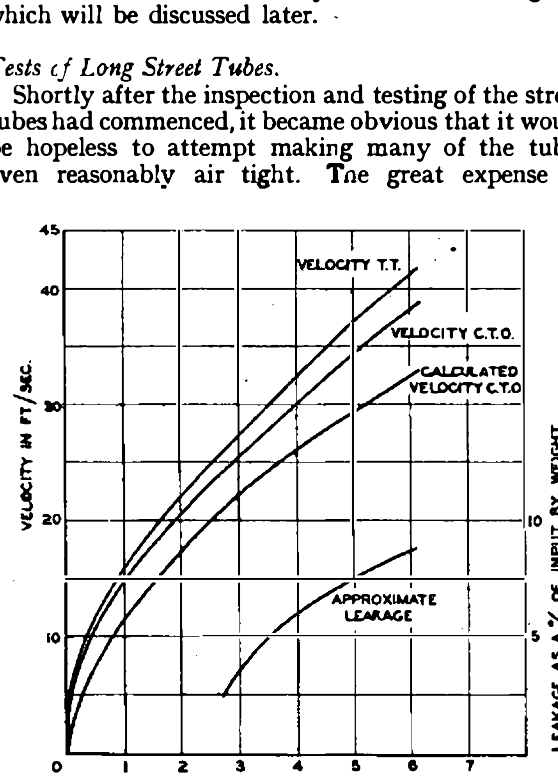


Fig. 12.—Airflow Conditions in Long Tube with Moderate Leakage.

excavating in the City, and the absence of any method of locating the individual leaks of a series in a long tube, made it necessary to limit the reconditioning work to the removal of dents, blockages and the worst of the leaks.

It was decided, therefore, that some leakage must be accepted, the only problem remaining being how much air was likely to be necessary to work the leaking tubes. The standard tube test gives no real indication of this, especially when applied to a long tube. The test to determine the air required took the form of a measurement of the air supplied and a simultaneous measurement of the air leaving the distant end (vice versa for a vacuum tube) using the nozzles already described. Fig. **12** shows the results obtained with a tube which was among the best of those examined in the preliminary survey.

The curves include one showing the result of applying to a tube (C.T.O./T.T.) from C.T.O. to the London Wall office the expression for ${}_aV_1$ given in equation (8). Agreement with the tests results is not good, but if it is assumed that leakage from the tube is confined to the portion in the neighbourhood of the C.T.O., the differences between the curves are not greater than might be anticipated.

Conclusion.

It cannot be pretended that the theories propounded in this article have been completely substantiated by the results obtained in the tests, but it is claimed that there is sufficiently close agreement between the two to indicate that the suggestions are on the right lines. No complete expressions for carrier transit times, etc., have been derived because it was thought that it was useless to do so until the ground work had been made secure by more careful and systematic tests, which were not possible for the reasons previously mentioned.

It may well be wondered what justification there can be at this late stage for expending thought in analysing the mechanism of a method as old as the pneumatic tube. One excuse might be made that all knowledge carries its own reward, but there is another. Although the street tube is obsolescent it is by no means certain that the house tube is equally so. It is being used on a steadily increasing scale for the conveyance of bills, tickets, money, samples, etc.; and with the rising cost of manpower, labour-saving methods of all sorts are likely to find new spheres of use. The house tube offers considerable scope as a means of reducing to a minimum the amount of low grade labour used in transport of official papers, etc.

Finally the author would like to record his thanks to the members of the L.T.R. Power Section who assisted in the tests and the preparation of the drawings, and to the London Passenger Transport Board for permission to publish the results of the train tests.

Book Reviews

"Telephony," Vol. 1. J. Atkinson, A.M.I.E.E. 513 pp. 694 ill. Sir Isaac Pitman & Sons, Ltd. 35s.

Although this book is stated to be a new edition of Herbert and Procter's "Telephony," the general layout and method of treatment differs so widely from that of previous editions that it is in fact an entirely new publication. As with Volume I of the previous edition, the book deals only with general principles and manual exchange systems, leaving Volume II (now in course of preparation) to cover automatic exchange systems.

Since there are many excellent textbooks available on Electrotechnology, the author makes no attempt to cover electrical principles; for somewhat different reasons he has also excluded reference to External Plant and Transmission Theory. Many will agree, however, that the additional information on telephone signalling and switching included in the space thus made available is ample justification for the omissions.

The outstanding feature of the present volume is the novel treatment accorded to the subject in that the various signalling, transmission and switching principles have been dissociated from the exchange systems to which they normally apply and, as the author claims, it is thus possible more effectively to compare the merits, limitations and field of application of each method. Having disposed of general principles in some 13 chapters the remaining nine chapters are devoted to a description of the complete circuits involved in the various manual systems used in this country and include chapters on the Sleeve Control System, Auto-manual and Trunk Exchanges, Power Plant and Maintenance and Fault Testing.

The exhaustive description of fundamental circuit elements will enable the student to benefit to the full from his reading of later sections of the book. Of further value to him will be the exercises (with answers) included at the end of each chapter and the useful appendix giving extracts from the City and Guilds Regulations and Syllabuses for their examinations in Telecommunications Engineering. Completed in 1947, the whole work is well up to date and can be recommended with confidence; it will undoubtedly rank as a new standard work on the subject. Whether considered as a reference work for the telecommunications engineer or as a textbook for the student, it does far more than merely maintain the high standard set by earlier editions. J. R.

"Wireless World" Great Circle Projection Map. Iliffe & Sons, Ltd. 2s. 6d. (3s., post free).

Readers of the article on zenithal-equidistant maps in the July 1948 issue of the Journal may be interested in this published map drawn with London as the centre. It was prepared by the late J. St. Vincent Pletts whose article in the "Wireless World" as long ago as 1919, drew attention to the use of these maps in connection with radio communication. The world is represented on a circular graticule just over two feet in diameter and although no place names are marked in on the map, a table at the bottom gives the latitude and longitude and local time relative to G.M.T. of about 160 of the more important towns. The scale of the map along lines radiating from London is one thousand miles per inch. A footnote suggests that if distance is required in kilometres a metric rule should be used, but there does not appear to be any advantage in using one since the scale is 633 kilometres per centimetre or 1,609 kilometres per inch, neither scale being particularly convenient. Although based on London, the map will give bearings which are sufficiently accurate for many radio purposes from anywhere in the British Isles to points between two thousand and ten thousand miles away. T. K.

Tungsten Carbide Tipped Tools

F. S. LEWIS

U.D.C. 621.9

This article outlines the manufacturing processes involved in the production of tungsten carbide tipped tools, indicates the special grinding technique employed and draws attention to the improved performance obtained as compared with that for normal high-speed steel tools.

Introduction.

TUNGSTEN carbide tipped tools have been in use in the Post Office factories for a number of years for machining operations on a wide range of both metallic and non-metallic materials. Tools in common use include turning and parting tools, formed cutters and reamers.

The cutting tips, suitably brazed on steel shanks (see Fig. 1) remain sharp for long periods, enable larger and faster cuts to be used and can be employed to operate satisfactorily at temperatures of up to about 900°C, without coolants.

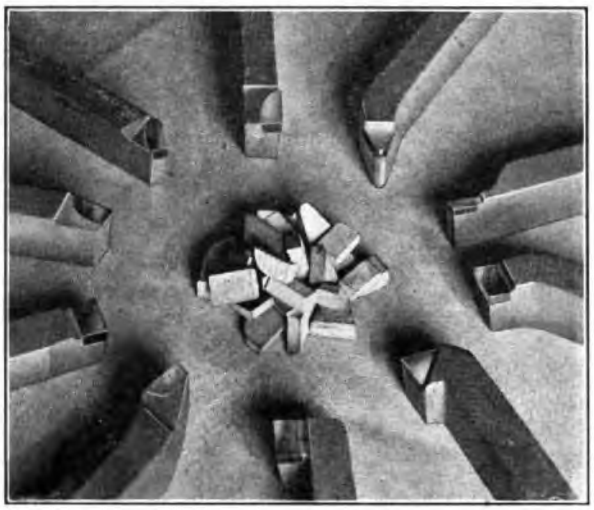


FIG. 1.—SOME TYPES OF TIPS AND TOOLS.

During the last war tools of this type were used extensively and in a large variety of shapes for cutting tough materials such as nickel-chrome and molybdenum steel. Their use undoubtedly contributed to the success of mass production methods for the mechanised vehicles, etc., used in modern warfare.

Tips have also been developed for the wearing edges of gauges, micrometers, glass drills, coal cutters and dies, and for application in many other instances in which high resistance to wear is required.

The major constituent of the tip is mono-tungsten carbide, one of the hardest substances known. This compound is very brittle and it is made into a usable alloy by a special process of powder metallurgy in a way such that small particles of tungsten carbide are cemented together by a metal of lower melting point, generally cobalt, thus producing a "cemented" carbide.

All raw materials used in the manufacture of the tools must be of the highest possible purity, since most impurities, if present in more than a minute trace, lead to low hardness, porosity and brittleness. During the processing of the powders every care is taken to prevent contamination by dust, etc., and all trays, vessels, containers and plant with which the powders come into contact are made of non-rusting material, usually stainless steel.

Initial Processes.

Wolfram, an ore composed mainly of tungstate of iron, manganese and silica, is subjected to chemical processes for the extraction of ammonium paratungstate or pure tungstic oxide which is then reduced to tungsten metal powder in electric furnaces at a temperature of 800-1,000°C, in an atmosphere of hydrogen.

Rigid control of temperature and rate of hydrogen flow is necessary to ensure a uniform product and the metal so produced has a purity of 99·9 per cent. The particle size of the tungsten powder can be controlled within any desired limits, to suit the grades required, by varying these conditions. To obtain fine grain and high hardness in the finished products, the particle size of the tungsten metal is about 1 micron (0·001 mm). The reduced metal is sieved and sorted in grain size and oxygen content.

The next stage is the process of converting tungsten metal powder into tungsten carbide, and it is interesting to note that in this operation all the operators carry out their duties in "slow motion" procedure; no hurried actions are permitted, and all draughts are excluded from the building. These precautions are necessary to prevent the super-fine powder from being scattered about. The powder is mixed for several hours with a predetermined and accurately controlled amount of lamp black (pure carbon). The homogeneous mixture is then packed into graphite boats and heated in a special furnace to 1,500°C in a hydrogen atmosphere. The effect of the high temperature is to cause a chemical combination to take place between the tungsten and carbon so that tungsten carbide is formed.

The resulting carbide is crushed and sieved and samples are taken for determination of the carbon content, etc. Theoretically, tungsten carbide contains 6·12 per cent. of carbon, and every effort is made to produce material to this figure; the limits allowed are very small and not much more than a very minute trace of "free" (uncombined) carbon is permitted.

Cobalt metal powder is produced from pure, finely sieved black cobalt oxide in a manner similar to that used for tungsten carbide. Here, again, grain size is of paramount importance since any departure from specification will influence the subsequent ball-milling and sintering operations. The cobalt content used in the alloy varies between 4·5 per cent. and 20 per cent., depending on the required application, and, in addition, some grades of tip include small quantities of titanium carbide and tantalum carbide, each of which is prepared in powder form at the initial stage.

The powder constituents are thoroughly mixed by prolonged ball-milling in stainless steel mills with carbide balls and the operation is carried out wet, since more efficient mixing and finer grain sizes are thus obtained. At the end of the milling period, which may be from a few hours to several days, the contents of the mills are emptied and dried in vacuum ovens. The powder is then sieved and subjected to final tests. If satisfactory, lubricants such as a solution of camphor in petrol or paraffin wax in carbon tetrachloride are added to assist in the subsequent pressing operation.

At this stage, when the powder processing is complete, samples are taken from each canister and are analysed both chemically and spectrographically to check the composition. This is followed by the preparation of sintered test-pieces which are examined for porosity, hardness, density, micro-structure and toughness. When the material has passed these extensive tests the powder, contained in stainless steel canisters, suitably labelled with the grain size and composition, is ready for the manufacture of tips to proceed.

Manufacture of Tips.

The powder undergoes an initial pressing operation whereby it is formed into ingots or blanks. This is carried out by placing the powder in steel moulds and subjecting to hydraulic pressures up to 15 tons per sq. in. The ingots so produced are very fragile and they are therefore subjected to a so-called pre-sintering process in electric furnaces for about half an hour at temperatures of 700-900°C, in an atmosphere of hydrogen. The effect of this pre-sintering treatment is to give the material a chalk-like consistency with sufficient mechanical strength to enable it to be cut and ground to the required size in preparation for final sintering. If paraffin wax has been used to reduce friction during pressing, two preliminary heat treatments at about 40°C are necessary to effect the removal of the wax.

The pre-sintered ingots are cut into pieces of required size and the shaping is carried out with metal-bonded diamond impregnated wheels or special silicon carbide wheels; in some cases the pieces may also be turned or cutter-ground. In shaping the tips, allowance must be made for shrinkage which varies between 20 per cent. and 30 per cent., depending upon the pressure used during forming. Each dimension is therefore increased to allow for this.

A recent development is the use of automatic moulding presses. They are fed from a hopper into the die, and the tips are pressed and finally ejected. By this means, tips of a required shape and size can be produced at a high rate.

The formed pieces are now ready for final sintering. They are packed into graphite boats and sent to the final sintering furnaces and it is during this very important stage that certain changes take place which result in changing the material from a soft, brittle substance into a dense hard alloy. When the material reaches a temperature of approximately 1,200° C, the cobalt begins to dissolve tungsten carbide and as the temperature increases more and more carbide is taken into solution. This alloy of cobalt and tungsten carbide has a much lower melting point than that of pure cobalt and the liquid so formed "wets" the minute carbide crystals which, by surface tension and stress, are drawn together into a compact dense mass. By this means it is possible to produce perfectly sintered material at temperatures well below that of the melting point of pure cobalt.

To obtain the best properties in the sintered material the temperature and time of treatment must be closely controlled; these conditions vary with the grain size and analysis, the time of treatment being between one-half and two hours. During the whole sintering period an atmosphere of hydrogen is maintained in the furnace, the primary object being to prevent oxidisation of the carbide, although the reducing atmosphere also removes slight traces of oxygen which may be present in the material.

The finished tips are now subjected to a rigid dimensional and quality inspection consisting mainly of density, hardness and fracture tests, and, where necessary, microscopical examination is carried out.

Although the presence of cobalt gives the tip a useful degree of toughness it is still fairly brittle on account of its hardness; toughness increases with increasing cobalt content, but hardness suffers to some extent. The hardness obtained is between 1,300 and 1,700 Vickers Diamond Hardness depending on the grade. An important property of the material is its ability to retain its great hardness at the high temperatures generated during machining, whereas other types of ferrous machine tools lose their hardness at temperatures over 500-600°C.

As previously mentioned, the material is a cemented carbide, the particles of carbide being held in a matrix of cobalt, and acquires its hardness by virtue of the inherent hardness of the tungsten carbide. It is therefore obvious that no heat treatment subsequent to final sintering can alter the hardness. Methods used for hardening steel are without effect on the material and may result in the cracking of the tips.

The design of the carbide tipped tools differs basically from that of high-speed steel tools because of the difference in physical properties. Steel tool practice generally is unsuited to the sintered carbides and, particularly, the acute cutting angles permissible with steel tools should not be used. Suitable tip dimensions in relation to shank sizes having been considered the next process is the brazing of the tip to the steel shank. The shanks for cutting tools are usually 0·35 per cent. carbon steel of correctly selected section, milled and ground. Four methods of brazing are used:—

(1) Oxyacetylene torch used for occasional brazing of small quantities.

(2) Gas or electric furnace for all types and sizes

(3) Electric resistance tool tipper, and

(4) high frequency induction heating, a most excellent and speedy process used where large quantities of tools are to be brazed (see Fig. 2).

FIG. 2.—HIGH FREQUENCY INDUCTION HEATING FOR BRAZING.

In each process the setting-up procedure is similar ; the tip, shank and brazing gauze are all cleaned and freed from grease by carbon tetrachloride ; the flux is applied to the entire end of shank, the sheet and tip, the sheet is placed between the tip and shank with a liberal overhang and heat is then applied. When the brazing metal is seen to melt, the tip is pressed well back into the recess with a rod so as to squeeze out any excess of brazing metal and held until set. The tool is then immediately plunged into a bin of graphite powder, lime or mica, and left to cool. This prevents oxidation and ensures a gradual dissipation of heat ; when cold, excess flux can be removed by hot water.

Some idea as to speed of brazing with the high frequency induction process is conveyed by the fact that the heating time is in the region of 15/20 seconds. It can be appreciated, therefore, that when dealing with large quantities of similar tools, automatic time control to switch off the current can be used to advantage.

Grinding.

Correct grinding is necessary to obtain the best results from the tipped tools. Ordinary grinding methods are not satisfactory as the exceptional hardness of the tungsten carbide necessitates the use of special methods. Silicon carbide wheels of 14 in. diameter are used for the rough grinding, running at peripheral speeds of 5,000 ft. per minute, and lubricated with soluble oil in water. For finishing and grinding of special precision tools diamond impregnated wheels are used, either metallic or resinoid bonded (usually phenol formaldehyde). They cut quickly and remain cool and the free cutting action results in an absence of excessive local heating. The metal-bonded wheel provides a practically indestructible grinding face which remains smooth and free from ridges and in which it is virtually impossible to form grooves. This type of wheel is well lubricated with water and the cut is light. The resinoid bonded wheel is not used with water but can be lubricated with a thin oil. The grinding machines on which these wheels are used are of a special type, as only one side of the wheel is used, a reversible motor being fitted to enable right- and left-hand tools to be ground. The tool is firmly held in a jig and is traversed backwards and forwards to the impregnated grinding edge, grinding away from the cutting edge of the tool (see Fig. 3). The finished and lapped tool tip then takes on the appearance of a black diamond and is ready for use.

It is of interest to note that a special tipped tool is produced, known in the trade as a "Chip Breaker," as the problem of chip disposal at high speeds is known to cause some concern. This tool breaks the turnings into small chips so that the work can be cleared while running ; an unbroken chip coming off at high speed is difficult to remove and can be dangerous to the operator.

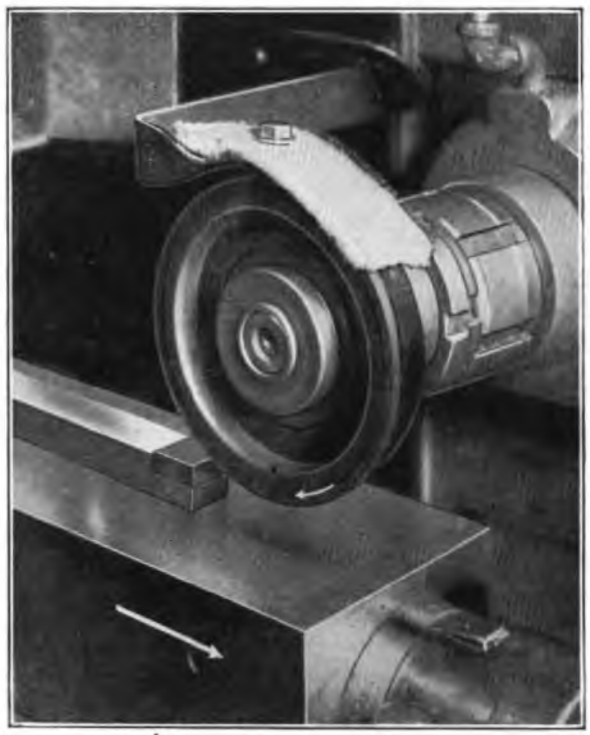


FIG. 3.—GRINDING A TIP.

Acknowledgments.

The author extends his thanks to A. C. Wickman, Ltd., for technical data supplied and for permission to reproduce photographs.

Mechanical Trunk Fee Accounting

K. M. HERON, A.M.I.E.E., and
D. L. BENSON, Grad.I.E.E.

U.D.C. 681.1 : 657 : 654.15

Part I.—Principles of Punched Card Accounting

The article describes the equipment and processes used in a field trial, in which trunk statements containing details of calls made by subscribers are prepared by means of punched card machines. Particulars of a Trunk Charge Calculator and of mechanical sorting and tabulation equipment will be given in Part 2.

Introduction.

THE existing practice of the British Post Office in respect of trunk call accounting is to present each subscriber with a statement showing date and charge for each trunk and toll call completed. This information is obtained from the tickets prepared by the controlling operators.

The method by which charges for trunk calls are calculated and carried into a particular subscriber's statement involves a series of manual processes. Apart from the monotony of the work, which is largely concerned with sorting tickets into calling number order, the manual processes have been developed to a high degree of efficiency and are economical in the labour required for their operation.

It has long been recognised, however, that some of the repetition processes, e.g. sorting tickets into numerical order, could be accomplished by the use of machines. Such equipment, which operates under the control of cards punched in accordance with a pre-arranged code, has been used for a number of years by the Post Office, in the Savings Bank Department and the Engineering Department.[1]

At the conclusion of the war, a study group was set up to investigate and report upon the possibility of mechanising trunk accounting procedure. This group, in their report, outlined a scheme using punched card equipment and recommended that a trial should be held in an Area using equipment manufactured by Powers Samas Accounting Machines, Ltd., with a view to introducing the scheme on a wider scale.

The Present Manual Accounting Processes.

For an understanding of the mechanical system, a brief description of the present manual accounting practice is of assistance.

An operator controlling a trunk or toll call records upon a ticket the calling and called subscriber's number, the time at which the conversation commenced, the duration of the call in minutes and any details of additional services rendered, such as on personal and fixed time calls. These data, referred to a table of charges, fix the fee for the call, the amount being determined and written on the ticket by the exchange clerical staff. Tickets relating to calls connected in the different charge periods (full or cheap rate) are stored in separate batches, and, in cases where a manual board handles traffic from a number of exchanges, the tickets are segregated into batches representing calls from each individual exchange. These batches of tickets are despatched daily to the Telephone Manager's Office.

