RA Roe Petersfield

THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

Vol. 47 JANUARY 1955 Part 4

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Price 2/6 net

THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

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Vol. 47 January 1955 Part 4

Programme Circuits on Cable Pairs Loaded at 500-Yard Intervals

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U.D.C. 621.372.221:621.395.97

This article gives a brief outline of the problems involved in providing programme-type circuits for the occasional outside broadcast and describes a method, now undergoing field trials, for providing suitable lightly loaded cable pairs. A feature of the scheme is the adoption of extensive building-out to overcome the effects of irregular spacing between the loading coils, thus avoiding the construction of additional jointing chambers.

INTRODUCTION

IN addition to the permanent network which has been set up for the transmission of programme material, good quality programme-type circuits are frequently required by the B.B.C. for outside broadcasts. These temporary circuits from the outside broadcast point to the B.B.C. premises are unidirectional circuits consisting of the local end from the outside broadcast point to the nearest exchange or repeater station, the main link section between the terminal exchanges or repeater stations and the local end to the B.B.C. premises.

The main link section generally consists of one or more unidirectional programme-type links, known as Occasional Programme (O.P.) Links. These links are set up between Post Office premises on routes where outside broadcasts are frequent enough to warrant them, and can easily be switched to form part of an Outside Broadcast (O.B.) Circuit. In addition the links may be used to augment the permanent programme circuit network or to make good, on a temporary basis, faulty permanent circuits. In the past these links have been provided on one or more of the following plants:—

(*a*) Screened pairs, unloaded or loaded.
(*b*) Unscreened pairs, unloaded or loaded.
(*c*) Phantoms on carrier cables.[1]
(*d*) Bunched loaded pairs (i.e. the unloaded phantom) where the side circuit loading is too heavy to obtain the required bandwidth.

Outside broadcasts will naturally vary widely in their location, from the large city with a dense telephone network to the remote country situation with a scarcity of line plant. Thus the circuits required will vary considerably in length, and to be able to provide them rapidly it is desirable that cable pairs with a suitably high cut-off frequency be available at every exchange and repeater station. The requirements for an outside broadcast from any one locality, however, may be frequent or occur only once, and this point must be taken into consideration when the question arises of making special provision against the possibility of a demand for a programme circuit. On most routes it would be uneconomical to provide cable pairs solely for outside broadcast use and consequently the circuits should be suitable for use as revenue-earning traffic circuits when not in use for programme purposes.

This article describes a method, now undergoing trial, for providing pairs with normal repeater station spacing (approximately 35 miles) which will be suitable for normal traffic circuits and for occasional programme circuits.

PERFORMANCE REQUIREMENTS

There are two C.C.I.F. specifications for programme circuits, the 1936 "International Broadcast Circuit" and the 1949 "Normal Broadcast Circuit", having effectively transmitted bands of 6,400 c/s and 10,000 c/s respectively. These limits have been agreed and, although plant provided to meet the 1936 specification cannot be completely upgraded, the following standard of performance has been adopted by the British Post Office for permanent programme circuits:—

(*a*) *Bandwidth.*—The minimum guaranteed band is 50-6,400 c/s but endeavour is made to provide a band of 50-8,500 c/s on all circuits and to reach the higher standard of 10,000 c/s on new cables.
(*b*) *Response.*—The variation with frequency referred to the 800 c/s value, after allowing for cable temperature, shall be, 100-8,500 c/s, ± 1 db.; 50-8,500 c/s, ± 2 db.; 50-10,000 c/s, ± 3 db.
(*c*) *Crosstalk.*—The near-end and far-end crosstalk between two programme circuits or between a programme circuit and a telephone circuit shall not be worse than 78 db.

TYPE OF CIRCUIT, LOADING AND SPACING

Permissible Circuits.

When setting up a link for an outside broadcast every endeavour is made to provide the specified performance requirements for a programme circuit. Owing to acoustic inferiorities, background noises, etc., at the outside broadcast point, however, the quality can but rarely equal that of a studio performance and hence some relaxation on the specified value of crosstalk may be permitted.

Permanent circuits are usually provided on unloaded or lightly loaded screened pairs or on the phantoms of 12- and 24-circuit carrier cables, but it would obviously not be economic, nor is it necessary with a relaxed crosstalk limit, to provide occasional programme circuits with these types of plant. Alternative methods of using the unscreened pairs normally available in any area, i.e., unloaded, bunched loaded, phantom working or lightly loaded pairs, must then be considered.

Objections to the use of unloaded unscreened pairs are that the circuits would be of construction entirely different

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[1] "Music Circuits on the Phantoms of 12- and 24-circuit Carrier Cables." H. J. Marchant and L. R. N. Mills. *P.O.E.E.J.*, Vol. 42, p. 124.

from the other circuits in the cable and it would be necessary to limit repeater section lengths to 12 miles to avoid excessive noise. The level difference between the unloaded and the loaded pairs would result in a near-end crosstalk value well below the C.C.I.F. recommendation. Bunched loaded pairs, being virtually unloaded, suffer from similar objections.