In the Telephone Manager's Office, the bundles of tickets are filed on receipt in exchange and date order. When tickets for ten days have been received, the accumulated tickets for each exchange are sorted into numerical order in respect of the calling subscribers' numbers, the date order being retained, and then returned to the file. Tickets received over the second and third ten-day periods are treated similarly and at the end of the month the three batches of tickets for each exchange are inter-sorted into calling subscribers' number order. Thus, at the end of the month, tickets for any particular exchange are in numerical order, and tickets relating to calls made by a particular subscriber are in date sequence.

At the end of the month, the tickets are listed on the subscribers' trunk statements, the date and charge for each call being printed on the form by means of a simple accounting machine. This machine is manually operated by means of a keyboard and includes a device which automatically adds individual charges and presents a total sum. These operations are repeated in each month of the accounting period, the totals for calls made in previous months being brought forward monthly so that when the tickets for the last month of the accounting period have been listed the statement shows the total amount due for calls made during the accounting period, and is then ready for despatch to the subscriber with his main account.

Proposals for Mechanised Accounting.

The problem involved is, in simplest terms, that of transferring information recorded by a telephonist on a ticket on to a particular subscriber's trunk statement. This entails calculating the fee due in respect of the call and printing the calculated amount on the statement in the correct date order. In mechanising the procedure it was also desired to improve the present form of trunk statement by showing not only the date and charge for each call, but also the name of the exchange to which it was made and the type of call where this affected the charge, e.g. personal or fixed time call.

These requirements were examined and it was found that with one exception the existing processes and equipment used by the firms specialising in punched card accountancy were capable of fulfilling, or at least could be modified to meet, P.O. requirements. The exception was the means by which the fee for a call was calculated, and while both British manufacturers of punched card machinery submitted proposals, these were not wholly satisfactory to the Post Office. At this stage the Engineering Department was consulted and undertook to design and produce an equipment to work in conjunction with the punched card machinery to calculate call fees.

[1] *P.O.E.E.J.*, Vol. 32, p. 94.

The proposals were based upon the use of a card which originates as a telephone ticket and is subsequently punched to encode the information inserted by the controlling telephonist. Such " dual purpose " cards are a well-known feature of punched card systems. The physical dimensions of the card are dictated by the punched card equipment and fortunately the " Powers Four " card is of almost the same shape and dimensions as the standard trunk ticket; thus the space available for the insertion of written information by the controlling telephonist is not seriously reduced.

Basic Principles of Punched Card Accounting.

In general, punched card accountancy involves three basic operations: (*a*) coding the information in terms of punched holes; (*b*) sorting cards to the desired order; and (*c*) printing the information required. Other operations are included to meet varying requirements, the most usual being an operation to check the accuracy of the punched holes.

Installations operate on the principle that cards of fixed dimensions and common to a particular system are perforated with holes according to the code employed by that system. The various machines recognise this code and function within their limitations according to the information " punched in " to the card.

The " Powers Four " Card.

A card of the Powers Four series printed to indicate punching positions is shown in Fig. **1**. Viewed along the length of the card there are 36 columns, in each of which there are 11 possible punching positions (the eleventh position is located above the **0** position). Thus any integer in a decimal system can be encoded in each column by perforating one position in the column. Alphabetical information can also be encoded on a basis of one letter or symbol to each column by perforating one or two positions in each column. This provides sufficient combinations to encode the 26 letters of the alphabet together with such symbols as are required.

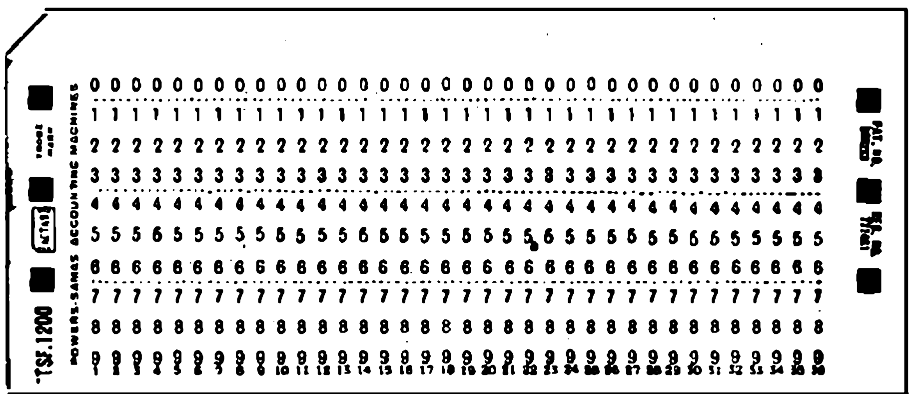


Fig. **1**. Powers-Four Card.

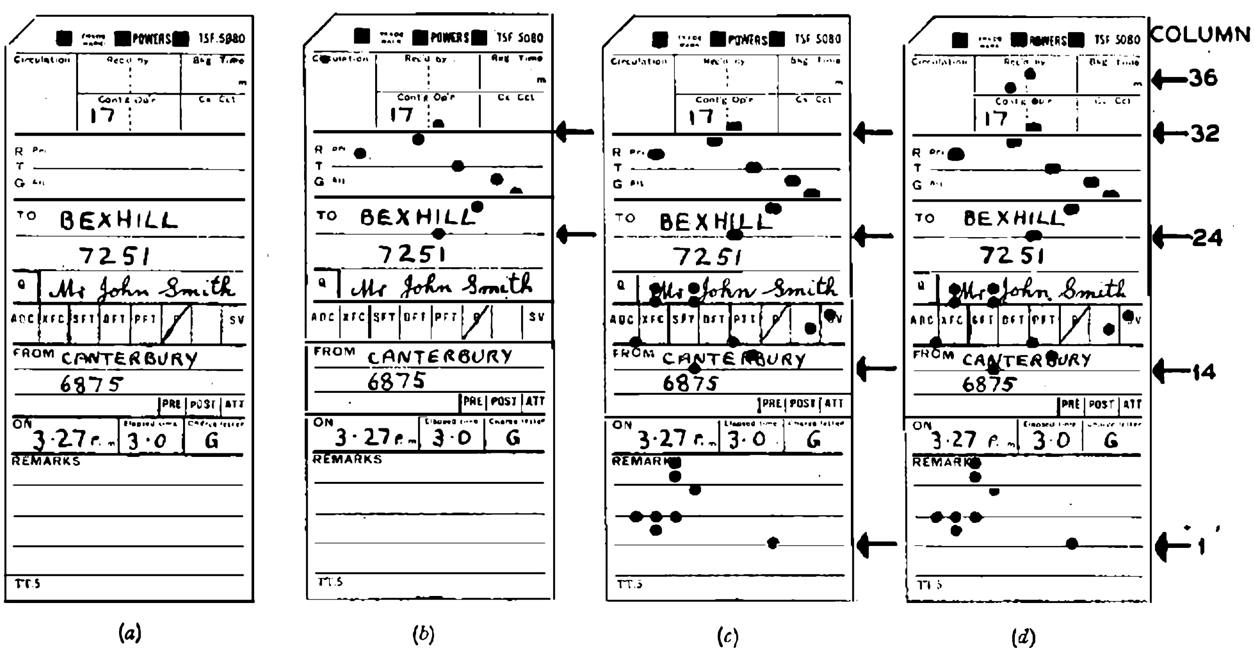


Fig. **2**. Stages in the Preparation of a Ticket.

(*a*) Manuscript entry. (*b*) Initial Punching. (*c*) Check Punching. (*d*) Verified and Call Charge Punched.

Processes and Equipment used in Field Trial

A new dual-purpose ticket, type T.T.5, is being used for timed calls at parent manual boards in the Area selected for the field trial. Fig. **2**(*a*) is a facsimile of a ticket showing manuscript entries in respect of a trunk call. The ticket layout has been designed so that the subsequent punching operations do not obliterate essential data, since the ticket represents an accounting voucher and may be required for reference in cases of dispute.

Fig. 3. Automatic Key-Punch.

The charge letter, shown in the box on the right side of the ticket, is inserted by the exchange clerical staff by reference to a table which defines the radial separation between called and calling exchanges in terms of a charge letter. In the illustration, charge letter G indicates that the distance between called and calling exchanges is between 35 and 50 miles, for which the three-minute call charge for full and cheap rate periods is 1s. 10d. and 1s. 2d. respectively. The tickets in bundles each relating to the calls made from particular exchanges and sub-divided into those for full and cheap rate periods, are despatched at daily intervals to the Telephone Manager's Office.

Initial Punching Operation.

The perforation of the cards to encode the written information is done by a manually controlled, power-driven punching machine (Fig. 3), known as an " automatic key-punch " (abbreviated to A.K.P.). Fig. **4** gives a general view of the machines in use on the trial installation.

The A.K.P. incorporates mechanism for extracting cards from a magazine and feeding them through two intermediate positions, in which positions the cards remain stationary, to the delivery magazine. A manual keyboard is provided which, via Bowden type cables, causes the operation of punch " knives " or rods. These rods when operated are retained in that position by means of latches, against the restoring force of helical springs. The manually operated keys control the position of a perforation in any column, and a selecting mechanism distributes key signals to each column in sequence, commencing at column 1. Thus, supposing it is required to punch information in columns 3, 18 and 34. On depression of a key the column - selecting mechanism will communicate any keyed signal to a punch rod in column 3, the actuated rod being latched. Restoration of the key causes the column-selecting mechanism to move to column 4. Depression of a "skip" key indicates that column 4, and possibly subsequent columns, are not required for punching and the column-selecting mechanism moves until it meets a mechanical stop, which in this case would be set at a position appropriate to column 18. After keying information into column 18, depression of the " skip " key would cause the mechanism to slide until it reached a stop indicating column 34. The mechanical stops are set before a batch of cards is inserted into the machine. When all necessary information has been keyed the operator depresses a " punch " key, which causes the card to be forced into contact with the latched

Fig. 4. The Canterbury Installation.

rods and thus perforated in the selected positions.

In the initial punching stage the operator depresses keys in respect of the following data :—

(*a*) The type of call, e.g. ordinary call, personal call, fixed time call, for which data column 24 is allocated.

(*b*) The calling subscriber's number, which is recorded in columns 25 to 29 (five columns to deal with five-digit numbers).

(*c*) The call duration in tens and units of minutes, which is punched in columns 30 and 31 respectively.

(*d*) The charge letter, which is recorded in column 32.

A batch of cards representing calls originated from a particular exchange is inserted in the feed magazine. Depression of the punch key causes the bottom card in the magazine to slide forward to a "viewing" position, intermediate between the magazine and the punching mechanism. In this position the A.K.P. operator reads off the essential data from the card, in the sequence (*a*) to (*d*) above, and depresses the requisite keys in accordance with this data. At the conclusion of this operation, depression of the punch key causes the card to move forward to the "punching" position, where it again comes to rest. Concurrently, the next card in the batch moves from the magazine to the viewing position. In the punching position the card is accurately located on the punch plate, which is drilled in all possible punching positions, the drillings being of slightly larger diameter than a punch rod. The punch plate and card are lifted under control of a camshaft, and the card material is forced into contact with the latched punch rods and thus perforated. On restoration of the punch plate the latches are operated and the punch rods reset to normal positions. The punched card remains on the punch plate until the next depression of the punch key, when it is fed forward and deposited in the delivery magazine. Concurrently a card which has been viewed and for which the data has been keyed is deposited on the punch plate. Fig. 2(*b*) shows the appearance of the card at the conclusion of initial punching. The data punched refer to that inscribed on the ticket. In this initial operation, experienced operators can attain punching speeds of up to 1,000 cards an hour.

Check Punching.

It is recognised that this initial punching operation, which records data on which the call charge will be assessed and the subscriber's number to which the charge will be posted, is liable to error on the part of the A.K.P. operator. To reduce the possibility of mistakes passing undetected each batch of cards is again punched in respect of the basic data. This second operation is performed by another operator on an A.K.P. Additional information is also punched in the cards at this stage. The operations involved are as follows :—

(*a*) Check punching in columns 24 to 32 inclusive, data being read from the card.

(*b*) Punching of information common to a batch of cards, e.g. date of call (day and month), code for full rate or cheap rate period, code number of originating exchange and parent group centre.

(*c*) Punching of called exchange name in columns 14 to 23 inclusive, suitably abbreviating names of more than ten letters.

Operation (*a*) is performed in a manner identical to that in the initial punching operation. The A.K.P. in this second punching operation, however, is set so that the punch rods perforate the cards in positions slightly off centre compared with the initial operation. This off-centre punching causes a round hole inserted at the first operation to be transformed into an oval shape at the second operation, assuming that both operators punch identical information.

Operation (*b*) relates to information common to a batch of cards and is inserted into each card by means of a process known as "gang punching". The operator presets and locks the punch rods equivalent to the data to be inserted and thus each card is perforated in accordance with this common information without further effort by the operator.

The called exchange name is recorded in columns 14 to 23, and commencing at 14 each column records a letter of that name. Thus, with the card in the viewing position, the operator reads and keys in the punching code in respect of the called exchange name. This completed, the operator reads and keys the information in respect of type of call, calling subscriber's number, duration and charge letter, all of which was punched in at the previous operation. With the depression of the punch key the ganged and manually keyed information is punched into the card. The appearance of the card at the conclusion of this operation is as shown in Fig. 2 (*c*). The elongated or "ovalised" holes in columns 24 to 32 will be noted.

Automatic Verification of Punching Accuracy.

The cards, after the second punching operation, are passed to an automatic verifying machine. This machine can be set to examine any number of columns simultaneously, to confirm the absence of round holes in these columns. For trunk call cards the machine is set to examine columns 24 to 32 and with a batch of cards in the feed magazine, each card in turn is fed forward into a mechanical "sensing" unit. In this unit the card is forced into contact with blunt ended steel rods, aligned one above each possible punching position. The difference in the area of perforation as between a round hole and an ovalised hole is detected by the blunt steel rods, which control the card delivery mechanism. Thus, providing that no round hole exists in any column on which the verifier has been set to check, the particular card in the sense plate is permitted to feed through into the delivery magazine. Prior to delivering a checked card, the verifier causes a small hole to be punched on the card edge, outside the normal punching positions, to serve as a record that the card has been passed through the verifier.

If, in the preceding punching operations, there has been any mistake, then a card may contain one or two round holes in the columns to be verified (24 to 32). In such cases the machine permits the card to feed into the delivery magazine and releases a marker card from a special pack contained in a second feed magazine. This marker card has a coloured edge, and the card corner is not cut away. The marker card follows the faulty card into the delivery magazine and, when the batch of cards is removed, indicates the adjacent card which contains divergent information. In such cases the faulty card is returned to the punching operators, and a "correction card" is punched to contain all the necessary information shown on the incorrectly punched card. The two cards are marked with cross reference serial numbers, the original card being filed, while the correction card is checked and inserted in the batch.

The automatic verifier is power driven and verifies cards at the rate of 200 per minute.

Calculation of Call Charge.

The call charge due is computed by an automatic calculator, which operates in conjunction with a punched card machine termed a "sensing/punching machine." This machine extracts from a punched card the basic data relating to a trunk call and transmits this information in the form of electrical signals on marking leads to the calculator. From the data received, the calculator computes the charge and transmits signals back to the machine via a separate group of marking leads. In the machine these signals are converted via electromagnets to produce operation of the requisite punch rods, and at the appropriate period a card is perforated as required in columns 34, 35 and 36 to indicate the call charge.

Fig. **2**(*d*) shows the card after perforation in respect of call charge values in columns 35 and 36. The charge shown represents 3s. 4d. and as it does not include pounds column 34 is left unpunched.

The calculator and associated sensing/punching machine can deal with cards at an average rate of 100 per minute. The equipment, with the calculator to the left, is shown in the photograph (Fig. 5).

Sensing/Punching Machine.

The machine was developed by Powers Samas from a standard automatic key punch and modified to operate as follows.

Power for machine operation is provided by a 230 volt ½ h.p. motor, the shaft of which is coupled to the machine via an electrically controlled clutch. A transient operation of the clutch solenoid causes the machine to perform a sequence of operations, which, when concluded, effect forcible restoration of the clutch. Such a sequence of operations is termed a "machine cycle".

A feed magazine is mounted at the front centre of the machine, into which is inserted a batch of cards, punched, verified and ready for charge calculation. Following operation of the clutch, the bottom card in the batch is fed forward and comes to rest on the sense plate. The card is located accurately on this sense plate which is of slightly larger dimensions than the card, and has holes drilled in all possible punching positions. Mounted above the sense plate and separated from it by a small gap, are a number of steel rods, each aligned above the possible punching positions on the columns to be sensed, in this case 3, 24, 30, 31 and 32. These "sense" rods are tapered at the ends, the end diameter being less than that of a punched hole. Each rod at its upper extremity

FIG. 5. CALCULATOR AND SENSING/PUNCHING MACHINE.

controls an individual break contact, which disconnects a circuit whenever the rod is lifted against the pressure of an individual helical spring.

With the card in position, the sense plate is raised and the card material is forced into contact with the tapered ends of the sense rods, except in positions where the card is perforated. Thus, where a sense rod impinges on the card material the movement of the sense plate is communicated to the rod, causing the associated break contact to open a circuit, while contacts associated with rods positioned above a card perforation remain closed. At the extremity of the sense plate travel, a master contact closes and connects earth (positive side of the battery is at earth potential) to the common side of all break contacts. Those break contacts at normal, i.e. those associated with the sense rods situated above card perforations, transmit the earth signal forward to the calculator, causing sense storage relays to operate and lock. Relay storage is necessary since the master contact earth is applied for some 50 milliseconds, after which the signal is disconnected and the sense plate restored to normal.

With the sense plate lowered to the normal position the card retaining stops are released and the card, gripped along its short sides by power-driven rollers, is moved forward to the punch plate where it again comes to rest, restrained by a further set of card stops. Concurrently with this operation, a new card from the bottom of the batch is delivered from the magazine to the sense plate.

The punch plate is similar to the sense plate. Mounted above the punch plate are the punch rods, which can be moved towards the plate and retained in this advanced position by latches. The movement of the punch rods is controlled by the armatures of solenoids, via steel connecting rods. Each punch rod is controlled by an individual solenoid, of which 30 are provided. The punch rods are in this instance fitted above columns 34, 35 and 36, allocated for call charges in terms of pounds, shillings and pence, respectively.

The charge computed by the calculator is transmitted to the solenoids, causing certain punch rods to move and latch in the operated position. Shortly after the arrival of a card on the punch plate, the machine cycle terminates, and if the charge value has not been transmitted to the solenoids before the end of the cycle, the clutch is released and the mechanism stops, awaiting the call charge signals and a re-operation of the clutch.

With the commencement of the next machine cycle, the sense plate lifts to sense the new card and the punch plate rises in unison. The card on the punch plate is perforated in one or more of the columns 34, 35 and 36 according to the call value. The card on the sense plate is sensed as described previously, the storage relays in the calculator having been released on completion of the calculation in respect of the previous card. Both plates lower to the normal position, and the punched card feeds forward into a delivery magazine, while the sensed card occupies the vacated position on the punch plate. These operations are repeated on a cyclic basis until the delivery magazine is emptied, or the machine is stopped by the operator.

The machine is controlled by the calculator and the various control keys and indicating lamps are mounted in a small sub-assembly on the side of the machine. The signal lamps indicate to the operator the reasons for calculator stoppage.

Book Reviews

"Klystron Tubes." A. E. Harrison. McGraw-Hill Book Co. 271 pp. 153 ill. 17s. 6d.

This was the first book to be published dealing exclusively with velocity-modulated valves which acquired such importance in the development of radar.

Although the book contains valuable chapters on practical aspects, the approach is mainly theoretical. By neglecting the effects of space charge and considering only the motion of individual electrons in the field existing in the absence of space charge, the author has kept the mathematics in an easily understood form throughout. The book is very well illustrated with theoretical characteristics derived from the mathematical development.

After two introductory chapters on general construction and cavity resonators, the third chapter develops the theory of electron bunching in a field-free drift space. The theory follows the lines originally stated by D. L. Webster, and in this connection it seems unfortunate that no references are made in the text to the fairly complete bibliography given at the end of the book. Although the theoretical development neglects space charge for simplicity, it is thought that at least some mention should have been made of the work of W. C. Hahn and J. Ramo published in 1939 on the electron wave theory of velocity-modulated valves, which takes account of space charge.

The theory is applied in the next two chapters to calculate the theoretical characteristics of the two-resonator amplifier, and of frequency multipliers.

The theory of reflection bunching is developed in Chapter 6 and this is applied in Chapter 7 to determine the theoretical characteristics of reflex oscillators such as those used as local oscillators in receivers. It is noteworthy that in this case the author states that the effects of space charge are quite important.

The theory of the two-resonator amplifier is extended in Chapter 8 to the two-resonator oscillator. Some valuable new material on multi-resonator tubes is included in Chapter 9. Three types are considered, of which the most important to the communication engineer is probably the three-resonator amplifier in which a useful power gain and output can be obtained. Interesting curves show the large effect of detuning the second resonator when it is not loaded. Details of power gain obtainable at various output powers with various bandwidths would have been of great practical interest but unfortunately are not included.

Chapter 10 contains valuable new material on the subject of modulation of klystrons. Frequency, phase, amplitude and the various types of pulse modulation are considered. The author stresses the preference for frequency modulation of klystron oscillators, and theoretical derivations, made in earlier chapters, of the frequency dependence of reflex klystron or double-resonator klystron oscillators on beam or reflector voltage are applied.

Further chapters deal with mechanical and thermal tuning, klystron operation and use, stable power supplies and microwave measurements. The summary of microwave measurement techniques is a useful introduction to a subject on which, at the time this book was first published, no other book was available. R. F. J. J.

"Technical Literature." G. E. Williams, B.Sc.(Eng.), A.M.I.E.E. George Allen & Unwin, Ltd. 117 pp., 7s. 6d.

The author of this book is Head of the Editorial Department of the Institution of Electrical Engineers and his views on the preparation and presentation of articles and scientific papers are worthy of careful study by all concerned in technical authorship.

Early chapters deal with the broad outlines and general arrangement of a Paper, the choice of words, notes on composition and the construction of paragraphs and sections. These lead to a constructive analysis of the accepted rules governing the preparation of a manuscript in the form expected by Professional Institutions and similar bodies. A further chapter includes a description of the editorial work necessary before a Paper appears in print and a knowledge of this procedure will do much to ensure harmonious relations between authors and editors !

The book concludes with a 12-page appendix outlining the psychological principles relating to the communication of knowledge and a useful note on " Editing Standards ".

From the beginning emphasis is placed on the suggestion that intelligibility by itself is insufficient ; an article should also possess literary qualities if it is to be wholly convincing to the reader. A few technical authors are of course endowed with exceptional gifts of lucid exposition, but those less fortunate will find the guidance offered in this book is of great value. G. E. S.

An Electronic Regenerative Repeater for 7½-Unit Start-Stop Telegraph Signals

R. O. CARTER, M.Sc., A.C.G.I., D.I.C., A.M.I.E.E.
L. K. WHEELER, B.Sc.(Eng), A.M.I.E.E.
and A. C. FROST.

U.D.C. 621.394.645

The basic principles involved in the regeneration of start-stop telegraph signals are described, and the performance requirements of a repeater are deduced. A detailed description is given of a repeater utilising 14 miniature valves, which fulfils these requirements. Field trials of an earlier model, inserted between two tandem-connected radio-telegraph links, showed that under bad radio conditions, a reduction in error rate of up to 4 to 1 was obtained by the use of the repeater.

Introduction.

DURING and since the war there has been widespread interest in the possibility of using electronic means for some of the processes involved in start-stop telegraphy which are at present performed mechanically.

Greater ease of production and reduced maintenance costs are two of the advantages which might result. As regards the teleprinter itself, so long as the process of transmission of a message commences with the manual operation of a keyboard and finishes with the typing of a message in ink on paper, an appreciable part of the machine must necessarily remain mechanical, and there is therefore room for considerable difference of opinion on the advantages to be gained by replacing some or all of the remaining functions by non-mechanical devices. The function of a regenerative telegraph repeater, however, is to receive telegraph signals which may have become distorted in transmission, to regenerate, i.e., re-form them as undistorted signals, and then to retransmit them, either directly into a receiving teleprinter, or over a further telegraph link. It is evident that this involves no process which is essentially mechanical, though it may be found convenient, in the interests of standardisation of circuit arrangements, to retain a polarised telegraph relay at the output for retransmission. Moreover, the greatest advantage is gained from a regenerative repeater when it is inserted in the middle of a telegraph circuit consisting of two or more links in tandem. The signals may be so badly mutilated after transmission over the complete circuit that no device will be able to interpret the characters correctly, but if the signals are regenerated after transmission over part only of the circuit, before the distortion has become too great to be handled by a regenerative repeater, the distortion at the receiving end may be sufficiently small to enable the circuit to be worked satisfactorily. The repeater may therefore be located at an office where there is little, if any, mechanical equipment; the staff may be employed mainly in the maintenance of voice-frequency telegraph systems and telephone repeaters, and will more readily take to the maintenance of an electronic than of a mechanical telegraph repeater.

Applications of Regenerative Repeaters.

There are two main applications for regenerative repeaters, so far as this country is concerned (*a*) in conjunction with radio-telegraph circuits, the repeater being connected either between two radio links which are operated in tandem, or between a radio link and a line circuit on which the radio link is extended to the terminal teleprinter; and (*b*) in conjunction with a switched telegraph system, when the number of links in tandem becomes large enough to introduce intolerable distortion. Although the repeater about to be described was developed primarily for use on radio links, and all the trials so far carried out have been with this application, it is also suitable for line circuits.

Fundamental Principles of the Regeneration of Start-stop Telegraph Signals.

In start-stop telegraphy, in contradistinction to synchronous telegraphy, the timing of the train of operations associated with the transmission of a character is independent of the timing of any other character, and a fresh character may commence at any arbitrary time after the conclusion of the preceding character, depending on the instant of depression of the appropriate key on the keyboard of the transmitting machine. To achieve this, the code signals representing each character are preceded by a start signal which is the same polarity ("space") for all characters, and are followed by a stop signal, which is also the same polarity ("mark") for all characters. This is illustrated in Fig. **1**, which shows the start signal, the five code elements and the stop signal representing the letter D.

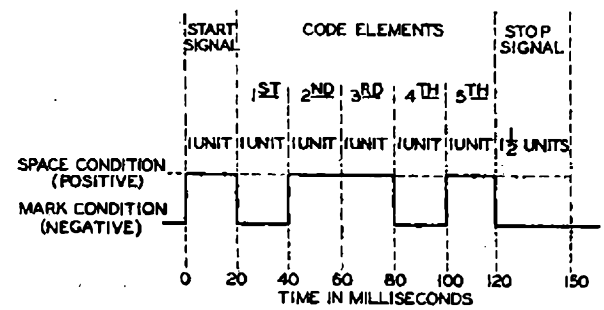


Fig. 1.—Letter "D" in 5-Unit Teleprinter Code.

In the 7½-unit code working at a transmission speed of 50 bauds, the start signal and each of the code elements has a nominal length of 20 milliseconds, and the stop signal a nominal length of 30 milliseconds. Now, when a telegraph link is subject to noise, fading or other causes of distortion, the initial effect will be to distort the waveform of the received current; as, however, the receiving apparatus associated with the link usually terminates in a telegraph relay, the effect of the distortion as observed in the output of the relay will not be one of waveform but of an alteration in the time interval between any two changeovers or instants of modulation in the train of signals representing a character. It is possible for any instant of modulation to occur either later or earlier than it would have occurred if the cause of distortion had been absent. Since, as already explained, the train of operations in the receiving teleprinter is initiated at the commencement of the received start signal, it is the time interval between this instant and any other instant of modulation which is of importance in determining whether or not the character will be correctly received.

The teleprinter incorporates a mechanical " gating " system, which " samples " the incoming signal at the centre of the correct time position of each element relative to the beginning of the received start signal, i.e., at 30, 50, 70, 90 and 110 milliseconds. If this gating were perfect and were carried out in negligible time, it is evident that any instant of modulation could occur up to 10 milliseconds early or late without causing the character to be incorrectly read. As 10 milliseconds is 50 per cent. of a unit signal at 50 bauds, such a machine would be said to have a margin of 50 per cent. In practice, with mechanical selection, a margin greater than 40 per cent. is difficult to achieve, and under practical conditions margins of about 30-35 per cent. are normally maintained.

It is evident that a regenerative repeater, whether it be mechanical or non-mechanical, can operate on the same gating principle. Since each element is " sampled " at the centre of its nominal position in time, the retransmitted signal must lag by at least half an element behind the signal received by the repeater, but this is of no practical consequence. If a repeater of this type is used at the receiving end of a circuit, immediately before the receiving teleprinter, an improvement will result only in so far as the repeater may have a greater margin than the teleprinter ; that is to say, signals in which some of the instants of modulation have suffered a time displacement relative to the start signal which is greater than the maximum tolerable by the teleprinter, but below the maximum tolerable by the repeater, will be correctly received. Since the repeater cannot have a margin greater than 50 per cent., the improvement may not be large. Where, however, the repeater is used in the middle of a multi-link telegraph circuit, the improvement may, for the reasons already given, be much greater.

A mechanical regenerator operating on the above principle was described in an earlier issue.[1] Preliminary experiments with an electronic equivalent showed that two additional refinements were desirable, at any rate when the repeater was to be used in conjunction with radio links. A third additional feature is required if the repeater is to be used in a switched telegraph network. These will now be described.

(1) *Automatic Stop Insertion.* On a radio link a signal element may sometimes suffer more than 50 per cent. distortion or may be lost completely, i.e., a mark may become a space or vice versa. When the element is one of the code elements, it is inevitable that a wrong character is received, but the cause of the error will not affect any characters other than the one in which it occurs. When the faulty element is the stop signal, however, the teleprinter, or the regenerative repeater, whichever is receiving the signals, may not be restored to the rest condition at the conclusion of the character, but may start on another cycle of operations corresponding to the reception of another character. If, at some time during this cycle, the start signal of the next character arrives, it will be treated by the teleprinter or repeater as one of the code elements, depending on the part of the cycle which has been reached at the time. If further characters are then received in rapid succession, with no idle period between them, it is possible for the receiving device to remain out of step with the signals for a considerable period, i.e., the characters printed will be those represented by the last elements of one character followed by the first elements of the next. Thus, one cause of error can produce many false characters.

When a simple type of repeater is used, in which the polarity of the retransmitted stop signal is determined by sampling the polarity of the incoming line at 130 milliseconds after the beginning of the start signal, it is found in practice that two effects occur under conditions of stop-signal mutilation ; (*a*) the repeater can get out of step with the incoming signal, and (*b*) the receiving teleprinter, operated from the retransmitted signals either directly orover a further link, may get out of step with the regenerative repeater. Considering the simple case where the output of the repeater is connected directly to a teleprinter, it is evident that whereas with the repeater in circuit there are two places where the apparatus can get out of step with the signals, if reception had been carried out directly on a teleprinter without the repeater, there would only have been one place where this was possible. In the course of field trials it was frequently found that, due to this cause, fewer errors were obtained when receiving directly on a teleprinter than with a regenerative repeater, in spite of the fact that the margin of the repeater was appreciably better than that of the teleprinter. The remedy adopted is known as " automatic stop-signal insertion". It consists in arranging that after the conclusion of the retransmission of the fifth code element of a character, the repeater inserts a stop signal of the correct polarity, regardless of the polarity of the incoming line. In the repeater being described the enforced stop-signal lasts for 20 milliseconds (one signal element) and the control is then restored to the incoming line ready for the reception of the next character. This is long enough to bring the receiving teleprinter to rest, and short enough to ensure that the next start signal is not missed even under adverse conditions, i.e., with the transmitting teleprinter running at the upper limit of permissible speed, and with considerable distortion preceding the repeater. It is worth noting that the precise length of the enforced stop signal is not very critical when $7\frac{1}{2}$-unit transmission is used. The question is not quite so simple with 7-unit transmission, i.e., when the nominal length of the original

[1] *P.O.E.E.J.*, Vol. 26, p. 171.

stop-signal transmitted by the teleprinter is 1 unit (20 milliseconds) instead of $1\frac{1}{2}$ units (30 milliseconds).

(2) *Short Start Rejection.* On both radio and line links, short spurious periods of spacing or start signal polarity may occur, lasting a few milliseconds. These arise from noise or fading on radio links and from brief line circuit interruptions. If one of these occurs during the transmission of the code elements of a character, an error may be produced, but only if it coincides with one of the instants of selection. If, however, it occurs during an interval between successive characters, the receiving device may commence a cycle of operations, and if the next genuine character starts to arrive during the cycle, the device may get out of step with the signals in the same way as described under (1). Even during an idle period, if a succession of short spaces arrives, spurious characters may be printed.

No special measures are taken in the teleprinter to guard against these effects, but the inertia of the receiving electromagnet renders it unresponsive to very short signals. This safeguard is not present in an electronic receiver, as used in the regenerative repeater, unless some device is specially inserted for the purpose. It is evident that periods of space longer than 10 milliseconds must not be rejected, since they might be genuine start signals with up to 50 per cent. distortion. However the repeater does not attempt to retransmit correctly characters in which the code elements have suffered more than 50 per cent. distortion and there is no reason to provide any greater margin of the start signal length. Hence, if a short start rejection device is incorporated, it is reasonable to reject any start signal shorter than 10 milliseconds. In the present repeater, the facility is provided as follows. On receipt of spacing polarity, the cycle of operations in the repeater commences. If the spacing condition does not persist for at least 10 milliseconds, the repeater restores to the rest condition and no signal is retransmitted.

(3) *Suppression of Automatic Stop Insertion.* In some telegraph systems (e.g., switched networks) it is necessary to transmit a long space (i.e., longer than one character) signal as a clearing indication. To provide this facility, the repeater is arranged so that the reception of five spacing code elements in a character causes the suppression of the facility of automatic stop insertion. Thus, an "all space" character will be correctly regenerated if the commencement of the received stop signal falls within the margin of the repeater, but if the condition of the receiving line does not revert to mark until later than this, a continuous space is transmitted until the mark is received.

Summarising the functions performed by the repeater,

(*a*) Its cycle of operations commences on receipt of spacing or start polarity.

(*b*) The start signal is "checked". If the duration is less than 10 milliseconds, it is rejected as spurious; the repeater reverts to the rest condition and awaits a new start signal. If it exceeds 10 milliseconds, it is accepted as genuine, and the repeater commences to retransmit a start signal.

(*c*) The polarity of the incoming signal is sampled at 30, 50, 70, 90 and 110 milliseconds after the beginning of the received start signal, and the polarity of the retransmitted code elements correspondingly determined.

(*d*) At 130 milliseconds after the beginning of the received start signal, an enforced stop signal (mark polarity) is inserted, unless all the five code elements have been read as space. When this occurs a stop signal is retransmitted only if one is received, otherwise a continuous space is transmitted until the received signal returns to mark.

(*e*) At any time later than 140 milliseconds after the commencement of the received start signal the repeater is ready to receive, and in due course check, a new start signal. The earliest time at which the new start signal can have been checked is therefore 150 milliseconds, and this is also the earliest at which the repeater can commence to retransmit a new start signal. Since the stop signal commenced at 130 milliseconds, it follows that the minimum length of stop signal is 20 milliseconds.

The Experimental Repeater.

An electronic regenerative repeater designed on the aforementioned principles is shown in Fig. **2**; the output relay is mounted separately. It includes 14 miniature valves which, together with their associated circuit components, are mounted in two

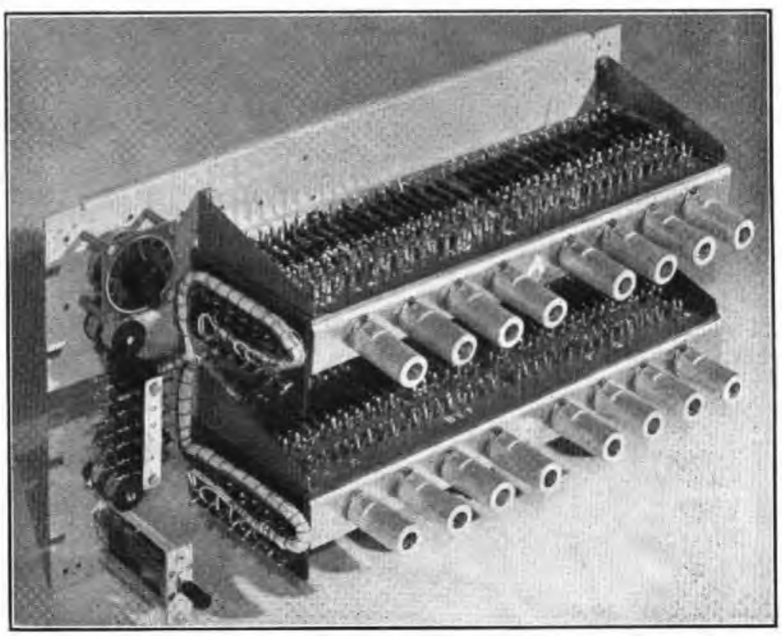


FIG. 2.—EXPERIMENTAL REPEATER (TWO VALVES ARE SPARES).

units to simplify assembly and the grouping of intimately allied circuit elements. Except for the valves and the output relay, the components comprise resistors and capacitors only. The repeater has been designed to receive signals from any circuit terminating in a relay (e.g., V.F.T. channel or physical circuit). For reception direct from a long physical circuit an additional amplifying stage could be added.

A block-sectionalised circuit diagram is given in Fig. 3. The letters within the blocks indicate the are received from the timing circuit at 10, 30, 50, etc. mS. At these instants, if the line signal is a mark (negative polarity) the anode current remains cut off because the suppressor grid is biased to cut-off, but the screen grid passes current and a short negative pulse is produced at the screen-grid. If the signal is a space, negative pulses are produced at both anode and screen grid. These mark and space selecting pulses operate the Output Trigger Circuit which controls the setting of the Output Relay. The coupling circuit from the

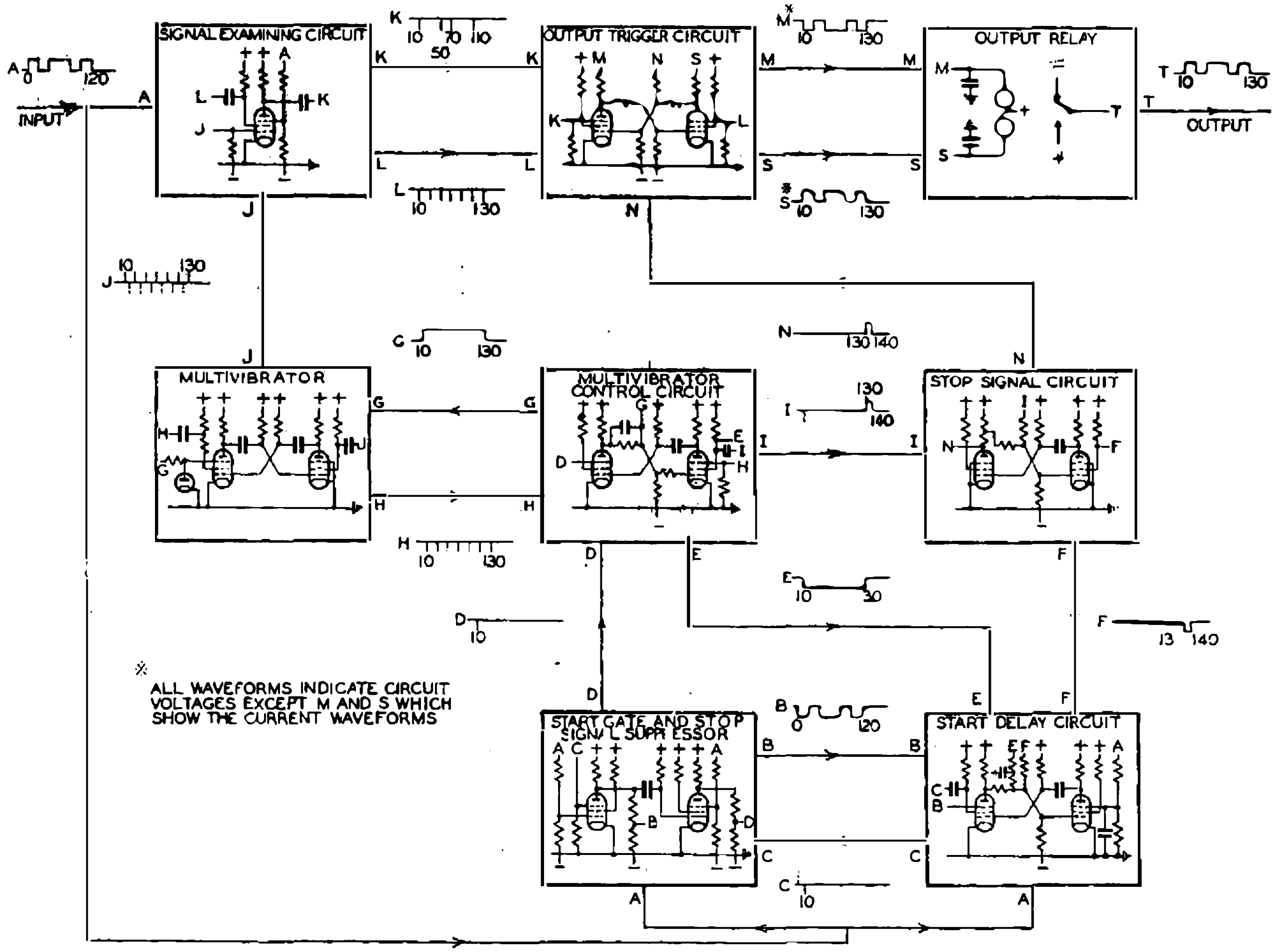


FIG. 3.—SECTIONALISED DIAGRAM OF REPEATER.

points of connection to the correspondingly lettered leads terminating at the block, and the voltage waveforms in various parts of the circuit are shown with figures to indicate time in milliseconds after the commencement of the receiving cycle.

Signal Circuit.

The Signal Examining Circuit consists of a differential gate circuit which is opened for a very short period at the theoretical mid-instants of each element in a character, and the outputs from the circuit are controlled by the polarity of the incoming line signal. The valve is normally biased to cut-off at the control grid and can only conduct when the examining pulses anode of the signal examining circuit has a longer time-constant than that from the screen, so that the effect of the anode pulses is predominant. The output trigger circuit is the well-known Eccles-Jordan trigger which has two stable conditions. Mark selecting pulses cause the first valve to conduct and space selecting pulses cause the second valve to conduct. The polarised output relay is connected differentially in the anode circuits of these valves and is operated to mark or space accordingly. This trigger circuit is also connected to the Stop Signal Circuit and is forced to the marking condition when the latter is operated, even though a space selecting pulse is received at the same time.