The objections to phantom working on audio cables are mainly due to excessive noise and to the attenuation (approximately 3·5 db. per mile at 8,000 c/s for an unloaded phantom on 20/88/1·136 pairs), which prohibit their use.

The remaining alternative of employing lightly loaded pairs offers the best solution.

Permissible Loading.

To maintain a satisfactory signal level the overall loss at 800 c/s of unamplified links for outside broadcasts, when routed entirely on loaded or unloaded underground cable pairs, should not exceed 12 db., and this limits their use to short-distance local links.

With amplified links on loaded cable, the type of loading permissible is dependent not only upon the bandwidth required but also on the maximum spacing between amplifiers. The spacing between amplifiers is in turn determined by the amplifier gain and the permissible crosstalk. Crosstalk limits the spacing to a cable loss of 22 db. between amplifiers for the normal trunk and junction circuit and this spacing must, therefore, be taken into consideration if the programme link is to be also suitable for normal traffic use.

From an examination of the performance to be expected from various types of loading (examples of a few are shown in Table 1), it appears that suitable cable pairs can be

TABLE 1

Performance Expected from Various Loadings

Loading	Cut-off (Approx.)	Attenuation per mile		Amplifier Spacing	Objections
		1,000 c/s	8,500 c/s		
20/8/1·136	12,000 c/s	1·00 db.	1·14 db.	12 miles	Portable amplifiers required
20/16/1·136	8,700 c/s	0·76 db.	0·86 db. (at 6,500 c/s)	16 miles	Cut-off too low
20/16/0·568	12,500 c/s	0·59 db.	0·75 db.	22 miles	High attenuation
20/22/0·284	15,000 c/s	0·38 db.	0·60 db.	34 miles	—

provided by loading 20-lb. conductors with 22-mH coils at 500 yards spacing. This type of loading would allow single links, or links in tandem, suitable for wideband working and which, in addition, would have the same nominal attenuation over the normal speech frequency band as the associated speech circuits in the cable.

Loading Coil Spacing.

Loading coils are normally sited as nearly as possible at the correct spacing such that individual loading coil section lengths do not differ (*a*) from the average and (*b*) from an adjacent loading coil section by more than 1 per cent. Little difficulty is foreseen in siting coils at 500 yards intervals, within these limits, where a new duct line is to be provided for the cable. Where a new cable is to be provided in an existing duct track, however, or where a few pairs in an existing cable are to be reloaded for programme work, regular spacing cannot be obtained without the construction of a large number of new jointing chambers. This could not be justified merely for the insertion of a few coils, usually four, at the correct spacing.

For 500 yard spacing to be economical it is thus desirable that every fourth coil should be at the main loading points for the cable concerned and the remaining coils be inserted at the nearest available joint to the 500 yard points, so avoiding the construction of additional jointing chambers. Under these conditions, however, the spacing would vary considerably from the nominal 500 yards—up to 70 yards in normal circumstances, with occasional larger variations. One of the effects of this irregular spacing is a reduction of the effective frequency band.

As seen from Table 1, 20-lb. conductors loaded with 22-mH coils accurately spaced at intervals of 500 yards would provide circuits having a cut-off of approximately 15,000 c/s, which is far higher than that required for broadcasts, so that a wider tolerance in the spacing can be considered provided the frequency characteristics remain reasonably free from irregularity.

IMPROVEMENT OF IMPEDANCE/FREQUENCY CHARACTERISTIC BY BUILDING-OUT

Difficulties in setting up and maintaining circuits are inevitable when the frequency characteristic is irregular, and the B.B.C. is particularly concerned with the maintenance of a smooth frequency response. This is to avoid "rolls" in the characteristic which may be additive when links are used in tandem.

Humps or irregular variations in the insertion loss/frequency characteristic and in the impedance/frequency characteristic curves of a cable are caused by a proportion of the power sent into the cable being reflected back from some point or points along the circuit at which one or more of the primary constants (*R*, *L*, *G* or *C*) of the circuit are not uniformly distributed with length.

To ensure that the primary constants are uniformly distributed the specification for a cable system demands that the impedance/frequency characteristic of each cable pair shall not differ by more than a certain percentage (usually 5 per cent.) from a smooth mean curve drawn through the actual characteristic of the same pair. Whilst direct correlation between the deviations of the impedance/frequency characteristic and the insertion loss characteristic is not possible (since the effect of a cable irregularity near the centre of the cable on the impedance characteristic is less than that of an irregularity near the termination) it is generally recognised that the impedance/frequency characteristic is the best guide to the electrical uniformity of a cable.

With modern coil-loaded cable the length distribution of *R*, *L* and *G* is normally as uniform as is practicably possible but, whilst the capacitance requirements are secured almost entirely in the manufacturing stage, a further equalisation of the capacitance can be obtained during the laying of the cable, with the object of ensuring that the mean capacitance of any individual loading coil section does not differ from the average mean capacitance by more than 2 per cent., nor from the mean capacitance of an adjacent loading coil section by more than 3 per cent.

If, however, the loading coil section lengths vary considerably, as envisaged with 500 yards spacing, normal balancing will have little effect. The mean capacitance of the circuits in a loading section cannot be altered by the usual crossing of quads or pairs and only a minor reduction of length deviation can be achieved by the grading of factory lengths. Further reduction of length deviation of capacitance can only be obtained by the provision of building-out networks, i.e. capacitors for artificially increasing the mutual capacitance of the circuits.

Building-out.

Fig. 1 shows the impedance/frequency characteristic curves of a cable pair loaded with 22-mH coils at the joints nearest to the 500 yard points. It will be appreciated that, before building-out, the circuit is unsuitable for programme working. The fluctuations in the characteristic

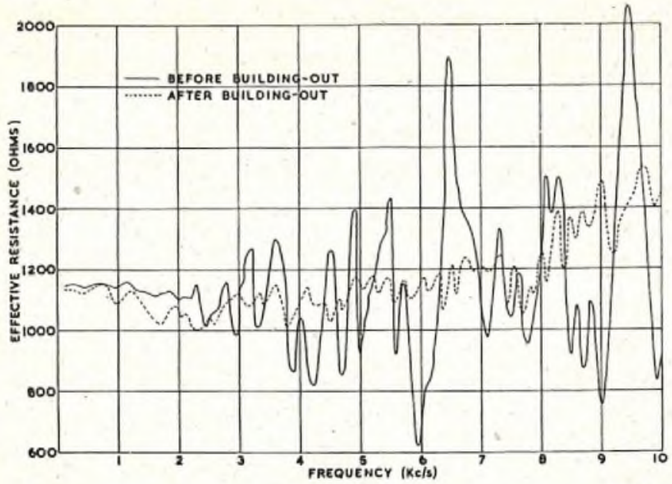

FIG. 1.—IMPEDANCE/FREQUENCY CHARACTERISTIC OF CABLE PAIR LOADED WITH 22-MH AT APPROXIMATELY 500 YARDS.

curves were caused by the unequal capacitances of the irregular loading coil sections which varied between 430 and 577 yards. These capacitances can only be equalised by the adoption of building-out networks.

Field trials have proved that to meet the requirements of occasional broadcasts, with this type of loading, it is not necessary to employ full building-out such that individual sections do not differ by more than a fixed percentage from either the length of the longest section or the section with the largest capacitance value. Satisfactory circuits may be obtained using a system of "graded" building-out between the short and long sections such that any individual section does not differ from its adjacent sections by more than the equivalent of 10 yards of cable.

Two methods of "graded" building-out may be employed:

(*a*) by building out the capacitance of an individual section so that it does not differ from the values of adjacent sections by more than the capacitance equivalent to 10 yards of cable, or

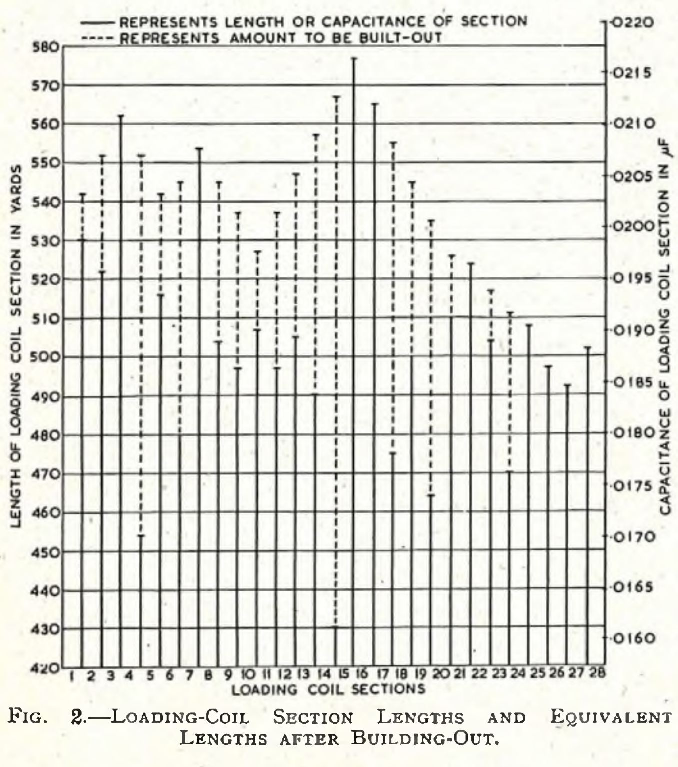

FIG. 2.—LOADING-COIL SECTION LENGTHS AND EQUIVALENT LENGTHS AFTER BUILDING-OUT.

(*b*) by building out the length of an individual section, with a capacitor value, so that its equivalent length does not differ from the equivalent length of adjacent sections by more than 10 yards of cable.