Start Circuit.

The first valve of the Start Gate and Stop Signal Suppressor inverts the incoming line signal and its output, which goes negative when a start signal is received, triggers the Start Delay (or orientation[2]) Circuit. The start delay circuit is a pulse trigger, also known as a " flip-flop " or " one-shot multivibrator", which is a variant of the basic Eccles-Jordan circuit. It has one stable and one unstable condition ; the duration of the latter is predetermined in this instance to be 10 mS. If the incoming start signal is normal (i.e. longer than 10 mS), the trigger restores at 10 mS but if the line condition returns to mark before this period has elapsed, the relaxation period of the circuit is terminated prematurely by the suppressor grid of the second valve becoming negative, a slight delay in this action being produced by a resistance-capacitance filter. In either case, a short negative pulse is generated at the screen of the first valve which is coupled to the suppressor grid of the first valve of the start gate and stop signal suppressor circuit. The coupling between the first and second valves of this circuit has a long time-constant so that normally, the second valve is cut off either at the control grid or at the suppressor grid, which is connected to the input line. If a normal start signal is being received, the second valve is cut off at the control grid, but the suppressor grid is at approximately zero potential. When the first valve receives the delayed start pulse at the suppressor grid, it produces a short positive pulse at the control grid of the second valve. This in turn produces a short negative pulse to initiate the operation of the main timing circuits. Should the start signal be less than 10 mS long, the second valve is cut off at the suppressor by the negative line potential before a positive pulse can affect its grid, so that no negative pulse is generated to start the main timing circuit.

For the remainder of the character period, the start delay circuit is guarded by the Multivibrator Control circuit and the stop signal circuit against reoperation by subsequent space signals.

Main Timing Circuit.

The multivibrator control circuit is a pulse trigger with a natural period of approximately 130 mS, the operation of which is initiated at 10 mS by the negative pulse which is received from the start gate and stop signal suppressor. In its operated condition this control circuit removes the negative bias on the suppressor grid of one valve of the Multivibrator and permits it to oscillate at its natural period which is accurately adjusted to 20 mS. The differentiated output of the multivibrator gives short positive pulses at intervals of 20 mS, commencing at 10 mS. These are the examining pulses applied to the signal examining circuit. Negative pulses generated at these instants by the multivibrator are received by the multivibrator control circuit and synchronise its period to exactly 120 mS so that the multivibrator is stopped at 130 mS after producing 7 examining pulses.

Stop Signal Circuit.

The restoration of the multivibrator control circuit produces a positive pulse which initiates the action of the stop signal circuit, a pulse trigger of 10 mS period. This biases the output trigger circuit to mark for this period. As a new start signal cannot be examined until 10 mS after the end of this period, the minimum length of the retransmitted stop signal is 20 mS.

Suppression of Automatic Stop Signal.

The intervalve coupling in the start gate and stop signal suppressor circuit has a time-constant such that the negative potential developed at the grid of the second valve, when a change of signal from mark to space occurs, will not decay sufficiently to permit the valve to conduct before 110 mS if no marking element is received. If a marking element is received during a character, the grid becomes positive, but the suppressor grid is biased to cut-off by the line condition. The time-constant of the coupling is, however, sufficiently short to permit the valve to conduct before 130 mS (the instant when the multivibrator control circuit would normally restore to initiate the stop signal). If this occurs, the suppressor grid of the first valve in the multivibrator is held negative, preventing full recovery to the unoperated condition, until the input reverts to mark.

Power Supply.

From a mains driven power unit, the repeater is supplied with + 150V stabilised, −150V and 6·3V A.C. for valve heaters, the total power consumption being about 35 watts.

Performance.

The repeater has a receiving margin of greater than 48 per cent. (*c.f.* teleprinter about 35 per cent.) when the timing circuits are correctly adjusted. Variations in speed, i.e. in the frequency of the multivibrator, do not exceed 0·1 per cent. for 10 per cent. change in mains voltage.

A field trial of a repeater of earlier design[3] inserted between two tandem-connected radio telegraph links produced the following results. During periods of moderately bad reception, when an unrepeatered circuit was giving 1 error in 1,000 characters, the insertion of the repeater improved the error rate to 1 in 1,500. When conditions were considerably worse, giving an error rate of about 1 in 50 without the repeater, the rate was improved to 1 in 200 when the repeater was inserted. At first sight these improvements may appear disappointing. It must be remembered, however, that when the transmission conditions are such that the distortion in one radio link exceeds 50 per cent., even a perfect regenerative repeater cannot read the characters correctly. From a practical point of view, the reduction in the work and in lost

[2] This may be termed an orientation circuit since its function is analogous to the orientation control fitted to some mechanical telegraph receivers to permit adjustment of the times of element selection relative to the start signal, to compensate for wear or slight inaccuracies in mechanical components.

[3] This design followed similar principles ; the circuitry was basically simpler, but 26 valves were required.

circuit time involved in correcting errors, represented by the above improvements in error rate, renders the repeater well worth while.

Conclusion.

An attempt has been made to include all the facilities which appeared to be necessary or desirable for the regeneration of teleprinter signals transmitted either over radio links or land-lines. Some of the facilities might be omitted and the design correspondingly simplified, if a repeater of less general application were required. For example, if " short start rejection " and " automatic stop suppression " were not required, a repeater designed on the same basic principles would contain 8 valves instead of 14.

The importance of the number of valves depends on the extent of the use to be made of regenerative repeaters. If they are confined to special positions, e.g. at the ends of radio links, on international circuits, or on inland point-to-point or switched circuits consisting of an exceptional number of links in tandem, then the numbers involved will be so small in comparison with the total equipment in the network that the number of valves and the bulk and power consumption of the repeaters are of only minor importance in comparison with efficiency, reliability and ease of maintenance. On the other hand, if it were proposed to fit a regenerative repeater to a large proportion of the links in a telegraph network, so as to, make them " zero trunks " (i.e. of no distortion), then a reduction in the number of valves by even one or two would be important, and it might be worth omitting some features which gave only a small improvement in performance in order to reduce the size and power consumption of the repeater.

At the present time, the restricted type of application appears to be the more probable.

Book Reviews

" Elementary Telecommunications Practice." W. T. Perkins, A.M.Brit.I.R.E., A.M.Inst.B.E. George Newnes, Ltd. 272 pp. 173 ill. 12s. 6d.

Rearrangement of the City and Guilds of London Institute's Telecommunications Examinations syllabus in 1946 introduced Elementary Telecommunications Practice as a new subject and the author states that his aim was to produce a small volume covering the syllabus of the new examination. The need for such a book is admitted, but on many points the author can hardly be said to have achieved his intentions.

The author has omitted to deal with a number of sections of the new syllabus such as dissipation of heat in electrical apparatus, power rating of coils and resistors, the multiple principle, switchboard jacks, contact materials and pressures, and battery charging.

The practical description of telecommunication apparatus follows normal lines but explanation of fundamental elementary principles is often vague and confusing. This failure to treat fundamental principles to the extent required by elementary students is the main weakness of this book.

The radio aspect is disappointing. The chapter on aerial systems is weak and sometimes inaccurate. Special features of inductors, capacitors and resistors for high frequencies are not discussed in sufficient detail.

The section on telegraphy is reasonably adequate, but it is unfortunate that the description of a Morse key and details of the numerical part of the Morse code have been omitted.

Vague treatment of elementary principles, a number of inaccuracies and omissions make the value of the telephone aspect, which constitutes the main part of the book, somewhat doubtful. For example, neglect to derive the law for resistors in parallel from first principles on pages 11 and 37 leads to a wholly unconvincing treatment on the necessity for a central battery of negligible resistance. Again, an inaccurate statement appears on page 18 and in Chapter IV, that " when charging secondary cells it is usual to keep the charging current constant throughout the charge."

Chapter II does not explain the importance of avoiding closed magnetic circuits and this leads to a confusing statement on the significance of the residual gap in relays, while, on page 144 is made the remarkably brief statement that the induction coil is necessary in telephone instruments to obtain a voltage step-up to line.

Page 161 is confusing on the fundamental reasons why transmission bridges are required, as the separation of the two lines for signalling is not explained, and chapter XI omits to explain the fundamental reasons for, and the general arrangements of, the multiple.

In a book published in 1948 it is regrettable to see an old type relay diagram in Fig. 2, an old type coaxial cable in Fig. 147, and the repeated references to condensers instead of capacitors.

The foregoing comments, which could be extended, will serve to indicate that the book will require extensive revision to meet the requirements for which it was intended.

S. W.

" Tables of Bessel Functions of Fractional Order." Vol. I. 413 pp. 1948. Prepared by the Computation Laboratory of the National Applied Mathematics Laboratories, National Bureau of Standards, New York. Columbia University Press.

An important class of functions which arise in the applications of mathematics to engineering problems are Bessel functions. Sometimes an engineer is inconvenienced by a lack of tables of such functions. Consequently he will welcome any extension of the existing tables and particularly the present volume of $J_n (x)$ Bessel functions of fractional orders $n = \pm 1/3$, $\pm 2/3$, $\pm 1/4$, $\pm 3/4$. These functions are of great value in the solution of some of the more difficult differential equations encountered in the theory of telecommunications. For example, they arise in the theory of non-uniform transmission lines in which the series impedance varies as x^m and the shunt admittance as x^{-m}: again, they are met with in the Carson-Pollaczek analysis of wave propagation in stratified media. In the problem of wave propagation round the earth, Bessel functions of orders 1/3 and 2/3 are encountered, and the present tables will be useful when numerical results are required.

The book gives recurrence formulæ from which the reader can obtain from these tables the values of Bessel functions of fractional orders greater than unity ; this feature may be of value in connection with the numerical analysis of problems involving vibrating sectorial membranes.

The present volume is likely to prove of very great value to the physicist and engineer ; and it is encouraging to find that such a concerted effort is now being made to extend the existing tables of Bessel functions. H. J. J.

A Miniature Audio-Frequency Amplifier

W. T. DUERDOTH, B.Sc., A.M.I.E.E., and
J. GARLICK, B.Sc., A.M.I.E.E.

U.D.C. 621.395.645.029.3

This article illustrates the application of circuit design techniques to miniaturisation by reference to a design of an audio-frequency line amplifier which occupies a space of only $2\frac{1}{2}'' \times 2\frac{1}{2}'' \times 4\frac{1}{2}''$. The design also serves as an example of the employment of more than one feedback path.

Introduction.

"MINIATURISATION" as applied to equipment for the Services has been an important study for some years past, but the demands of extreme portability have not made themselves felt in Post Office line transmission equipment. However, when there is shortage of accommodation, economy of mounting space becomes of greater importance. A preliminary study has, therefore, been made of the possibilities of miniaturisation of audio-frequency line equipment.

It is recognised that the problem must be viewed broadly and that reduction in size of certain selected items might not be worth while if other items cannot also be made smaller. As a beginning, the miniaturisation of the audio-frequency line amplifier has been studied, and this article describes an efficient unit having a performance better than that of existing amplifiers. Although designs of the associated line transformers and equalisers have yet to be studied, a note of the extent to which reduction in size should be practicable is included.

Experience with existing line transmission equipment shows that a large proportion of faults is due to non-soldered or dry-soldered connections. This amplifier uses a miniature valve with a B7G base and, to eliminate holder troubles, soldered connections are used. The abandoning of the usual panel mounting in favour of a more open construction has increased access to components and should assist in the observation and elimination of dry-soldered joints. The amplifier is arranged to jack in and so to be readily removable from the panel to facilitate maintenance; the power connections are the only unsoldered connections in the unit, soldered straps being provided for the input and output circuits.

The normal repeater station supply of 130 volts does not permit the type of valve suitable for line amplifiers to be used to the best advantage, and under suitable operating conditions it is possible to obtain improved performances by using 250 volts H.T. With this voltage it is possible to obtain the same output power from the valve without increased anode dissipation by using a reduced anode current. In addition, the raising of the screen voltage to 250 volts tends to cause an increase of anode current which can be prevented by an increase in the cathode resistor. This results in an increased amount of D.C. feedback, so that the anode current is maintained constant for a longer period; this may increase the useful life of the valve.

Component developments which have taken place during the last 10 years are not such as to produce much saving in space. Available valves are rather smaller, but there has been no improvement in available magnetic materials. Considerable reduction in size can only be achieved therefore by more compact assembly of components and by the use of an improved circuit which will enable the performance required from individual components to be relaxed. The CV 138 is a suitable high-slope pentode ($g_m = 7{\cdot}5$ mA/V) smaller in size than earlier valves such as the P.O. VT 149 ($g_m = 2{\cdot}2$ mA/V), but the value of the increased slope is somewhat offset by the higher anode current (10 mA compared with 5 mA) necessary to realise the slope, so that the design of the output transformer is made more difficult due to the increased polarisation.

In capacitors, the metallised paper construction has made available a range of capacitors suitable for decoupling circuits and which occupy only about a third of the space of foil capacitors.

Existing transformers occupy considerable space, and as there has been no outstanding development in core materials, an amplifier considerably smaller than existing types can be made only through major changes in circuit technique. In particular, the transformers could be reduced in size if they were within the feedback loop, but with a single feedback path, stability considerations make this impracticable; however, if a subsidiary feedback path is introduced,[1] a stable amplifier can be constructed with feedback over the output transformer, so that the requirements for this transformer are greatly relaxed. Even with multipath feedback circuits, the inclusion of both transformers within the feedback loop is likely to present a stability problem which itself will impose limitations on the transformer designs. Although external to the feedback path, the input transformer can be reduced in size by designing it as a high-pass filter, details of which are given later.

Design of Amplifier Circuit

The specification* requires an overload point of +17 db., but with 250V H.T. supply, the CV 138 is capable of delivering about +24 db. into its optimum load. For this amplifier, therefore, the anode load can conveniently be raised above this optimum to give additional stage gain, in which case the design of the output transformer becomes the limiting factor. An anode load of 35,000 ohms is the maximum realisable with a $\frac{3}{8}$ in. $\times \frac{3}{8}$ in. core so that with a valve slope of $7{\cdot}5$ mA/V the voltage gain from the grid of the valve to the 600-ohm line winding of the output transformer T2 (Fig. 1) will be 27·5 db.

No advantage is obtained by connecting the input transformer T1 inside the feedback loop, since phase-

[1] British Provisional Patent 34976/46.

* See Appendix I.

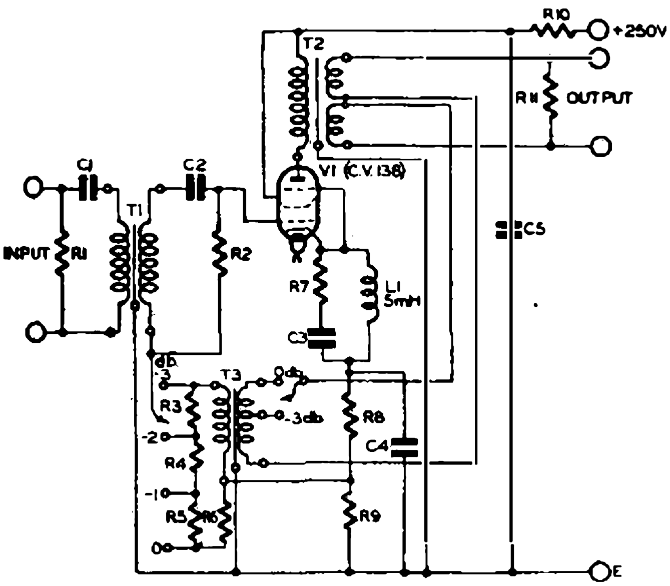


Fig. 1.—Circuit Diagram.

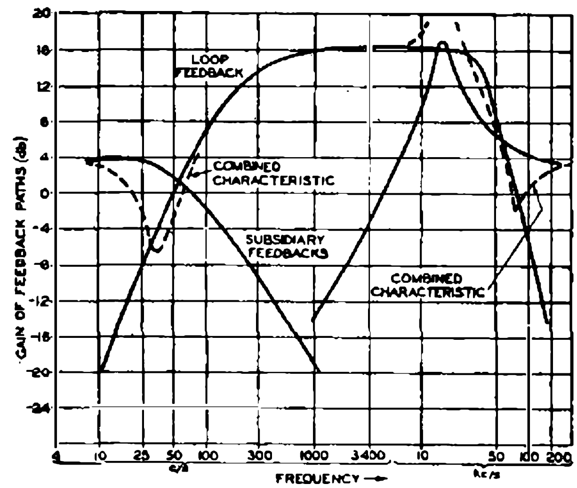


Fig. 2.—Amplitude of Loop and Subsidiary Feedback Voltages.

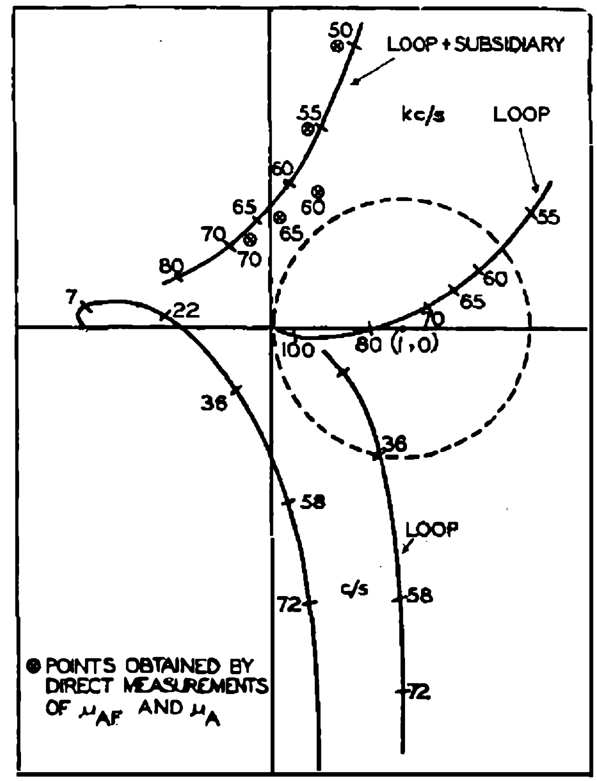


Fig. 3.—Nyquist Diagram of Loop and Subsidiary Feedback on 30 db. Gain Setting.

shift requirements outside the working band would put a more severe limitation on the transformer design than do the given return loss requirements. The maximum voltage step-up has been obtained from the input transformer by designing it as a high-pass filter.

With a $\frac{7}{16}$ in. × $\frac{1}{4}$ in. mumetal core, a step-up of 21·5 db. is obtained, while meeting the input return-loss requirements and allowing for variations in the core material.

The input transformer and valve stage together provide a forward gain of 49 db. With total transformer losses of 2·0 db. about 17 db. of feedback can be expected when operating with a gain of 30 db. This is ample to ensure that the gain/frequency response and harmonic generation are within the specification.

Feedback Paths Necessary for Stability.

Since the output from the amplifier is to be balanced with respect to earth, the feedback voltage, taken from the line winding of the output transformer, must be fed back to the grid circuit through a transformer T3; thus the ultimate slope of the loop feedback characteristic at high frequencies will be 24 db./octave. The connection of about 17 db. of loop feedback alone would under these conditions cause instability, particularly as additional phase-shift is caused by the grid circuit impedances. At low frequencies the ultimate slope is 12 db./octave, so that some 17 db. of feedback is unlikely to cause oscillation, although the stability margin may not be very large.

To make the amplifier stable at high frequencies and to improve the stability margin at low frequencies the feedback characteristic has been modified by subsidiary voltages[1], obtained across two networks C3, R7, L1 and C4, R8, R9 in the cathode circuit which, while having little effect within the working frequency band, considerably modify the characteristic on either side. The amplitude responses of the loop (that is with the subsidiary feedback disconnected) subsidiary and combined (loop plus subsidiary) feedback voltages are shown in Fig. 2, and the corresponding Nyquist diagrams in Fig. 3.

A minimum margin of stability occurs at 72 kc/s when the 24 db. gain setting is used.

Input Transformer.

Because of the higher slope of the CV 138 compared with that of earlier valves such as the P.O. VT 149, less voltage step-up from the input transformer is necessary, so that a smaller transformer is possible. By utilising the shunt inductance of the transformer as an element of a high-pass filter,[2] a further reduction in size is possible. To reduce the effects on the return and transmission losses of differences in the permeability of samples of the core material, the filter has been designed to, and terminated on both sides with, twice the nominal input resistance (R1 and R2). A voltage step-up of 21·5 db. is thus obtained on a $\frac{7}{16}$ in. × $\frac{1}{4}$ in. mumetal core, while meeting the return-loss requirements.

An analysis of the network is given in Appendix II.

The Valve Stage.

With the maximum possible anode load (35,000 ohms) ample power output is available, so that it is convenient to feed the transformer from the high impedance valve and to obtain the required output impedance by the connection of a suitable resistor across the line winding of the transformer. The output impedance is substantially equal to this shunt resistance since the current feedback renders the impedance of the output transformer sufficiently high.

The design of the output transformer is dependent on the D.C. flux produced by the anode circuit. An increased anode current increases the slope available from the valve but decreases the maximum anode load that can be obtained from a transformer of a given core size. However, examination of this problem shows that the maximum stage gain is obtained when the maximum permissible anode current is employed. For this amplifier an anode current of 9 mA is satisfactory and a 2-mil gap is used in a radiometal core which is subjected to some 60 ampere-turns polarisation. The gap in the core reduces the sample-to-sample variation of the shunt inductance which has considerable influence on the stability margin at low frequencies.