The amount of capacitance to be added to the individual sections can be calculated, or determined graphically from measured capacitance values or measured lengths of cable. The pillargraph method shown in Fig. 2 provides a pictorial display of the spacing of the coils in a typical scheme and forms a ready means for determining the additional capacitance required, by either of the methods, to give a gradual increase in equivalent length between the short and long sections.

Of the two methods, (*a*) is technically the more sound as it also corrects for any deviations in the capacitance values of the cable. Its adoption, however, would cause delays in installation, it being necessary to await the complete laying of the cable and measurement of capacitance values before estimating the building-out required. Method (*b*) has, therefore, been adopted for future trials.

INTER-CONNECTION OF LINKS AND LOCAL ENDS

Treatment of End Sections.

To reduce to a minimum the fault liability and the time taken in setting-up occasional circuits, it is necessary to restrict the use of amplifiers, line matching transformers and matching networks to the least number possible. It is thus normal practice to make a connection between a short unloaded local end and the loaded programme link at the end near to the outside broadcast point with transformers only. The mismatch introduced at such a junction will produce slight irregularities in the insertion loss/frequency characteristic, but these can usually be tolerated provided there are no other irregularities in the circuit.

To avoid the introduction of further irregularities when programme links are worked in tandem by direct extension of cable pairs, it is desirable that the end sections at the junction of the links should be true half-coil or half-section terminations. When, however, it is necessary to employ an amplifier at the junction of the links the actual end sections may be extended, up to 50 yards, by the internal cabling between the cable ends and the amplifier. The capacitance of this internal cabling may, therefore, be an appreciable percentage of the capacitance of a nominal 500 yard loading coil section and may completely upset a half-coil termination. For this reason it has been decided that half-sections shall be regarded as the standard termination for all occasional programme links.

Whenever possible the end sections should be less than 50 per cent. of the adjacent full section as this will permit the fitting of matching networks at the repeater station, when necessary, to provide true half-sections, due allowance being made for the capacitance of the internal cable. In the case where the actual end section is 50 per cent. or more of the adjacent full section it may be built-out to form a full section and a coil inserted in the first convenient cable joint from the termination; alternatively it may be built-out as required by a matching network in the repeater station.

The design of suitable matching networks is in hand and it is expected that these will take the form of a 51-type apparatus can which will be fitted at some convenient point between the cable termination and the programme jumper field.

Transformers.

In order to minimise the terminal reflections at amplifier points it is necessary to employ a terminating impedance which is substantially equal to that of the cable. 1,200 ohms has been found to provide a sufficiently close compromise over the complete frequency range and for this reason a new programme transformer (Transformer No. 204 HH) with a 2 : 1 impedance ratio has been introduced.

Equalisation

Trial equalisation of various cable lengths has shown that repeater sections of up to 20 miles in length present no difficulty, but with sections over 20 miles difficulties arise due to the steepness of the insertion loss characteristic with increasing length. It has been previously mentioned that 22-mH loading at 500-yard intervals permits a maximum spacing of 34 miles between amplifiers and as it is virtually impossible to equalise any greater length, unless the frequency range is curtailed, it appears that a repeater section of 34 miles can be regarded as the absolute maximum for this type of circuit.

Equalisation during the trials has been carried out in the following manner:—

Sections 20 Miles or Under.—Low-frequency equalisation was obtained using a parallel combination of resistance and capacitance between the centre points of the receive line transformer. Commencing with a capacitor of 2 μF, the resistor value was adjusted until the loss at 100 c/s was the same as that at 1,600 c/s. An adjustment of the capacitor value was then made to give similar losses at 500 and 1,600 c/s. By repeating this process, once or twice, values can be found which will give a low-frequency characteristic which is flat or falls smoothly by not more than 0·4 db. between 50 c/s and 2,000 c/s.

For high-frequency equalisation use was made of the constant impedance resonant-type equaliser[2] (Equaliser No. 7) designed by the usual techniques.

Sections Over 20 Miles.—At the lower frequencies a simple R-C network did not provide sufficient equalisation and it was necessary to employ a combination of R-C network and constant impedance network. The selection of the correct values when using two networks to equalise the same section of the frequency range causes some difficulty and no easy rules have been formulated.

At the higher frequencies a constant impedance resonant-type equaliser with a very steep characteristic is required. These equalisers can be designed by the usual methods, but it is probable that, owing to the steepness of the curves, the normal equaliser component tolerances will necessitate some measure of individual adjustment in addition to the normal design procedure.

To obtain satisfactory overall equalisation it has been necessary to extend the range of Equaliser No. 7 by the introduction of the following units:—

Unit No. 7H	288 and 408 mH	0·8 and 1·1312 μF
Unit No. 7J	1·13 and 1·6 mH	0·00315 and 0·00445 μF
Unit No. 7K	0·56 and 0·8 mH	0·00157 and 0·00222 μF

The 7H unit is required for L.F. correction, and the 7J and 7K units enable equalisers with very steep slopes to be constructed.

Field Trials

The following cable systems were chosen for field trials of the method of building-out loading coil sections on various types of cable:—

Exeter-Torquay No. 5	20 lb. pairs.
Taunton-Weston-Super-Mare No. 1	40 lb. screened pairs.
Chester-Colwyn Bay No. 2	40 lb. screened pairs.
Bridlington-Hull No. 3	20 lb. pairs.

In all cases good-quality circuits were obtained and typical curves of the frequency response are shown in Fig. **3** for a 20-lb. pair loaded with 22-mH coils at a nominal 500 yards spacing.

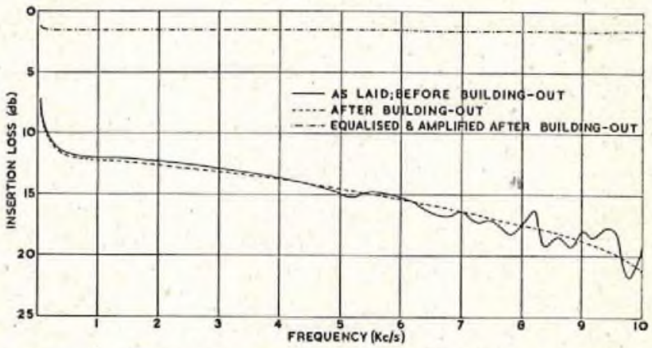

Fig. **3**.—Insertion Loss/Frequency Characteristics of Loaded Pairs, 20/22/0·284.

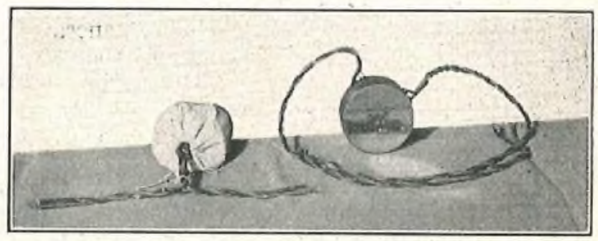

Fig. **4**.—Typical "Unicoil".

Fig. **5**.—"Unicoils" and Building-Out Capacitors inserted in Cable Joint.

The problem of installing the loading coils and building-out capacitors was eased by the adoption of canister loading, later superseded by the "Unicoil", i.e. an individual coil enclosed in a screening container and having flexible lead-out connections. A typical coil is shown in Fig. **4**. Each coil is enclosed in a linen bag which also forms a convenient point to house the capacitor. This enables the coils and capacitors to be inserted into the normal cable joint nearest to the 500 yard point, as shown in Fig. **5**, thus avoiding the construction of additional jointing chambers.

The fitting of the building-out capacitors has been carried out by Regional Staff after the acceptance of the cable from the cabling contractor. Similar trials are now being undertaken by the contractors, on certain new routes, as part of the normal installation work.

Conclusions

22-mH loading at a nominal spacing of 500 yards on suitably built-out 20-lb. conductors offers a ready means of providing good-quality circuits for the transmission of outside broadcast programme material. In addition the circuits, having the same attenuation over the normal speech frequency range as the associated speech circuits in the cable, are suitable for use as traffic circuits when not in use for occasional programme purposes.

Acknowledgments

The authors are grateful for the advice and help given by their colleagues in the preparation of this article.

[2] "Constant Impedance Equalisers: Simplified Method of Design and Standardisation." F. Pyrah. *P.O.E.E.J.*, Vol. 32, p. 204.

Experimental Electronic Director —Field Trial Results

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U.D.C. 621.395.34:621.318.572

A previous article[1] described the development of the experimental electronic director up to the stage of its preparation for a field trial. The present article places on record some of the results and experiences gained from two years' continuous trial of this electronic equipment in a public automatic telephone exchange.

Introduction

THE principal objective of the field trial was to discover how electronic switching equipment would behave under the practical conditions of continuous 24-hour service in telephone exchanges. This information was required as there is no comparable experience on which to draw; although the switching equipment uses many components identical with those used in radio and transmission equipment, these components are often used in a different way and the various tolerances in the limits of their performances have a different significance.

The six experimental electronic registers and their common translator constructed in the laboratory were installed at Richmond (London) telephone exchange in December, 1951, and, after engineering tests, they were brought into public service (during the normal hours of engineering attendance) in March, 1952, and into full 24-hour public service on 1st May, 1952.

As explained in the previous article, the electronic directors were designed to imitate precisely the facilities of the present standard two-digit directors. This enabled the six electronic registers to replace the existing six electro-mechanical directors on level five of the A-digit selector, where they handle all the calls starting with J, K, or L as the first code digit. Because the electronic equipment has been arranged to busy itself under fault conditions, four of the electro-mechanical directors were wired into the last four choices of the level and are thus able to take over from the electronic registers in the event of failure. This would give partial service in the event of complete failure during the busy hour, but an alarm would indicate such a failure and arrangements have been made so that two more electro-mechanical directors can be cut in.