The current feedback is obtained from the centre point of the output transformer and is fed to the grid via a step-up transformer T3 designed to give a flat response over the working band. The gain control is obtained by adjusting the loss in the feedback circuit. A 3 db. step is obtained by a tapping on the transformer and three 1 db. steps are obtained by tappings on the closing resistors (R3, R4, R5 and R6).

Tests Results on the Experimental Models.

A few models of an experimental design have been constructed to the circuit of Fig. 1, and tested ; some typical results are given in Tables 1 and 2.

In an amplifier employing more than one feedback path, the determination of the effect of the feedback on gain stability and harmonic generation by valves and transformers is complex. The valve characteristics are modified by a factor equal to the combined feedback, or in the notation of Appendix III by $(1-\mu_1\beta_1-\mu_1\mu_2\beta_3)$, while the transformer characteristics are modified by the amount of feedback which exists at the output transformer with the subsidiary feedback connected, that is by

$$1-\frac{\mu_1\mu_2\beta_3}{1-\mu_1\beta_1}$$

[2] British Provisional Patent 37805/46.

TABLE 1

MAXIMUM AND MINIMUM GAINS

Freq. (c/s)	Gain (db.) max.	Gain (db.) min.
Nominal	30·00	24·00
300	29·90	23·95
500	29·80	23·90
800	29·80	23·90
1,500	29·90	24·00
2,500	30·00	24·10
3,400	30·05	24·15
200	30·00	24·05
6,000	30·05	24·25

TABLE 2.

INPUT AND OUTPUT IMPEDANCES

Freq. (c/s)	Return loss against 600 ohms (db.)	
	Input	Output
300	25	27
500	30	31
800	26	34
1,500	24	37
2,500	23	38
3,400	21	38

In the present amplifier, some subsidiary feedback in the working band has been unavoidable, although it has been minimised so as to obtain the maximum reduction in the harmonic generation of the output transformer. For a typical amplifier, these amounts of feedback are given in Table 3.

TABLE 3.

Freq. (c/s)	Factor reducing harmonic in output transformer (db.)	Combined feedback, i.e. factor modifying valve characteristic (db.)
300	11	13·4
500	13·7	14·9
800	14·4	15·7
1,500	13·9	16·1
2,500	12·2	16·2
3,400	10·3	16·2

The harmonic generation in the amplifier will be worst under conditions where there is least loop feedback, and measurements have therefore been made with the 30 db. gain setting. The results in the table show that the harmonic content in the output does not exceed 5 per cent. for output powers up to +22 db. and that with an output power of +17 db.

the signal/harmonic ratio is better than 42 db. The transformer harmonics are greater at low frequencies and measurements have therefore been made at 300 c/s as shown in Table 4.

TABLE 4.

Level (db.)	Level of 2nd harmonic below signal (db.)	Level of 3rd harmonic below signal (db.)	Total percentage harmonic
+5	53·5	61·0	0·22
+10	50·5	60·5	0·31
+15	45·5	57·0	0·59
+17	43·0	54·0	0·74
+20	40·5	46·5	1·07
+21	39·5	43·5	1·20
+22	37·0	34·5	2·4
+23	27·5	26·5	6·4

Mechanical Considerations.

Although the amplifier described has not yet been developed for Post Office use, some features of the mechanical construction which have been incorporated may be of interest.

The amplifier is mounted in a screening can about 2½ in. × 2½ in. × 4½ in., one end carrying the plug for connection to the power supply jack, and the other end the soldering tags for the input, output and gain control connections. Fig. **4** shows the layout used for some experimental models. Several improvements, such as a more reliable power supply plug and a framework consisting of bakelite moulding, will undoubtedly be necessary if the amplifier is produced in quantity.

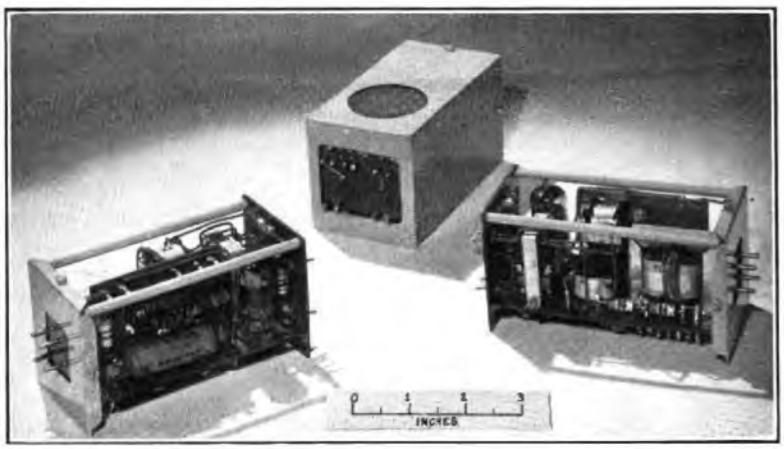


FIG. **4**.—AN EXPERIMENTAL MODEL.

Many amplifiers have frequently to be connected in tandem in a single circuit and must, therefore, have a fault liability considerably lower than is necessary for many other types of communication equipment. With this in mind it was considered that the mechanical strength and the contact fault liability of the B7G valve base were not consistent with this high standard of reliability, and it was decided to weld nickel soldering wires to the valve pins, making the valveholder unnecessary. This construction, together with the compact nature of the amplifier, makes maintenance of the amplifier *in situ* impracticable, so to facilitate removal and replacement the amplifier has been constructed to plug into a power supply jack, the input and output leads being soldered direct to the amplifier wiring.

Considerations of heat dissipation make it impossible to mount on a bay as many amplifiers as their size allows unless forced ventilation is employed, and it may therefore be desirable to interpose associated equipment, such as line transformers or equalisers, between the amplifier units on the amplifier bay. Alternatively, a somewhat larger unit comprising an amplifier complete with attenuation equaliser, possibly in the feedback path, and input and output transformers with tappings arranged to match the lines directly, might be used; this would achieve a further saving of space.

POSSIBLE SIZE REDUCTION OF TOTAL EQUIPMENT

It is important to consider the effect of the redesign of the amplifier on the saving of total equipment. With existing P.O. equipment, four amplifiers are mounted on a 19 in. × 7 in. panel and the four sets of associated line transformers and equalisers occupy a similar panel; the panel area per channel is therefore 66·5 sq. in.

Disregarding heat dissipation, it should be possible to mount twelve of the new amplifiers on a 7 in. panel, i.e. 11 sq. in. per amplifier. By redesigning the line transformers on ⅜ in. × ¾ in. cores their mounting space could be halved; at present it is assumed that no reduction in size of the equaliser unit is possible. On this basis, the auxiliary equipment for 12 amplifiers could perhaps be mounted on a 10-in. panel, thus reducing the total panel area per channel to about 28 sq. in. Thus complete redesign might lead to a space reduction of about 58 per cent. while redesign of the amplifier alone might yield about 33 per cent.

APPENDIX I

AMPLIFIER SPECIFICATION

The following requirements have been used as a basis for the present design :—

(*a*) The maximum gain of each amplifier shall be 30 ± 0·5 db. at 800 c/s.

(*b*) The gain at 200 c/s shall not be more than 1·5 db. lower than the gain at 800 c/s.

(*c*) In the frequency range 300-3,400 c/s, the gain shall not differ from that at 800 c/s by more than 0·5 db., and in the frequency range 3,400-6,000 c/s the gain shall not differ from that at 800 c/s by more than 1·0 db.

(*d*) The gain of the amplifier shall be adjustable in six steps of 1·0 ± 0·1 db. from the maximum setting.

(*e*) The input and output impedances of each amplifier expressed as a return loss against 600 ohms shall be greater than 20 db. at 800 c/s, and greater than 15 db. at all frequencies within the range 300-3,400 c/s.

(*f*) The harmonic distortion with an output of +17 db. at 800 c/s shall not exceed 5 per cent. of the fundamental.

APPENDIX II

The Design of the Input Transformer as a High-Pass Filter[2]

Since the input transformer is not included inside the feedback path, the transformer characteristics will add directly to the amplifier characteristics.

To obtain the step-up required together with a shunt inductance sufficient to meet the return loss specification would have required a $\frac{3}{8}$ in. × $\frac{3}{8}$ in. Mumetal core, but the use of a smaller core is possible by designing the transformer as a high-pass filter employing the shunt inductance as one of the elements, though the reduction in size is somewhat offset by the introduction of the capacitor elements. Difficulties also arise due to possible variations of up to ± 40 per cent. in the shunt inductance of individual samples, and a single constant-k section, closed with its design resistance, will then show excessive variations in return loss. This variation, and the size of the capacitors required, are both reduced if the design resistance of the filter section is equal to twice the nominal input resistance required and if the filter is then terminated on both sides with its design resistance. This network is shown in Fig. 5, where the shunt loss of the coil is represented by $\frac{mxR_oQ}{2}$

The impedance presented by the network at the terminals A—A is given by :—

$$\frac{Z_{AA}}{R_o} = \frac{A + jB}{C} \quad \text{.......................(1)}$$

where

$$A = \frac{m^2Q^2\left(1+\frac{x^2}{2}\right)}{1+Q^2} + \frac{mQ^2\left(\frac{x}{2Q}+\frac{3}{2Qx}-1-\frac{2}{x^2}\right)}{1+Q^2} + \frac{1}{x^4}(1+x^2)$$

$$B = -\frac{m^2Q^2x}{2(1+Q^2)} + \frac{mQ^2\left(\frac{x}{2}+\frac{3}{2x}-\frac{1}{Q}\right)}{1+Q^2} - \frac{1}{x^3}(1+x^2) \quad \text{..(2)}$$

$$C = \frac{Q^2(1+x^2)}{x^2(1+Q^2)}\left[m^2x^2+2m\left(\frac{x}{Q}-1\right) + \frac{(Q^2+1)(x^2+1)}{Q^2 \cdot x^2}\right]$$

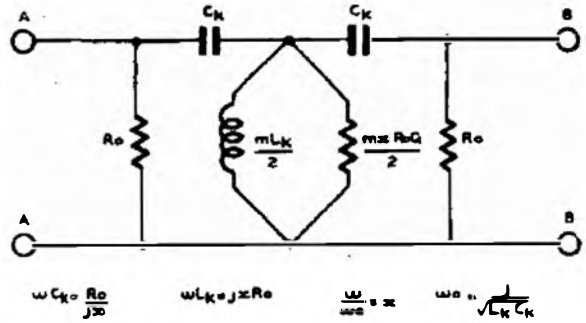


FIG. 5.—NETWORK FOR INPUT TRANSFORMER DESIGNED AS HIGH-PASS FILTER.

where $x = \omega/\omega_o$; $\omega_o = 2\pi \times$ cut-off frequency of the filter, and the variation of m from unity indicates the extent to which the shunt inductance departs from the nominal filter value.

The return loss will be smallest at the lowest frequency used, and if this is at say $x = 2$, then with 15-mil Mumetal stampings, which give a Q of 1·6 at 300 c/s, equation (1) can be evaluated for various values of m. The corresponding return losses are shown graphically in Fig. 6. It will be seen that a

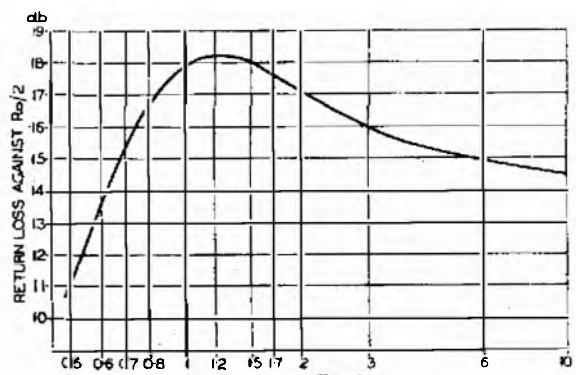


FIG. 6.—RETURN LOSS.

return loss of better than 15 db. at 300 c/s is obtained for $0{\cdot}7 \leqslant m \leqslant 6$.

The loss of the network may be defined as

$$20 \log_{10} \frac{\text{Generator E.M.F.}}{\text{Received P.D.}} - 6{\cdot}0 \text{ db.}$$

where the generator having an internal impedance $R_o/2$ is connected to A—A, and the received P.D. is the open circuit voltage at the terminals B—B. For the network of Fig. 5, the loss is given by :—

$$20 \log_{10} \frac{\sqrt{9 + 4x^2 + \frac{a}{m} + \frac{b}{m^2}}}{2x} \quad \text{..........(3)}$$

$$\text{where } a = \frac{12}{Qx} - \frac{18}{x^2} + \frac{4x}{Q} - 10$$

$$b = \left(1 - \frac{1}{Q^2}\right)\left(1 + \frac{10}{x^2} + \frac{9}{x^4}\right) \quad \text{.......(4)}$$

Taking the lowest frequency in the amplifier band as at $x = 2$, and using values of Q obtained on 15-mil

Mumetal stampings (i.e. about 1·6 at 300 c/s, falling to 0·5 at 3,400 c/s), loss curves between x = 2·0 and x = 28 (300 c/s — 3,400 c/s) for various m values are shown in Fig. **7**. It will be seen that to meet the

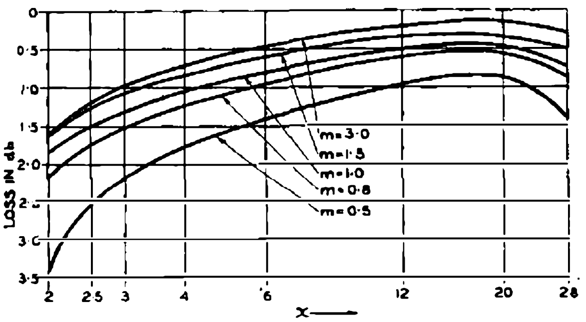


FIG. 7.—THEORETICAL LOSS WITH VARIOUS VALUES OF "m."

specification for both transmission and return loss, m must be restricted to between 1·3 and 3, i.e. m = 2·15 ± 40 per cent. This range of variation in m should be sufficient to allow for differences in individual samples of core material.

APPENDIX III

NOTATION USED FOR AN AMPLIFIER INCLUDING A SUBSIDIARY FEEDBACK PATH[1]

Forward gain $\mu_1\mu_2$ can be divided into two sections μ_1 and μ_2.

Subsidiary path is obtained at the division and has a loop gain $\mu_1\beta_1$.

Main path includes all the forward gain and has loop gain of $\mu_1\mu_2\beta_3$.

Quantity involved in stability criterion
$$= \mu_1\beta_1 + \mu_1\mu_2\beta_3$$

Factor reducing harmonics of μ_1
$$= 1 - \mu_1\beta_1 - \mu_1\mu_2\beta_3$$

Factor reducing harmonics of $\mu_2 = 1 - \dfrac{\mu_1\mu_2\beta_3}{1-\mu_1\beta_1}$

Book Reviews

"Royal Signals Handbook of Line Communication," Vol. 1. H.M. Stationery Office. 875 pp. 763 ill. 20s.

This is the first of two volumes produced by the School of Signals for Army use and sets out to cover the basic theory of line communication, including the necessary mathematics. It contains a wealth of information, presented in a form which can be readily assimilated; although well sprinkled with mathematics, it is very readable. While it is no substitute for the leading text-books on the subject, its lucidity will undoubtedly appeal to most students.

The mathematics, up to linear differential equations and harmonic analysis, and the basic theory of electricity and magnetism seem adequate but it is a pity that B.S.I. terminology has not been adhered to; we should have expected to read of capacitors having capacitance rather than of condensers having capacity.

Line communication is a very wide subject and some gaps are inevitable, but is it hardly to be expected that a book which devotes over 13 pages and 21 illustrations to balanced rectifier modulators and a whole chapter of 42 pages to negative feedback, should include only three lines on two-wire circuits. No reference can be found to balance-networks, return-loss or singing-point, there is only the most casual mention of equalisers and the only indexed reference to crosstalk is to a statement that on a long line it might be sufficient to drown the signal! Perhaps some of these deficiencies are made good in the second volume, dealing with practical applications.

In the chapter on feedback, which, on the whole, is excellent, the terms "parallel" and "series" feedback are used to describe the method of connection to the input circuit and not the method of derivation from the output circuit. This conflicts with common usage and may cause some confusion.

Silicon carbide is a material now in common use and it seems inappropriate to refer to it by a trade name "atmite" (with a small "a") to the exclusion of other proprietary brands. The reference to nickel-iron alloys, particularly Permalloy, are so incomplete as to be misleading.

It is to be deplored that H.M. Stationery Office have not provided a binding more appropriate to the hard usage which the book undoubtedly merits. R. J. H.

"Magnetic Materials." F. Brailsford. Methuen's Monographs on Physical Subjects. 156 pp. 86 ill. Methuen & Co., Ltd. 6s.

It may be said at the outset that in this book Dr. Brailsford has produced a worthy member of an already distinguished series. For a small book (150 pages only), it contains an amazing amount of information, each chapter being complete with a full set of references. The first half of the book is theoretical, the treatment being refreshingly free from higher mathematics, the remainder is devoted to a description of the now extensive range of magnetic materials.

The telecommunications engineer may be disappointed that so little has been included about materials which are his special interest, but as a whole the treatment is fair and balanced. Carbonyl iron is now made in both Britain and America and is available in a number of grades with various properties; the analysis in the table on p. 86 refers to one of the soft, decarburised grades and not to the usual powder used for high-frequency dust cores; this contains about 0·8 per cent. carbon and 0·5 per cent. nitrogen. There is no reference to the use of Permendur (50/50 iron-cobalt) for receiver diaphragms because of its high saturation value or to the use of 12½ per cent. molybdenum Permalloy with a Curie point of 40°C to adjust the temperature coefficient of Permalloy dust cores, or of Sendust. These are all small points; the omission of any reference to the work of Snoek and his collaborators, particularly on the ferrites is more important and will no doubt be rectified in the next edition.

The work as a whole will be very valuable to research workers and others concerned with the use and development of magnetic materials. C. E. R.

"Radio Data Charts." R. T. Beatty, M.A., B.E., D.Sc. (Revised by J. McG. Sowerby, B.A., Grad.I.E.E.). Iliffe & Sons, Ltd. 93 pp. 7s. 6d.

The popularity of this work is shown by the fact that this is the second impression of the fourth edition. It contains a series of forty-four abacs and claims to provide most of the essential data required in receiver design. It will undoubtedly continue to appeal to those who cannot live without their abacs. A. H. M.

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 :—

Shrewsbury Telephone Area ..	Manners, W. ..	Engineer	Major, Royal Signals	Member of the Order of the British Empire

Binding for Volume 41

This issue of the Journal completes Volume 41 and subscribers wishing to have their copies bound are recommended to make early application. Binding cases are also available as for previous volumes.

Particulars of the method of ordering and cost of bindings are given on p. 242.

Publication Delay

In spite of considerable efforts to reduce delay, the increased size of the Journal and Supplement and the continuing difficulties in printing work generally have reacted adversely on publication dates.

Although no early improvement in this situation can be foreseen, readers may be assured that the matter is engaging constant attention.

21st Anniversary of Holborn Exchange

It is a matter of considerable interest to record that Holborn, the first director automatic exchange to be opened in this country, came of age in November last, an event which was not allowed to pass without suitable recognition.

A large company of those associated with the exchange in various capacities during the twenty-one years of its existence met in the Holborn building to celebrate the occasion and an account of the proceedings is given on p. 239 of this issue.

The Institution of Post Office Electrical Engineers

London Centre

PROGRAMME OF MEETINGS—SESSION 1948-49

ORDINARY MEETINGS

To be held at The Institution of Electrical Engineers, Savoy Place, Victoria Embankment, W.C.2, commencing at 5.0 p.m.

Monday, 7th February.—" Improvements in Telephone Signalling." S. Welch, M.Sc., A.M.I.E.E., and H. J. Fleetwood, A.M.I.E.E.

Monday, 14th March.—" The Introduction of Automatic Switching to the Inland Teleprinter Network." H. E. Wilcockson, A.M.I.E.E., and C. W. A. Mitchell, A.M.I.E.E.

Monday, 11th April.—" Wire Broadcasting." F. Hollinghurst, B.Sc., A.M.I.E.E., and W. Prickett, A.M.I.E.E.

Tuesday, 3rd May.—" The Scientific Work of the Post Office." L. E. Ryall, Ph.D., B.Sc., M.I.E.E.

INFORMAL MEETINGS

To be held at the L.T.R. Headquarters Refreshment Club, 8th Floor, Waterloo Bridge House, S.E., commencing at 5 p.m.

Wednesday, 2nd March.—" The Validity of the Faults per Tel. per Annum Statistic as a Criterion of Telephone Service." S. Rudeforth, A.M.I.E.E.

Wednesday, 30th March.—" Transmission Performance—Introduction and Application to Subscribers Network." G. A. E. Fudge, A.M.I.E.E.

Wednesday, 27th April.—" Reproduction Services." A. W. Ford and W. R. Wickens.

A limited number of advance copies of papers to be read at Ordinary meetings will be available a few days before each meeting and application should be made to the Local Secretary, W. H. Fox, Tp. Branch, Alder House. (Telephone : MON 1802.)

Junior Section

London Centre

At the annual general meeting in May, the following were elected as officers and committee for the 1948/49 Session :—

Chairman : Mr. E. L. Tickner ; *Vice-Chairman :* Mr. A. G. Welling ; *Secretary :* Mr. J. Gregory ; *Assistant Secretary :* Mr. L. E. P. Matthews ; *Financial Secretary :* Mr. E. Davis ; *Visits Secretary :* Mr. D. O'R. Macnamara ; *Librarian :* Mr. W. P. Skinner.