The equipment, which is essentially of an experimental nature, was designed so that many of the circuit elements were working with small margins; in fact, it can be shown that, if all the components, etc., are near their specified limits, most of the elements will not function. By deliberately taking this liberty in the design, it was possible to adopt simpler circuit elements than would otherwise have been the case; and because of the narrow margins it was expected to discover more quickly the behaviour of components under a variety of operating conditions by provoking faults as soon as components started to drift, without the necessity for continually checking every component. Another reason for designing the equipment in this manner was that it resulted in a considerable saving in the number of components used, which in itself can reduce the overall fault rate of the equipment.

It should be noted that the complete suite of racks, shown in the photograph (Fig. 1), is mounted on rubber. This was done for two reasons: one, to give electrical isolation to the equipment and so prevent spurious earths and earth surges from affecting the circuits; the other was to give mechanical isolation from the rest of the exchange and so prevent soldered joints, components or valves from being damaged by continuous vibration.

It is not possible in a short article to do more than touch on the many problems involved and the experience gained on the introduction of such a new type of switching equipment into a telephone exchange. It is hoped, however, that the salient points mentioned will convey at least a general picture.

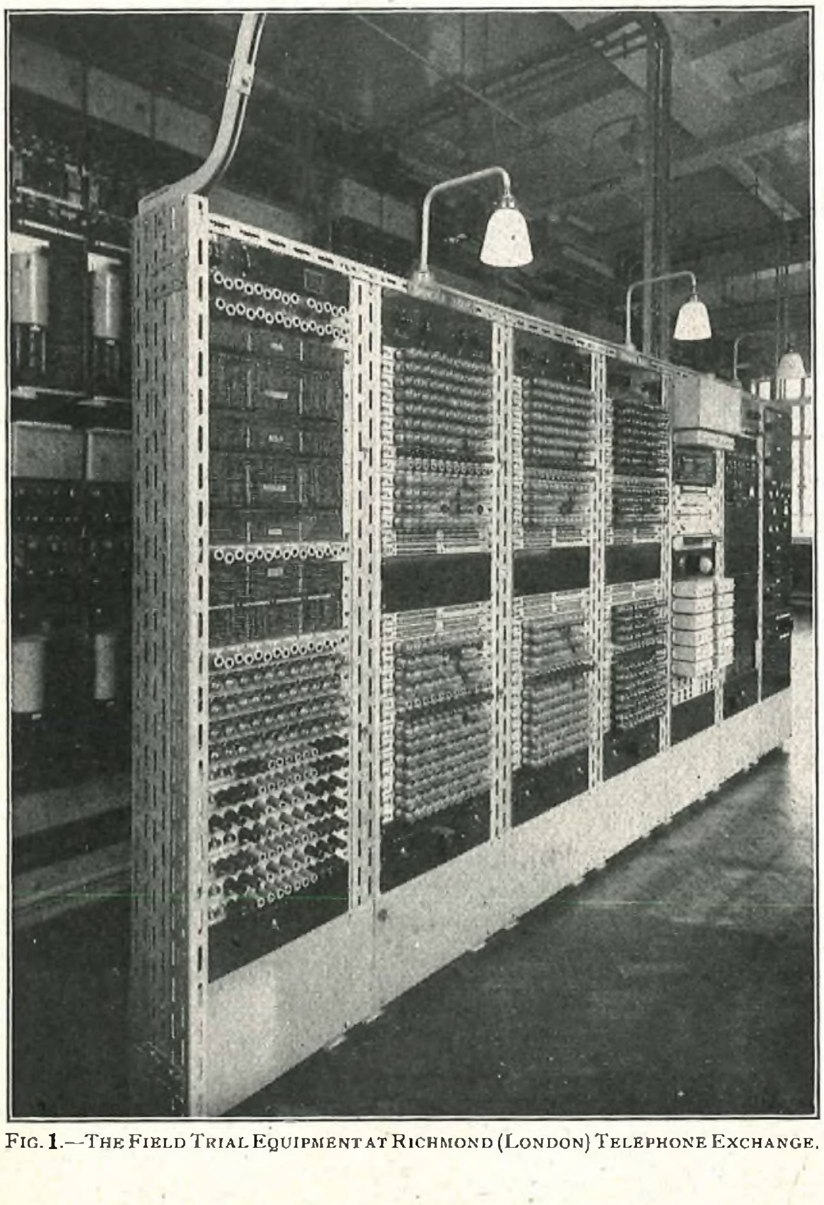

FIG. 1.—THE FIELD TRIAL EQUIPMENT AT RICHMOND (LONDON) TELEPHONE EXCHANGE.

† The authors are, respectively, Executive Engineer and Assistant Engineer, Telephone Development and Maintenance Branch, E.-in-C.'s Office.

[1] "An Experimental Electronic Director," K. M. Heron, H. Baker, and D. L. Benson, *P.O.E.E.J.*, Vol. 44, p. 97 and p. 169.

porting and Investigation of Faults.