Area Representatives : Mr. W. Peck (City), Mr. L. E. J. Penney (Centre), Mr. S. W. F. Stockwell (Circuit Laboratory), Mr. A. Lee (Long Distance), Mr. L. A. Sheen (North Area), Mr. J. Pattington (North-West Area), Mr. T. Ashpool (South-East Area), Mr. R. N. Fletcher (South-West Area), Mr. E. W. Bridle (Test Section), Mr. L. W. Evans (West Area).

The meeting was followed by a meeting of the London Centre, at which the President, H. R. Harbottle, O.B.E., B.Sc.(Eng.), D.F.H., M.I.E.E., gave a talk on "The Telephone Receiver." This lecture was complementary to last year's address on "The Carbon Microphone."

The following programme concludes the 1948-49 Session.

26th January.—" The Relay Director." D. G. Elliott.

24th February.—" The Synchrodyne Receiver." Dr. D. G. Tucker.

22nd March.—To be decided.

20th April.—" Television." T. Kilvington.

26th May.—Annual General Meeting.

Members are asked to make every endeavour to attend meetings and to utilise the facilities, as indicated on the membership card. Senior Section members are cordially invited to attend any meeting they desire. J. G.

(*Continued on p.* 242)

Regional Notes

Home Counties Region

AVELING-BARFORD TRENCH EXCAVATORS[1]

Experience to date with the above machines suggests that certain minor modifications and additions are desirable. They are being tried experimentally on one machine in the Home Counties Region and may be of interest to other users.

Loading. When hauling the machine up the skids on to a 4-ton lorry, the winch hawser tends to pull the tow-bar over to the side of the lorry, according to the position of the hawser on the drum; hence it is not possible to steer the machine on a central course. A guide fitted to the middle of a bar which can be attached at will to the upright members of the lorry body, ensures that the hawser is kept central.

Tow-bar. The normal tow-bar is too long to allow the machine to be hauled by the winch right into the lorry. For the last few feet it has to be manhandled. This can be avoided by the use of a tow-bar only 18 in. long or the short towing hawser referred to below.

Trench Clearing Plate. The machine is supplied with a clearing plate for the 18-in. digging chain only. The attachment of such a plate to the main rear member of the machine for use with the 11-in. chain appears well worth while. It ensures a reasonably level bottom to the trench and enables the operator to see the true depth of the trench while adjusting the digging boom over uneven ground.

Driving Chains. The sprockets for these are driven by separate spindles. With the 11-in. digging chain in use, the nearside driving chain can be removed and held as a spare.

Soil Clearing Chain. When fitting this chain, or tightening it after slacking off to reduce the width of the machine for loading, it is very difficult (unless full use is made of the chain adjusting screw) to draw the chain tight enough to allow the sprocket fixing bolt holes to coincide with those in the frame. Some form of adjuster, such as a car jack or stay tightener placed between the sprocket mounting and the body of the machine, makes it easy to push the sprocket back into position with the chain assembled.

Tools. The following additions are very useful.

(*a*) 3½-in. parallel bench vice, mounted behind the tool box on ¼-in. steel plate, for minor repairs *in situ*.

(*b*) A towing hawser with U bolts at both ends for attachment to the machine, and linked in a V to the lorry tow-bar, saves extensive manhandling on the work.

(*c*) Two spare anchor plate pins, to enable the normal pins to be repaired without holding up the job.

(*d*) A waterproof cover for the tool box.

MARGATE C.B. EXCHANGE

Prior to the war, Margate exchange was scheduled for transfer to automatic working, but on the outbreak of war work on the new building was stopped. The end of the war found Margate exchange depleted of positions and with a very long waiting list of new subscribers.

Due to the demand for buildings of a more essential character it was not possible to provide the new exchange at a reasonably early date. It was decided, therefore, to replace the sections on the main suite which had been recovered during the war, and to fill the multiple (4-panel repetition) up to the capacity of the sections, 2,800 lines, and to provide an island suite with a 6-panel multiple of 3,400 lines.

[1] *P.O.E.E.J.* Vol. 41, p. 73.

The changes in the cable formation between the end of the 4-panel multiple and the beginning of the 6-panel repetition proved to be somewhat involved and it was decided to make the changes in the C.T.S. of the island suite. Transfer circuits have been provided for calls on the main suite to subscribers whose numbers appear only in the multiple of the island suite.

The whole of the work, which included the shifting of the main batteries, changing the power plant from charge-discharge to a float scheme, and the provision of eleven additional sections was carried out by the local staff.

C. W. C.

FLIES IN A U.A.X.

For a few years it had been noticed that towards the end of the summer a certain U.A.X. in the Colchester area was troubled with flies. This year it again arose, but this time to a greater degree, and in spite of treatment with the usual fly sprays it became so bad that the lineman complained that he could stand it no longer.

The services of a Pest Control expert were obtained, and he advised spraying with Psylortox. This was done, and all flies in the building were killed, swept into heaps and about 3 gallons removed; on inspection a month later, only one dead fly was found on the floor. The liquid had left a fine white deposit on walls and apparatus but had had no ill effects, the faint and not unpleasant odour having prevented any more flies entering.

A survey in the neighbourhood of the U.A.X. at the time of the infestation revealed a profusion of ivy (*Hedera helix*) growing in the hedges, the bushes being in bloom and covered with myriads of flies, bees, wasps, etc., feasting on the nectar, plentifully supplied by this particular plant. The falling temperature in the evenings caused the flies to enter the U.A.X., the nearest building, via the ventilating slots in the gable ends and any other crevices, for warmth and apparently they remained there.

Investigations are being made to find some means of preventing the flies obtaining access in the future.

H. C.

London Postal Region

POST OFFICE (LONDON) RAILWAY TRAINING SCHOOL

Many of the engineering staff on the P.O. (London) Railway were recruited in 1926, when the Railway was opened for the transport of mails and, therefore, have the advantage of the initial training on the train control equipment and rolling stock; they have also gained valuable experience as the result of modifications carried out from time to time, which have brought the Railway up to its present state of efficiency.

With the introduction of the younger staff of technicians and skilled workmen, it became apparent that a comprehensive course of training was required to meet the needs of the Railway, and as much of the training is of a specialised nature and not available at either the Central or Regional School, the Engineer-in-Chief's authority was obtained for the setting up of a training school on the Railway.

For the practical work the Westbound Under-Platform area at the Western Central District Post Office (W.C.D.O.) station was equipped with a lay-out of standard track to represent the sections between the Western District Post Office (W.D.O.) station and W.C.D.O., and all relative equipment such as lever frames, train describers, illuminated diagrams, etc., were installed and connected. On this equipment the sequence of events can be studied and memorised, faults can be artificially produced and tuition given on methods of clearance. Tests, adjustments and maintenance are demonstrated and then carried out individually by the students. For any equipment which requires special explanation and which cannot be demonstrated at W.C.D.O. a visit is arranged to the station or district office for the further explanation and a demonstration on the spot.

In order that the staff should be made familiar with the essential differences and points of similarity of equipment on the Post Office Railway compared with a main line electrified railway, visits are arranged to British Railways Southern Region, Clapham Signalling School and to Waterloo, etc., and in this connection the railway authorities have been very helpful.

The lectures covering both parts of the syllabus are given in a suitably equipped room in the Western Central District Office. The syllabus is divided into two parts:

Part I. Three weeks' duration, covers basic electrical principles sufficiently to lead to a full understanding of the maintenance, overhaul, and installation of all P.O.R. and district office equipment. Practical demonstrations are given on nearly all points covered by the lectures.

Part II. Three weeks' duration, covers the Post Office Railway specialised equipment and touches upon special features of lifts and auxiliary plant generally which will be experienced in the Section.

On the last two days of the course a written test is taken covering the whole syllabus and the assessment of the students' ability is mainly based on this test. Class work, notes on lectures and films, oral answers, and practical ability observed during demonstrations and tests on plant, are also assessed during the course and influence to a small extent the final marks awarded.

By arrangement with the Central Office of Information, sound films on engineering subjects of special interest to the Railway Staff are shown during each course.

The results after the first session are very encouraging and there is little doubt that the training given will be of great value to the staff and to the Department.

W. D. M.

Midland Region

A NEW CABLING AID

A useful aid to cabling operations has been devised and used in the Leicester Telephone Area for some months. It consists of an old Morris Minor wheel, fitted with a suitable shackle, which may be anchored in the manhole or suspended over joint boxes or split-coupling excavations. The equipment is relatively cheap and made up of materials which are readily obtainable. It has proved a time-saving device and enabled recovered cable—which would otherwise have been scrapped—to be used again on other works.

By passing the towing rope over this wheel, cable may be drawn into manholes, etc., in direct line with the duct, thus avoiding damaging rope or cable by chafing on duct mouth or wear of rope on the rim of joint-box or manhole entrance.

Sufficient cable may be drawn into a manhole for jointing purposes without the laborious task of using a split grip to gain the amount when the manhole is small and a pulley tackle will not allow of sufficient clearance. By using this equipment, it is not necessary to have a man in the manhole to operate the split grip.

When drawing in cable by towing, the driver of the towing vehicle faces the cable drum and immediately observes any given signals to stop. Without this aid, the distance between cable drums and towing vehicle was increased as operations proceeded and involved one man being used solely for signalling. The photograph indicates a typical use.

CABLING AID IN USE FOR DIRECT PULL—SPLIT COUPLING.

South-Western Region

OLD WELLS AT LAUNCESTON

During the execution of a recent contract for duct work difficulties were encountered in the shape of old wells which necessitated strengthening and building-up work to complete the contract satisfactorily.

At the junction of Race Hill and Bounsalls Lane, a dry well some 30 feet deep was unearthed, and upon further examination, it was discovered that a large exit tunnel led off from it. The matter was reported to the Town Clerk and Borough Surveyor, who arranged for the tunnel to be explored. It was found that the tunnel, about 5 ft. 6 in. high and 2 ft. 6 in. wide, was well-preserved, and extended for some 100 yards, where it joined into another dry well with further tunnels leading off.

The antiquity and use of the underground passages is not known with any degree of certainty, but the opinion is that they are several hundred years old, and formed part of a water collecting system with the wells being used as storage tanks to ensure a constant water supply to parts of the town.

W. J. R.

North-Eastern Region

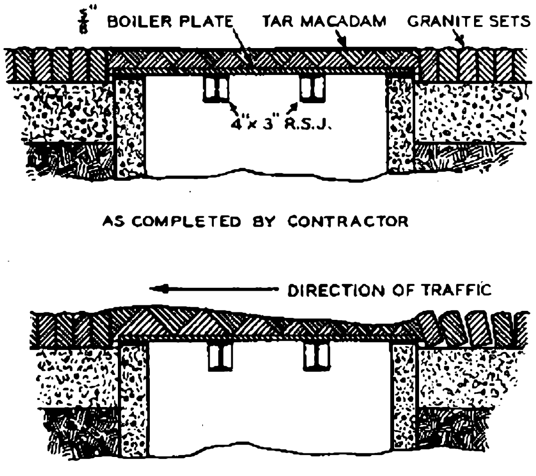
U.A.X. RELIEF—U.A.X.s No. 5

Urgent relief for a U.A.X. No. 5 has been provided by the installation of an additional 25-line unit in space vacated by the removal of the exchange batteries to a separate battery hut. There is no direct access between the existing four units and the new unit, all calls having to be routed via the parent. The lines are numbered 0120 to 0145 (excluding 0140) and these subscribers are instructed to dial " 01 " for all calls. If any two of these subscribers have a high proportion of traffic to each other they will be instructed to dial only the last two digits of their numbers to route the call direct, to avoid using two junctions. The M.D.F. was satisfactorily extended by using the top half of a Frame MD 0/240 to maintain adequate " lift up " space for the cable trench cover.

JOINT BOX AND MANHOLE FRAMES AND COVERS

A very convenient means of overcoming the shortages of frames and covers in footway positions has been to use 2½-in. reinforced concrete slabs of such dimensions that frames and covers can be fitted in their places without disturbing the surrounding reinstatement. Two slabs are used for No. 6 boxes. Holes are provided to enable the boxes to be opened with ordinary box keys.

Concrete slabs for carriageway positions have not been used to any great extent on account of the weight involved, but the alternative method of using boiler plate has been tried extensively though confined mainly to JRC1 and JRC9 types. The illustration shows the



FAILURE OF SUBSTITUTE MANHOLE COVER.

failure of one of these substitutes on account of the braking effect of trolley buses passing over the box at a point short of a recognised stopping place. After this experience the method was only employed in quiet thoroughfares.

An interesting experiment has been conducted at Bradford with the co-operation of the City Engineer. Badly worn manhole frames and covers along one of the main thoroughfares out of the city needed renewal as well as an adjustment of levels. There being little hope of obtaining the new frames and covers to replace the old ones, the City Engineer agreed to lift each one in turn, remove it to his workshops and there weld metal on to the chipping strips. Difficulty arose from the fact that both frame and cover had worn and, therefore, it was agreed to make the frame fit the cover. Both were suitably marked to facilitate subsequent replacement of the cover. Though it was expected that the covers might be subject to rotation this does not appear to have occurred. The method effected substantial savings in materials, but the total cost of modification approached that of new covers.

R. T. A. D.
G. K. H.

Welsh and Border Counties Region

CABLE DAMAGE CAUSED BY TREE

The Carmarthen-Milford Haven No. 3 M.U. Cable 308/20 P.C.Q.T.A. aerial cable, one of the largest types in use in this country, was erected during the war (1944), primarily to cater for Service circuits in West Wales. No duct space was available, but a good existing overhead route which could be strengthened allowed the erection of aerial cable to be completed in a comparatively short time.

The cable was supplied and erected by Siemens Bros., the route strengthening being carried out by the Department. U.S.A. Army personnel stationed in the district assisted the Contractor and Department in the strengthening and erecting operations.

The suspension is of 7/8 wire steel galvanised strand, of weight 148-lb. per 100 yards, with minimum breaking weight of 22,000 lb. The cable is 2·13 in. diameter and weighs 17·6 cwt. per 100 yards. Average length of span is 65 yards, the cable weight per span being, therefore, approximately 11·4 cwt.

The cable was drawn in from West to East, through saddled cable rings, positioned approximately 20 in. apart along the suspension wire. At joints, which are near poles in every case, the cable is directly supported, additional to the cable rings, by connection to the steel from two cable clamps, one each side of each joint, by 7/14 G.I. wire.

On 25th August, due to a high wind, a tree was blown down, falling parallel to the cable route, and came to rest supported by one of its branches, which lay across the steel suspension. The tree, partially decayed and lightly rooted, was growing from a banked hedge some 4 ft. from the line of the route, the bank being about 5 ft. high above road level.

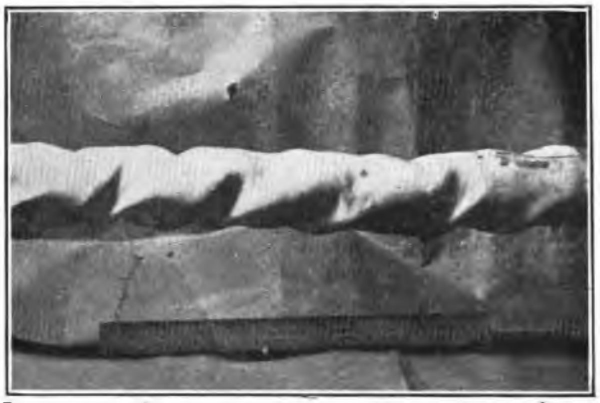
Six 150-lb. copper open wires running above the cable were broken and the weight of the tree depressed the steel (and cable) approximately 2 ft. below its normal catenary depth. As far as is known, no damage was caused to the cable and no circuits were affected.

In view of approaching darkness, the fallen tree was securely lashed to prevent any further movement until clearance work could be undertaken the following day.

On the morning of the 26th tackle was taken to the site and preparatory work to lift the tree (including sawing off branches other than that resting across the steel) was completed. The intention was to allow the tree to slide gradually off the steel and this operation was nearly completed (some 15 inches of the additional depression of the steel having been relieved) when suddenly the steel slipped along the branch and the spring-back of the steel set up a violent oscillation of the wire. The oscillation of the wire was sufficient to open the hooks of the cable rings and in a very short space of time (estimated to be less than 60 seconds) the cable fell from the suspension steel for a distance of 16 spans, approximately 930 yards.

In its fall, the cable tore away all anchoring devices (there were three intermediate joints), the G.I. wire holding the clamps to the steel breaking, apparently without causing any appreciable diminution in the speed of breaking away. The release of the cable from the rings was halted at the far end by a loading point where the stub was pulled out. In the other direction, the cable broke away only as far as the next pole, where it was held on a pole step. The immediate steps taken to lash the cable at this point saved further damage and temporary restoration of the circuits was effected by means of P.C.Q.L. cable laid along the hedge.

The cable was extensively damaged by striking pole steps and stays where it fell along the line of the poles and, where it fell on the hard road surface, was made conical in shape. The wires were pulled inside the sheath towards the point of commencement of the fall for some distance each side of every joint and, near the



DAMAGE TO CARMARTHEN-MILFORD HAVEN AERIAL CABLE.

end of the fallen cable, approaching the loading point, the cable was twisted, as though a spinning-strain had been imposed.

There is a slight slope in the direction of the fall, but it is significant that the opening of the hooks took place towards the direction from which the cable was originally pulled in. It is suggested that the oscillation allowed movement of the rings along the steel in that direction but that the rings bit on the steel in the other direction, preventing their movement along the steel.

The effect was described by a supervising officer who witnessed it as being like the action of a zipp fastener, and it is understood that this name is applied to the action. S. H. P.

CARDIFF AUTO-MANUAL EXCHANGE

In these days of building restrictions the good progress being made with the new building (see photograph) which has been designed to accommodate the Cardiff auto-manual exchange and repeater station is encouraging. It is expected that the building will be completed by March, 1950, and that some portions, including the accommodation for the M.D.F., will be available earlier.

The installation will include the automatic equipment for a 16,700 multiple with multi-metering, and through-dialling facilities with impulse regeneration. The manual board of 160 positions, for Toll and Trunk traffic, will be

CARDIFF AUTO-MANUAL EXCHANGE.

equipped for V.F. dialling and a cordless type directory enquiry desk will also be provided. F. W. L.

EXPERIMENTAL LIGHTING—CARDIFF LETTER SORTING OFFICE

An interesting experiment with lighting conditions has been carried out at the Letter Sorting Office at Cardiff. The bowls normally used with the semi-indirect type of lighting fitting have been replaced by translucent perspex rings 5 in. deep and having the same diameter as the top of the bowl. These rings, known as Liverpool Eye Screens, were designed originally to meet the Home Office regulation against naked filaments being visible to the working staff under certain conditions. Being open at the bottom, these rings give a considerable increase in direct lighting as compared with the bowls, and lumeter readings indicate increases up to 1·5 ft. candles on working positions. The advantages from cleaning and maintenance aspects are obvious. R. E. R.

Scottish Region

FLOOD DAMAGE

On Thursday, 12th August, 1948, the South-East of Scotland experienced the heaviest fall of rain for more than 25 years. At Berwick, 4·1 inches of rain fell in the 24 hours 10 a.m. Thursday to 10 a.m. Friday. Rivers rose many feet and were transformed in a few hours into raging torrents. At Kelso, the Tweed rose 17½ feet, the highest for over 100 years. Reports of the collapse of road and railway bridges, of landslides and of floods came in throughout the night, and by the morning 14 major roads and both main line railway routes were impassable.

The telecommunication services could not come through such devastation and havoc unscathed. The first reports reached Edinburgh shortly after 5 p.m. on Thursday when the Galashiels and Hawick junctions were reported faulty. This was quickly followed by the report of the isolation of Reston, a U.A.X. 12, on the River Eye, and of faulty junctions to Eyemouth. Jointing parties set out immediately, and in the early hours of the morning the Reston spur was reached, but further progress towards the exchange almost ended disastrously for the repair gang. They had become accustomed to driving through several inches of water in the pitch darkness, but noticing a landslide at the side of the road, stopped to investigate. Fifty yards ahead they found that the road was under water and that the bridge over the Eye had been washed away. The fault had been found !

By daybreak Friday, many more reports had been received. Duns, the County town of Berwickshire, was practically isolated due to a bridge over the Whiteadder having been washed away. At Musselburgh, on the mouth of the River Esk, a footbridge had collapsed, taking with it the Edinburgh-North Berwick and Edinburgh-Haddington cables. In the City of Edinburgh itself, there were 22 cable faults involving over 1,500 subscribers, and at Haddington, the County town of East Lothian, only 12 out of 300 subscribers' lines were working. The accompanying photograph, taken at Haddington, shows a cabinet which was submerged for several hours beneath at least 5 ft. of water. On opening this cabinet after its immersion, it was found to be in excellent condition, its insulation unimpaired and the desiccators quite dry. Some 18 other small exchanges, including the U.A.X. at Earlston, which was flooded to a depth of 18 inches, were isolated or working under onerous conditions.

Repair work was immediately put in hand and despite the difficulties of road communications, which frequently involved lengthy detours, the majority of faults were clear by Monday, 16th August. At Reston and Duns, interruption cables were erected across the broken bridges and at Musselburgh 350 yards of aerial cable was provided on an existing overhead route to replace the junction cables over the river and flooded portion of the

CABINET AFTER SUBMERSION BY FLOODS.

town. To restore service to Haddington subscribers, six lengths of cable were renewed and 1,400 pairs of wires changed over. In Edinburgh, 23 lengths were renewed and 3,500 pairs changed over. Apart from such major repair works, there were also many cases in which poles on subscribers' lines were washed away or small local cables were faulty.

In addition to the repair work, new lines were provided at Eyemouth and Ayton within a few hours of the request being received from the police. Only the railway embankment lay between these two towns and a new " lake " of 400 million gallons of water.

The main cable section had their busiest weekend for many years with 14 M.U. and C.J. cable faults scattered throughout the area. One cable, the Edinburgh-Galashiels-Coldstream had four separate faults. This did not make the location of them any easier !

The enormous damage to roads and railways and the widespread distress to homes and families increased still further the strain on the few remaining telephone and telegraph outlets and made their speedy restoration even more imperative. That they were restored so promptly reflects great credit on all the staff involved. D. G. B.

London Telecommunications Region

TWENTY-FIRST ANNIVERSARY OF HOLBORN EXCHANGE

The opening of Holborn, the first director automatic exchange, heralded a new era in the country's telephone history. In spite of the many problems to be solved and set-backs that occurred, the enthusiastic supporters of the new system won through knowing that the future of the telephone service in London depended upon the success of their efforts. At the opening of the exchange on November 12th, 1927, there were a few fearful hearts although the general atmosphere was one of confidence, but when the 21st anniversary of the opening was celebrated on 11th November, 1948, the atmosphere was one of well-earned jubilation. The exchange dining room at Holborn was packed to overflow by those who had been responsible for the installation of the exchange and its maintenance throughout the years. Many of the pioneers had since retired and others had changed their rank and location, but guests travelled from far and near to this unique re-nnion. The company which comprised the majority of the old originals from the operating and engineering sides of the staff must have numbered not less than 500 people.

The Chair was taken by Mr. J. F. McDonald, the Telephone Manager of the L.T.R. Centre Area. Those present included : Mr. A. J. Gill, Engineer-in-Chief, Colonel Sir Thomas Purves, former Engineer-in-Chief, Mr. F. I. Ray, London Regional Director, and all the members of the Regional Board, Mr. T. H. Edgerton, formerly Deputy Chief Regional Engineer, L.T.R., Mr. A. J. Leyland, who represented the Automatic Telephone and Electric Co., Ltd., of Liverpool (along with a number of the principal officers of the company), Colonel J. Reading, with Messrs. C. W. Brown and R. L. Bell of the Engineer-in-Chief's Office, Messrs. F. J. Tickner and J. McA. Owen from G.P.O. Headquarters, Mr. C. W. Pink, formerly Deputy Regional Director, L.T.R., and the redoubtable Mr. Horace Dive, who was Controller, Telephones, before retirement, Mr. J. W. Shepherd, Telephone Manager, South West Area, L.T.R., and Miss M. Bailey who was the Supervisor in charge of the exchange at the opening.

Following tea, the chairman called upon a number of speakers. Mr. Edgerton recalled the trials of the pre-opening days and his fears lest the apparatus should be worn out by testing before it could be brought into use.

Colonel Purves described Holborn as the exchange on which the Post Office had staked its future. Teething troubles were many and he recalled the occasion when the Gas Light & Coke Co. had combined with the Post Office to blow up High Holborn. It is now history that the gas mains in this thoroughfare caught fire and endaugered all the underground cabling.

The Regional Director said that like " The Island that loves to be visited " in Barrie's play " Marie Rose," Holborn cast a spell of enchantment on all who visited it.

Mr. Leyland of the A.T.E. Co. brought cordial greetings from old friends in Liverpool, and a telegram was read from his colleague, Mr. A. F. Bennett, who regretted his absence abroad and averred that Holborn was good for another 20 years.

Many other speakers, including Mr. H. T. Bines Clerk of Works at the opening, joined in eulogy of the fellowship and good service that had centred round the building which had just come of age, surviving many vicissitudes not the least of which were very near misses by bombs. Tribute was paid to many old stalwarts and to the memory of those who have passed on.

Unfortunately, Mr. G. F. O'dell was unable to be present but he sent a gilded key for the back door, as, he said, " entry by that method can be quite convenient on occasions ! "

The evening concluded with a first-class cabaret.

All those who were responsible for the organisation of the event are to be congratulated on an outstanding success. The old members of Holborn are very grateful to the present staff who were their hosts for the occasion.

Staff Changes

Promotions

Name	Region	Date
Area Engr. to A.S.E.		
Chapman, R. H.	H.C. Reg. to E.-in.C.O.	1.9.48
Exec. Engr. to Principal		
Coates, G. H.	E.-in-C.O. to Personnel Dept.	1.9.48
Exec. Engr. to Tel. Man.		
Lemmey, C. W.	E.-in.C.O. to Lancaster	19.9.48
Exec. Engr. to Princ. Sc. O.		
Bickley, H. D.	E.-in.-C.O.	22.9.48
Sen. Sc. O. to Princ. Sc. O.		
Walker, E. V.	E.-in.-C.O.	14.10.48
Engr. to Exec. Engr.		
Humphries, W. A.	E.-in-C.O.	1.9.48
Ayers, E. W.	E.-in-C.O.	27.8.48
Wells, H. M.	H.C. Reg.	2.9.48
Knox, J.	Scot.	17.10.48
White, R. W.	E.-in-C.O.	15.10.48
Asst. Engr. to Engr.		
King, R. R.	H.C. Reg.	21.9.48
Rolin, F. W.	L.T. Reg.	21.9.48
Baird, E.	Scot.	21.9.48
Rogers, A. H.	W.B.C. Reg.	21.9.48
Williams, J. E.	S.W. Reg.	9.10.48
Myers, B. L.	N.W. Reg. to E.-in-C.O.	30.10.48
Thorn, F. W. J.	W.B.C. Reg.	1.11.48
Wright, G. T.	Scot.	21.9.48
Stapley, G. R.	Mid. Reg.	9.10.48
Raffles, H.	S.W.Reg.	21.9.48
Hills, A. F.	E.-in-C.O.	21.9.48
Worthington, A. G.	E.-in-C.O.	21.9.48
Garfath, A. J. A.	H.C. Reg.	21.9.48
Mockbridge, W. C.	S.W. Reg.	21.9.48
Bell, W. T.	E.-in-C.O.	21.9.48
Wallis, I. H.	H.C. Reg.	21.9.48
Hargrave, L. R.	S.W. Reg.	21.9.48
Smith, W. R.	H.C. Reg.	21.9.48
Miller, E. W.	H.C. Reg.	2.10.48
McLeod, J.	Scot.	21.9.48
Carter, R. E.	E.-in-C.O.	21.9.48
Fox, G.	W.B.C. Reg.	1.10.48
Knight, A. R.	L.T. Reg.	21.9.48
McClements, J. S.	E.-in-C.O.	21.9.48
Thompson, S.	E.-in-C.O.	21.9.48
Dootson, G. W.	H.C. Reg.	29.9.48
Chisnall, W. E.	E.-in-C.O.	1.11.48
Bentley, W. C. B.	E.-in-C.O. to Mid. Reg.	10.10.48

Name	Region	Date
Asst. Engr. to Engr.—continued		
Banham, S. H.	E.-in-C.O.	21.9.48
Sallis, R. T. G.	E.-in-C.O.	21.9.48
Hood, J. B.	Mid. Reg.	21.9.48
Linsell, W.	L.T. Reg.	21.9.48
Wells, L. A.	L.T. Reg.	21.9.48
Kerner, S.	L.T. Reg.	10.10.48
Anthistle, A. W.	Mid. Reg. to W.B.C. Reg.	3.10.48
Arthur, J. C. C.	L.T. Reg.	21.9.48
Kent, S. T. E.	L.T. Reg.	9.10.48
Milton, A. G.	L.T. Reg. to E.-in-C.O.	9.10.48
Smith, J. R. G.	L.T. Reg.	21.9.48
Smith, F. J.	L.T. Reg.	21.9.48
Medcalf, L. W.	L.T. Reg.	21.9.48
Easton, W.	W.B.C. Reg. to N.E. Reg.	31.10.48
Cook, A. C.	Scot.	20.10.48
Inspr. to Asst. Engr.		
Newton, C. E.	E.-in-C.O.	1.10.48
Huke, G. A.	H.C. Reg.	28.6.48
Gilgrist, H. T.	N.W. Reg.	30.8.48
Technician to Asst. Engr.		
Immins, A.	E.-in-C.O.	1.3.47
Perry, E. T.	E.-in-C.O.	1.4.48
Harris, K. N.	E.-in-C.O.	8.4.47
S.W.I. to Inspr.		
Mannock, E. T.	E.-in-C.O.	9.6.47
Wicker, C. A.	H.R. Reg.	28.6.48
D'man. Cl. II to D'man Cl. I.		
Godwin, T. H.	L.T. Reg.	1.10.48
Webb, F. J.	L.T. Reg.	1.10.48
Atkinson, L. J.	L.T. Reg.	3.10.48
Ealey, S. J.	L.T. Reg.	1.10.48
Blackwell, C. F.	L.T. Reg.	1.10.48
Galloway, F.	L.T. Reg.	1.10.48
Cox, R. H.	L.T. Reg.	1.10.48
Briant, G. A.	L.T. Reg.	1.10.48
Robson, G. W.	L.T. Reg.	1.10.48
Pearce, C. C.	L.T. Reg.	1.10.48
Pusey, L. M.	L.T. Reg.	1.4.48
Firth, D. J.	N.E. Reg.	3.10.48
Sewell, T. W.	N.E. Reg. to S.W. Reg.	31.10.48
Smith, R.	H.C. Reg. to S.W. Reg.	10.10.48
Bell, W.	N.W. Reg. to H.C. Reg.	17.10.48
Taylor, W.	N.E. Reg. to L.T. Reg.	17.10.48
Williams, E. V.	W.B.C. Reg.	10.10.48
Edwards, H. G.	W.B.C. Reg.	26.11.48
Kitchingham, H. J.	L.T. Reg.	1.10.48
Storm, J.	Scot.	17.10.48

Transfers

Name	Region	Date
Exec. Engr.		
Hoare, E. R.*	E.-in-C.O. to Min. of Agr. & Fisheries	15.3.48
Engr.		
Warner, M. G. R.	E.-in-C.O. to Min. of Agr. & Fisheries	20.9.48
Wass, C. A. A.	E.-in-C.O. to Min. of Supply	4.10.48
Christmas, A. N.	E.-in-C.O. to Min. of Supply	4.10.48

Name	Region	Date
Prob. Engr.		
Fenemore, R. W.	E.-in-C.O. to Min. of Supply	20.9.48
Smith, C. E.	H.C. Reg. to E.-in-C.O.	7.11.48
Asst. Engr.		
Heaton, N.	E.-in-C.O. to N.E. Reg.	12.9.48
Winterburn, G. E.	E.-in-C.O. to N.E. Reg.	19.9.48
Cottam, A. R.	E.-in-C.O. to H.C. Reg.	1.10.48
Quellin, A. A.	E.-in-C.O. to N.W. Reg.	3.10.48

* Incorrectly shown as Exec. Off. in October 1948 issue.

Transfers—*continued*

Name	Region	Date
Asst. Engr.—continued		
Caines, G. E.	H.C. Reg. to E.-in-C.O.	1.10.48
Banfield, D. F.	E.-in-C.O. to Min. of Supply	17.10.48
Wase, A. E. N.	E.-in-C.O. to Patent Office	17.10.48
Alston, R. E.	E.-in-C.O. to Min. of Works	4.10.48
Wright, S. F.	E.-in-C.O. to Admiralty	13.9.48
Tresidder, W. M.	E.-in-C.O. to Patent Office	1.11.48
Withers, D. J.	N.I. Reg. to E.-in-C.O.	18.10.48
Asst. Engr.—continued		
Francis, E. H.	E.-in-C.O. to W.B.C. Reg.	15.11.48
Harding, F. J.	W.B.C. Reg. to E.-in-C.O.	15.11.48
Inspr.		
Newton, C. E.	W.B.C. Reg. to E.-in-C.O.	1.10.48
D'man Class I.		
Price, A. A.	Scot. to N.W. Reg.	17.10.48
Flynn, L. A.	N.E. Reg. to H.C. Reg.	27.9.48

Retirements

Name	Region	Date
Engr.		
Tansley, L. W.	H. C. Reg.	31.8.48
Gordon, J. T.	W.B.C. Reg.	30.9.48
Sutter, A. S.	Scot.	30.9.48
Warne, G. C.	L.T. Reg.	21.10.48
Platt, F.	W.B.C. Reg.	31.10.48
Blott, T. G.	S.W. Reg.	18.11.48
Asst. Engr.		
Betts, E. P.	Mid. Reg.	31.8.48
Hudson, P.	N.W. Reg.	1.8.48
Rodger, J.	Scot.	12.8.48
Back, R. C. J.	Mid. Reg. (Resigned)	31.10.48
Ayling, S. R.	E.-in-C.O. (Resigned)	5.11.48
Asst. Engr.—continued		
Bowen, R. F. R.	E.-in-C.O. (Health grounds)	14.10.48
Peak, C. H.	E.-in-C.O. (Resigned)	13.11.48
Waterhouse, W. H.	E.-in-C.O.	16.11.48
Inspr.		
Carpenter, C. H.	W.B.C. Reg.	13.10.48
Jenkins, W. F.	Mid. Reg.	23.9.48
D'man. Cl. I.		
Joscelyn, S. G.	W.B.C. Reg.	26.11.48
Germann, T.	E.-in-C.O.	30.11.48

CLERICAL GRADES

Promotions

Name	Region	Date
H.E.O. to Inspr. of Cler. Estab.		
Foord, F. C.	E.-in-C.O.	29.9.48
Manning, W. J.	E.-in-C.O.	29.9.48
E.O. to H.E.O.		
Hodgkiss, S.	E.-in-C.O.	29.9.48
E.O. to H.E.O.—continued		
Hutchison, A. J.	E.-in-C.O.	29.9.48
C.O. to E.O.		
Pitcher, B. J.	E.-in-C.O.	29.9.48
Read, Miss M. F. E.	E.-in-C.O.	18.10.48

Transfers

Name	Region	Date
E.O.		
Dabbs, S. E.	To Min. of Health	16.8.48
Johnson, H.	To Min. of Health	16.8.48
E.O.—continued		
Hawes, C. W.	To Min. of Supply	4.10.48

Retirement

Name	Region	Date
H.E.O.		
Wager, H.	E.-in-C.O.	21.8.48

Death

Name	Region	Date
H.E.O.		
Robertson, N.	E.-in-C.O.	9.10.48

(Ccontinued from p. 234)

Carlisle Centre

The Carlisle Junior Section has long been noted for the versatility of its programmes, and this reputation was well upheld by a most interesting visit to the United Steel Co.'s works at Workington in July last.

A party of thirty members followed, with intense interest, all the ramifications of the process by which high quality steel bars are produced from such fundamental materials as iron ore, limestone, coke, silica and powdered aluminium. The operation of tapping a furnace to withdraw molten iron ore was watched with something akin to awe.

Mysteries of the Bessemer process were explored, and the rolling and cutting of the finished product into suitable lengths and sections were well demonstrated.

Harrogate Centre

After a very successful Session for 1947-8 the Centre is enjoying what promises to be an equally successful programme for 1948-49.

The Committee for the year is as follows :—

Chairman : Mr. J. T. Winspear.
Secretary and Treasurer : Mr. L. Webster.
Committee : Messrs. E. G. Horsley, D. R. Lewis, J. L. Bagley and J. G. Cameron.

The remainder of the programme for 1948-49 is as follows :—

February 3rd. "Signals in the Far East." P. H. George
March 3rd. "Principles of V.F. Telegraphy." L. Webster.

J. T. W.

Maidstone Centre

The affairs of the Maidstone Centre are progressing most favourably, the meetings having attracted an average attendance of 60 per cent. of the total membership.

The programme for the remainder of the 1948-49 session includes the following :—

"Swedish Telephone Systems." S. W. Broadhurst.
"Costing and Accounting." A. G. Robins, A.M.I.E.E.
"The Telephone and the Future." W. A. Collett.

The officers elected for the 1948-49 session are :

Chairman : W. H. Craig.
Secretary : C. Tame.
Assistant Secretary : L. A. S. Barham.
Treasurer : R. W. Wallond.
Committee : Messrs. J. B. Shaw, E. C. Stevens, K. Silverston, J. Garrod, F. P. Wallond, A. Mercer.

C. T.

Portsmouth Centre

The above Centre is now once more in action and it is hoped that continued support will be given by members. An interesting programme has been arranged for the remainder of the 1948-49 Session, particulars of which follow.

February 8th. "The Development of the Trunk Cable Network." J. Balcombe.
February 19th, 26th, and March 5th. Visits to Portsmouth Power Station.
March 8th. "The Internal Combustion Engine." K. Salmon.
March 22nd. "Atomic Energy" (Film Show). T. Aldam.
April 5th. "Sound Recording." J. Baker.
April 23rd. Visit to Portsmouth and Gosport Gas Co., Hilsca Works.
May 24th. Annual General Meeting.

C. E. L.

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 2s. Subscribers can have their copies of Volumes bound, at a cost of 7s. 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 1s. 6d. (1s. 9d. post free) per copy, or 7s. per annum post free. Back numbers can be supplied, subject to availablity of stocks, at 1s. 6d. each (1s. 9d. post free). Orders for back numbers may be sent to the Local Agents or to the Publishers.

Post Office Electrical Engineers' Journal

Volume 41, April 1948—January 1949

INDEX

A

PAGE NO.

Acoustic Testing, "Dead" Room for 91
Aldeburgh-Domburg No. 6 Submarine System, The.. 1
Alert, H.M.T.S.; ex-German Cableship *Nordeney* .. 138
Amplifier, A Miniature Audio-Frequency 228
Analyser, A Speech Spectrum 188

B

Bass, N. K., and R. Goford. Duct Rodding with a Continuous Rod 130
Benson, D. L., and K. M. Heron. Mechanical Trunk Fee Accounting 216
Blind and Handless Operator, A Switchboard for a .. 63
Book Reviews 28, 44, 56, 72, 75, 82, 84, 110, 133, 169, 170, 192, 212, 221, 227, 233
Brimmer, W. L. and R. W. Palmer. The British Telephone Technical Development Committee .. 199
British Standard Codes of Practice 105
British Telephone Technical Development Committee, The 193
Brown, E. H., A. C. Hales and D. Harrison. Renovation of Telephone Switchboard Sections 134

C

Cable, Star-Quad Telephone, The Manufacture of 29
Cable Testing, Pulse Techniques in Coaxial 13
Calling Line Identification 92
Cameron, C. J., and W. A. Humphries. Shared Service 139
Carter, R. O., L. K. Wheeler and A. C. Frost. An Electronic Regenerative Repeater for 7½-Unit Start-Stop Signals 222
Centralised Fire Control Switchboard for London Fire Brigade 163
Codes of Practice, British Standard 105
Combridge, J. H. A Switchboard for a Blind and Handless Operator 63
C.C.I.F. Meeting, Stockholm, June 1948 154
C.C.I.R., Fifth Plenary Meeting of, Stockholm, June 1948 155
C.C.I.T., Sixth Plenary Meeting of, Brussels, May 1948 108
Construction of Zenithal-Equidistant Maps, The .. 85
Continuous Rod, Duct Rodding with a 130
Cook, A., and L. L. Hall. Criggion Radio Station .. 123
Criggion Radio Station 123

D

Davison, G. N., and R. J. Pickard. A Multi-Channel Radio Telegraph Equipment 148
"Dead" Room for Acoustic Testing 91
Deering, J. E. The Manufacture of Star-Quad Telephone Cable 29
Devereux, R. C. Overseas Exchange (Radio Services) 76
Duct Rodding with a Continuous Rod.. 130
Duerdoth, W. T., and J. Garlick. A Miniature Audio-Frequency Amplifier 228

E

Efficiency of Gradings, The
Part 1.—Determination of General Formulæ: Small Grading Elements 45
Part 2.—Grades of Service for Straight Gradings: Comparative Efficiencies of Various Arrangements 67
Electronic Regenerative Repeater for 7½-Unit Start-Stop Signals, An 222
European Switching Plan, The 50
Exponential Distribution in Statistics, Notes on the .. 10

F

PAGE NO.

Fifth Plenary Meeting of the C.C.I.R., Stockholm, July 1948 155
Fire Control Switchboard, Centralised, for London Fire Brigade 163
Frost, A. C., R. O. Carter and L. K. Wheeler. An Electronic Regenerative Repeater for 7½-Unit Start-Stop Signals 222

G

Garlick, J., and D. G. Tucker. A Highly-Selective Transmission Measuring Equipment for 12- and 24-channel Carrier Systems 166
Garlick, J., and W. T. Duerdoth. A Miniature Audio-Frequency Amplifier 228
Gerry, P. R. Principles of Overhead Line Construction 18
Gleadle, G. H. M. Ionospheric Disturbances 34
Goford, R., and N. K. Bass. Duct Rodding with a Continuous Rod 130
Gradings, The Efficiency of 45, 67
Grasby, C. W., and R. C. Kyme. A Tester for Measuring the Speed and Ratio of Loop Impulses .. 83

H

Hales, A. C., E. H. Brown and D. Harrison. Renovation of Telephone Switchboard Sections 134
Hall, L. L., and A. Cook. Criggion Radio Station .. 123
Harrison, D., E. H. Brown and A. C. Hales. Renovation of Telephone Switchboard Sections 134
Headquarters Notes 52, 111, 171
Heron, K. M., and D. L. Benson. Mechanical Trunk Fee Accounting 216
Highly-Selective Measuring Equipment for 12- and 24-channel Carrier Systems 166
Humphries, W. A., and C. J. Cameron. Shared Service 139

I

Identification, Calling Line 92
Institution of Post Office Electrical Engineers 109, 182, 234
International Telex
Part 1.—Signalling System, Subscribers' Station Equipment and Line Terminations 39
Part 2.—The Switchboard and Equipment .. 98
Ionospheric Disturbances 34

J

Junior Section Notes 52, 120

K

Kilvington, T., H. T. Mitchell and W. E. Thomson. The Construction of Zenithal-Equidistant Maps.. 85
Kyme, R. C., and C. W. Grasby. A Tester for Measuring the Speed and Ratio of Loop Impulses .. 83

L

Lewis, F. S. Tungsten Carbide Tipped Tools 213
Lewis, N. W. Notes on the Exponential Distribution in Statistics 10
London-Birmingham Television Cable, The
Part 1. General System and Electrical Requirements 183
Longley, H. A. The Efficiency of Gradings 45, 67
Loop Impulses, A Tester for Measuring the Speed and Ratio of 83

M

PAGE NO.