By arrangement with the London Telecommunications Region and the South-West Area of this Region, the maintenance of the equipment has been undertaken by the local staff in conjunction with their normal maintenance duties on electro-mechanical equipment. Some of these men were trained by the designers of the equipment during its construction and initial testing, while others were later given a shorter period of training partly in the laboratory, and partly on the field trial equipment itself.

Close liaison between the maintenance staff and the circuit designers has been possible and has proved very valuable, both to the designers, who have been able to study intimately the maintenance problems presented by the new switching technique, and to the maintenance officers, who had direct access to technical information and advice about the circuits.

In the training of maintenance officers, and subsequently in the field, stress was laid on the desirability of not only clearing faults, but also of locating and verifying the actual component giving rise to the trouble and, with the full co-operation given, the creditable performance was achieved that in only two out of a total of 118 cases was it found impossible to give a specific clear to a fault. These two faults were both reported by subscribers as cases of "wrong number"; one cleared itself while being localised, but the other was never observed despite every effort to provoke it, and neither has been reported since.

It should be noted that some faults took many weeks to clear; typical of this type were intermittent contacts and dry joints. In these the fault disappeared as soon as the equipment was touched, and, therefore, could not be located at the time. It was found, however, that if the equipment was left working, without further interference, the fault re-appeared, often several weeks later, at which stage it was usually possible to localise the fault because it had become more persistent and because the type of fault was already known.

The procedure adopted for faulting the equipment follows this general pattern:—

(*a*) The mal-functioning of the equipment is usually first indicated by the failure of a test call (six being made per day over each register, automatically).

(*b*) By arranging for the tester to repeat the test call while studying the visual pattern of the glowing tubes, the particular circuit element functioning incorrectly then becomes apparent.

(*c*) By being able to make the circuit repeat this particular function, or make repeated attempts at the function, the failure can be studied further with the aid of a voltmeter or an oscilloscope. This procedure enables the actual fault to be pin-pointed and verified fairly readily, and also discourages the tendency to change tubes and valves indiscriminately in the hope of clearing the fault.

Concerning (*c*), it must be admitted that a change of valve often removed or masked the symptoms of the fault because of the different characteristics of the new valve, or because a dry-joint was made to conduct again. Experience has shown the fallacy and inefficiency of this method. The original fault usually appeared again within a short time, which varied between a period of a few hours and one of several days, and therefore the fault still needed to be located and removed. Fault records also show that on this equipment, during the second year of the trial, only about one in three of the faults could be attributed to valves.

Detailed fault records and test results have been kept locally and the information passed regularly to the Telephone Branch of the Engineering Department, where it has been studied. If it was considered necessary, further tests were carried out by the local staff, under guidance, or the faulty components were returned to the laboratory for further investigation.

Routine Testing.

During the first year the cold-cathode tubes and valves in Registers 1, 3, 4, 5 and 6 were removed every six weeks from the equipment, their characteristics checked by a simple tester and the results recorded. These tests were stopped at the end of the first year as sufficient information had been obtained on this aspect and because it was desired to study the behaviour of this type of equipment when left undisturbed except for the minimum attention necessary to clear faults. Thus, during the second year the only attention given to the registers was to subject them to simple functional tests automatically, and clear any faults with a minimum of disturbance.

The functional tester merely passes a test number into a register and checks that a correct number is sent out; it does not make any limit tests on performance. In the normal way each register is tested only about six times a day, but even so the functional tester has revealed the presence of all but three of the total of 118 faults.

Aids to Maintenance.

Because of the large number of tubes and components in each register and the translator—there being over 200 valves and tubes and 1,000 resistors, capacitors, etc.—the circuit diagrams showing the complete circuit became too large and complicated to be handled conveniently or to be understood readily. Thus, during the design of this equipment the circuit was successfully divided among a number of foolscap sheets in such a way that each sheet represented a complete functional element, for example, a storage counter, incoming distributor, or outgoing distributor, sender, etc., each containing about 12 valves or tubes.

Care was also taken in the layout of the equipment to take advantage of the glow of cold-cathode tubes to give the maintenance officer a readily understood pattern of the glowing tubes. It was also found possible to arrange that all the circuits appearing on a sheet of the diagram represented all the apparatus mounted on one tray of the equipment. It should be mentioned, however, that although the requirements of an easily understood circuit diagram and of a suitable equipment lay-out are not synonymous, with care each can be arranged to help the other.

The design also enables the circuit to be held at any particular stage, or to make repeated attempts at a function, facilities which prove very useful while faulting.

It has been found that with the aid of the functional tester and the visual pattern of the glowing tubes, a fault can, in general, be localised readily to the failure of one of the functions. The equipment performing this function is contained within one tray which can be withdrawn for inspection and testing, and only one foolscap diagram is needed for reference to circuit details. The valves on the diagram are numbered to correspond with their positions on the tray, which enables circuit elements to be located easily and, having reached this point, the individual valve electrodes or components or wires can be readily recognised by the colour coding system adopted, without the need for individual signwritten letter or figure coding.