Manufacture of Star-Quad Telephone Cable, The
Part 3.—Quadding and Stranding Lays, Acceptance Tests and Sheath Defects 29
Mechanical Trunk Fee Accounting
Part I. Principles of Punched Card Accounting 216
Metson, G. H. Poisoning Effects in Oxide Cathode Valves 204
Miniature Audio-Frequency Amplifier, A 228
Mitchell, H. T., T. Kilvington and W. E. Thomson. The Construction of Zenithal-Equidistant Maps.. 85
Multi-Channel Radio Telegraph Equipment, A .. 148

N

Notes and Comments 55, 110, 170, 234
Notes, Headquarters 52, 111, 171
Notes, Junior Section 52, 120
Notes, Regional 57, 115, 175, 235
Note on an Experimental Packet-Counting Device, A 103
Notes on the Exponential Distribution in Statistics .. 10

O

Olympic Games, 1948, Telecommunications for the .. 157
Overhead Line Construction, Principles of 18
Overseas Exchange (Radio Services) 76

P

Packet-Counting Device, A Note on an Experimental 103
Palmer, R. W. and W. L. Brimmer. The British Telephone Technical Development Committee .. 193
Pearce, C. A. R. Pneumatic Tubes 206
Pearson, H. E. and J. E. Thwaites. Vacuum Technique —Some General Principles and Post Office Applications 199
Phototelegraph Service to Europe, The Post Office .. 189
Pickard, R. J., and G. N. Davison. A Multi-Channel Radio Telegraph Equipment 148
Pneumatic Tubes 206
Poisoning Effects in Oxide-Cathode Valves 204
Post Office Phototelegraph Service to Europe, The .. 189
Potentialities of the Vocoder for Telephony over Very Long Distances, The 22
Principles of Overhead Line Construction, The .. 18
Pulse Techniques in Coaxial Cable Testing 13

R

Radio Telephone Equipment, A Multi-Channel .. 148
Regenerative Repeater for 7½-Unit Start-Stop Signals, An Electronic 222
Regional Notes 57, 115, 171, 235
Renovation of Telephone Switchboard Sections .. 134
Reorganisation of Post Office Research 147
Research, Post Office, Reorganisation of 147
Rhodes, J. The Aldeburgh-Domburg No. 6 Submarine Cable System 1
Roberts, F. F. Pulse Techniques in Coaxial Cable Testing 13
Robinson, N. H. Calling Line Identification 92

S

Sallnow, C. W., and E. R. Smith. Telecommunications for the 1948 Olympic Games 157
Shared Service 139
Smith, E. R., and C. W. Sallnow. Telecommunications for the 1948 Olympic Games 157
Speech Spectrum Analyser, A 188
Spooner, J. W., and J. W. R. Thomson. A Trench-cutting Machine 73
Staff Changes 60, 121, 180, 240
Standard Frequency Transmissions in Great Britain 129
Stanesby, H and W. K. Weston. The London-Birmingham Television Cable 183
Star-Quad Telephone Cable, The Manufacture of 29
Statistics, Notes on the Exponential Distribution in .. 10
Submarine Cable System, The Aldeburgh-Domburg No. 6 1
Swaffield, J. The Potentialities of the Vocoder for Telephony over Very Long Distances 22
Switchboard for a Blind and Handless Operator, A .. 63
Switchboard Sections, Telephone, Renovation of .. 134

T

Telecommunications for the 1948 Olympic Games .. 157
Television Cable, The London-Birmingham 183
Telex, International 39, 98
Tester for Measuring the Speed and Ratio of Loop Impulses, A 85
Thomson, W. E., H. T. Mitchell and T. Kilvington. The Construction of Zenithal-Equidistant Maps.. 85
Thomson, W. J. R., and J. W. Spooner. A Trench-cutting Machine 73
Thwaites, J. E. and H. E. Pearson. Vacuum Technique —Some General Principles and Post Office Applications 199
Tools, Tungsten Carbide Tipped 215
Transmission Measuring Equipment for 12- and 24-channel Carrier Systems, A Highly-Selective .. 166
Trench-cutting Machine, A 73
Trunk Fee Accounting, Mechanical 216
Tucker, D. G., and J. Garlick. A Highly-Selective Transmission Measuring Equipment for 12- and 24-channel Carrier Systems 166
Tungsten Carbide Tipped Tools 215

V

Vacuum Technique—Some General Principles and Post Office Applications 199
Valves, Oxide-Cathode, Poisoning Effects in 204
Vocoder for Telephony over Very Long Distances, The Potentialities of the 22

W

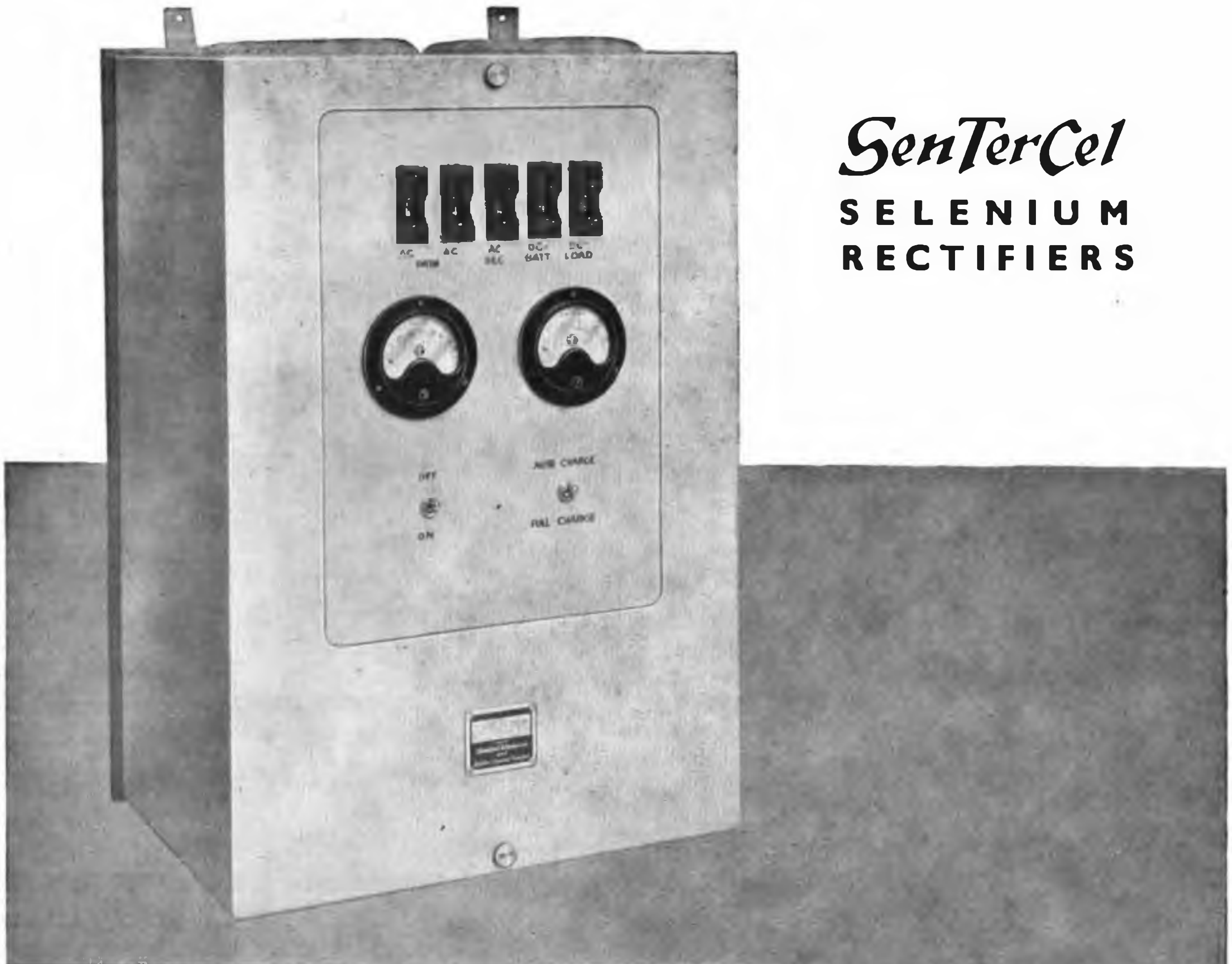
Waldram, A. H. T., and H. E. Wilcockson. International Telex 39, 98
Weston, W. K. and H. Stanesby. The London-Birmingham Television Cable 183
Wheeler, L. K., A. C. Frost and R. O. Carter. An Electronic Regenerative Repeater for 7½-Unit Start-Stop Signals 222
Wilcockson, H. E., and A. H. T. Waldram. International Telex 39, 98
Wooding, W. T. Centralised Fire Control Switchboard for London Fire Brigade 163

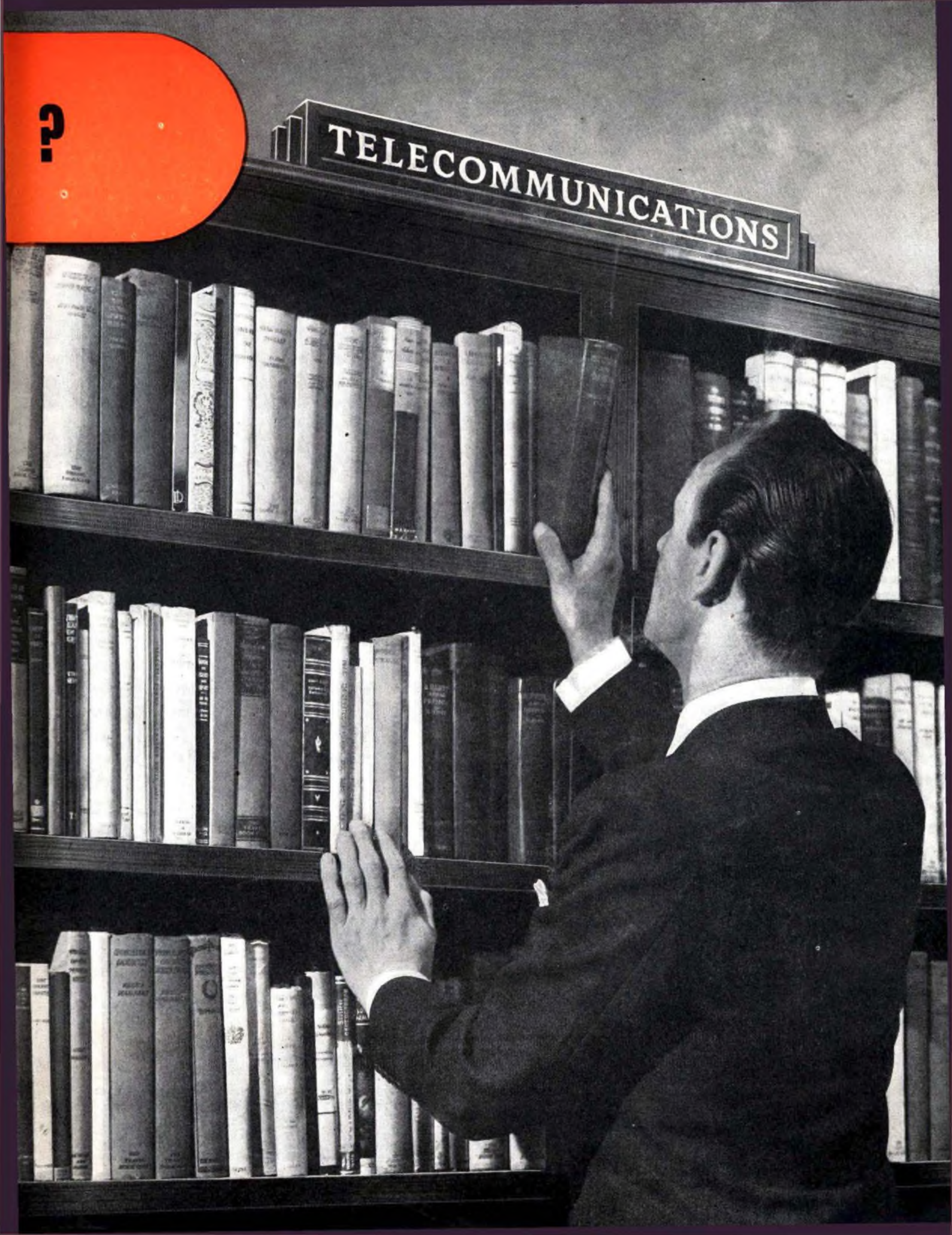
Z

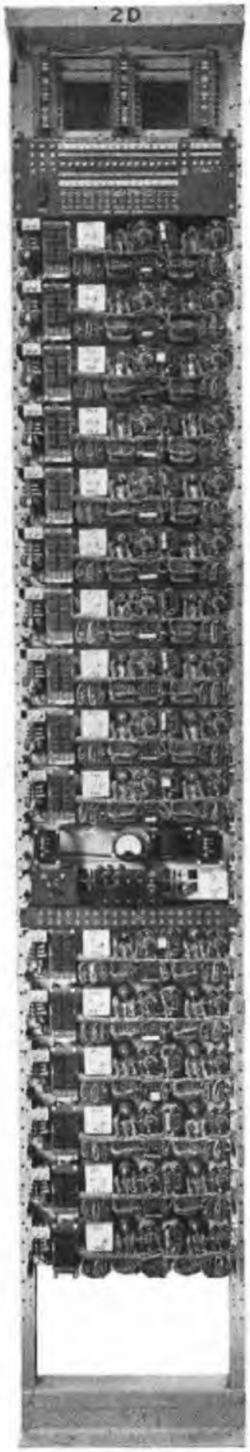
Zenithal-Equidistant Maps, The Construction of .. 8

INDEX TO ADVERTISERS

	Page
Alton Battery Co., Ltd., The	vi
Automatic Coil Winder & Electrical Equipment Co., Ltd.	xvii
Automatic Telephone & Electric Co., Ltd.	xii, xiii
Bennett College, The	vii
British Institute of Engineering Technology	xv
Creed & Co., Ltd.	viii
Edison Swan Electric Co., Ltd., The	vii
Ericsson Telephones, Ltd.	xvi
Evershed & Vignoles, Ltd.	xix
General Electric Co., Ltd., The	ii
H. T. A., Ltd.	v
International Correspondence Schools	xv
Muirhead	iv
Painton	xvii
Parmeko, Ltd.	ix
Pirelli-General Cable Works, Ltd.	xxii
Pitman, Sir Isaac, & Sons, Ltd.	xv
Salford Electrical Instruments, Ltd.	xxii
Savage, W. Bryan, Ltd.	v
Siemens Brothers & Co., Ltd.	xiv
Smith, Frederick, & Co.	iv
Standard Telephones and Cables, Ltd.	x, xx
Sullivan, H. W., Ltd.	x
Telephone Manufacturing Company, Ltd.	x
Tudor Accumulator Co., Ltd., The	xx
Tungstone Products, Ltd.	xvii
United Insulator Co., Ltd.	xx
Westinghouse Brake & Signal Co., Ltd.	i
Winn & Coales, Ltd.	vi




?
TELECOMMUNICATIONS



Bay mounting 2-wire Voice-frequency Repeater Equipment with covers removed

SIEMENS

TRANSMISSION EQUIPMENT

includes :—

2-wire and 4-wire Voice - Frequency Repeaters

Carrier Terminal and Repeater Equipment

for use with cable or open-wire lines. An 8 ft. 6 in. bay accommodates a complete terminal affording four channels, in the frequency range below 30 Kc/s, plus a voice circuit. This equipment has all the facilities of the famous "Apparatus Carrier Telephone, 1 + 4 Mark II" which was supplied by us in large quantities to the Services. It is now being produced to meet the peace-time needs of civil administrations.

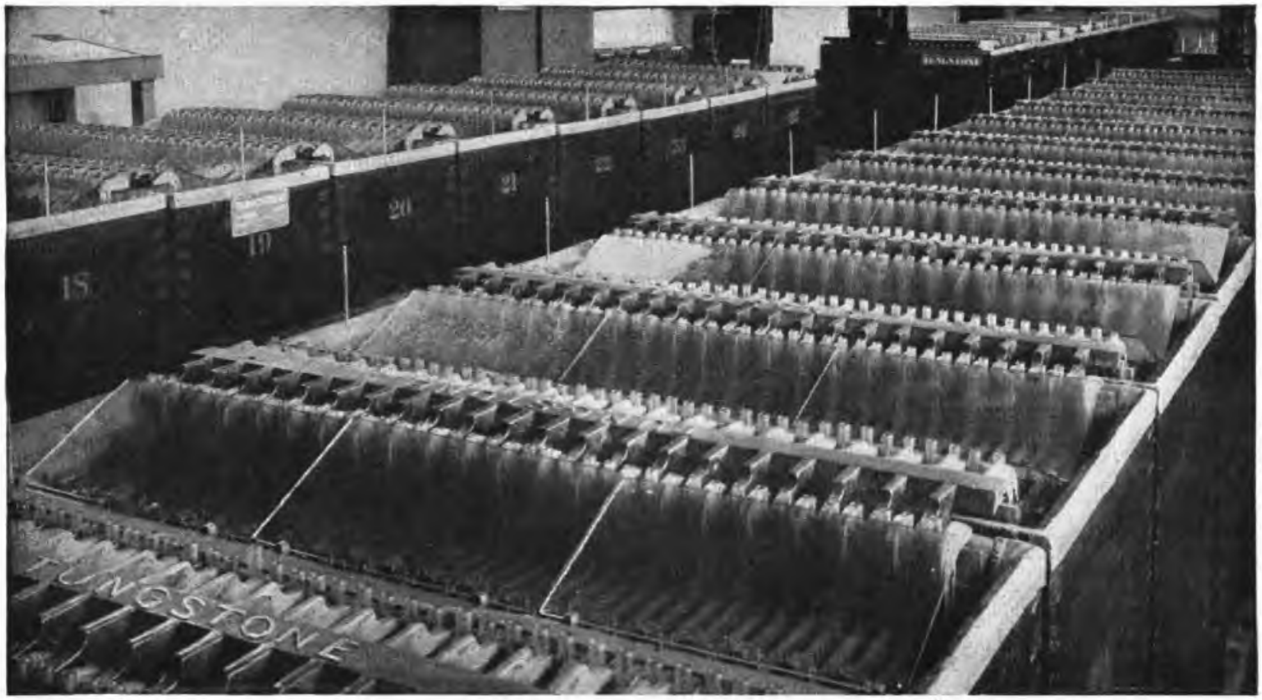
Multi-Channel A.C. Telegraph Equipment

for land lines, can be supplied for 6, 12 or 18 channels. Similar Equipment for Radio link Systems working on the 2-tone principle can be supplied as a 3-channel equipment.

Bay mounting equipment for 4-channel Carrier and one Voice Circuit

SIEMENS BROTHERS & CO., LIMITED
WOOLWICH · LONDON · S.E.18.

POWER BEHIND THE LINES



Tungstone Planté cells are being supplied to the British Post Office and to Posts and Telegraph departments abroad and conform fully to *G.P.O.* and *British Standard* specifications. Delivery is reasonable on all types and sizes.

Open type cells
Similar to the illustration above, 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 replatal of any size of existing Planté batteries.

Enclosed cells
Illustrated on the right, these are in sealed glass boxes, in capacities from 10 a.h. to 200 a.h., delivered in the U.K. filled and charged.

Technical Service
We are glad to advise on most suitable types and layouts for any installation and for any purpose.

Overseas Enquiries
Export customers are invited to cable or write their enquiries for batteries or parts. Visitors to London are welcome at our offices.

ENCLOSED TYPE CELL

TUNGSTONE *Batteries*

For further particulars write: **TUNGSTONE PRODUCTS LIMITED,**

St. Bride's House, Salisbury Square, London, E.C.4. Telephone: CENtral 8156 (4 lines.).

Cables: DILUTUM, London   Works: Market Harborough, Leicestershire.

TC1

NEW LONG SCALE MEGGER TESTERS

Trade Mark

★ NEW SCALE
Arranged to show effective length

The many users of Megger Insulation Testers throughout the world will appreciate the additional testing facilities provided by these new instruments.

Similar in appearance to the original Megger Testers in hard wood cases, each new instrument has two ranges and a twin scale with an effective scale length of 8½ inches. The megohm ranges are also greatly increased, the scales illustrated showing the comparison between the old and the new scale lengths on a 1000 volt instrument.

For particulars write for leaflet 051/1

NEW RANGES:—

500 volts 0-10,000 megohms
1000 volts 0-20,000 megohms
2500 volts 0-50,000 megohms

5/110 b

EVERSHED & VIGNOLES LIMITED · LONDON W.4

TELEPHONE: CHISWICK 1370 · TELEGRAMS: MEGGER, CHISK, LONDON · CABLES: MEGGER, LONDON

Printed by SANDERS PHILLIPS & CO., LTD., The Baynard Press, Chryssell Road, London, S.W.9, and Published by BIRCH & WHITTINGTON (Prop. Darling & Co. (Epsom) Ltd.), Epsom, Surrey.