The recognition of circuits and components is aided by the layout of the circuit diagram, where care has been taken in the grouping of components to form circuit elements and the grouping of these to form circuit functions, which is of great help in an understanding of the complete circuit; much in the same way as letters are grouped into words and then into sentences instead of being all strung together.

It has been found very useful to be able to adjust some of the supply voltages by a few per cent., as this often provoked a fault to occur regularly that had previously occurred only at rare intervals, or had merely been suspected, thereby enabling more rapid localisation to be carried out. By designing such a facility into certain parts of a circuit an overall marginal test could be carried out quite easily.

Difficulty was experienced at one stage in determining the state of a hot-valve circuit, for example, in trying to determine which valve of a trigger pair was conducting and which cut off, without disturbing the actual condition. It often happened that the mere application of a voltmeter or an oscilloscope was sufficient to upset the conditions so that the fault was lost for a time. However, it was found that the small cold cathode diodes (NT2 or CC3L) in series with a resistor of several megohms, could be used for testing purposes without disturbing the conditions. A detectable glow is given with a circuit drain of only a few microamps.

Analysis of Faults

An analysis of all the faults has been made to see if any firm correlation can be established between the many variables, e.g., type of fault, type of component, how used, where mounted, temperature, illumination, type of circuit, frequency of use, how handled, etc. From the statistics so produced, the following results and observations appear the most reliable.

Fig. 2 shows the faults recorded each month (four weeks)

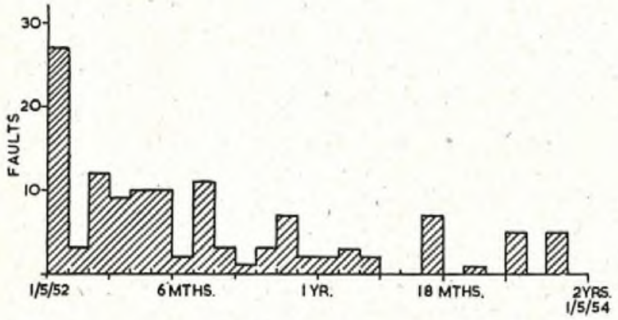

Fig. 2.—Graph Showing Variation in Four-Weekly Fault Totals.

over the whole period for the complete installation. It indicates how the numbers of faults have gradually dropped, and how the fault-free periods have gradually become longer. During the first year the maximum fault-free period was only three weeks, and this occurred twice, but during the second year there were fault-free periods of nine weeks, six weeks, and two of five weeks duration.

Although it has not been possible to prove on this equipment that one fault, or the clearing of it, is the cause of another, there is a definite tendency for faults to group themselves together in time.

It has been found that if faults separated from each other by less than a week are grouped together, they indicate this tendency. Thus, the average number of faults occurring in these groups during the second year was 3·5 with a maximum of 7.

It is suggested that the interference necessary to clear a fault, whilst not being the primary cause of another fault, does at least precipitate it, instead of leaving it to occur in its own time at a later stage. Examples of this are valve heaters, components or joints subsequently becoming faulty or disconnected, not necessarily on the tray of equipment withdrawn for faulting, but often on adjacent trays that had not been subject to gross interference. This grouping of the results does indicate, therefore, that interference with the equipment produces a greater fault rate, because components, etc., need to be replaced sooner than would otherwise be the case.

TABLE 1

Number of Faults on Each Equipment During Successive Six-monthly Periods

Periods (6 monthly)	1-6	7-12	13-18	19-24
Register 1 ..	19	6	—	2
Register 2 ..	—	1	—	1
Register 3 ..	15	3	1	1
Register 4 ..	8	4	1	1
Register 5 ..	9	6	1	1
Register 6 ..	7	4	2	1
Translator ..	8	—	4	3
Power Equipment	2	1	5	1

Table 1 shows how the faults have ranged over the whole of the equipment. It should be noted that neither register 2 nor the common translator were subjected to the regular six-weekly check of tube and valve performance which was applied to the remaining five registers during the first year, so these two equipments were only touched when clearing faults. To prevent any wrong conclusions being drawn from the very good performance of register 2 and the common translator (which contains about twice as much equipment as a register) it should be mentioned that this register had been used for demonstration and experimental purposes in the laboratory for about a year, while the translator had been used for about two years in the same way prior to installation at Richmond. Most of the original valves and all but two or three of the original components in these equipments are still in service. Thus, it appears that by the time this field trial started these equipments had got over their teething troubles and unstable components had already been replaced.

TABLE 2

Component Fault Analysis

Item	Number of Components in Installation	Faults per Thousand per Annum, based on:—			
		1st Year		2nd Year	
		Weeks 1-26	Weeks 27-52	Weeks 1-26	Weeks 27-52
Hot Valves	282	43	36 (21)	28 (21)	28
Cold-Cathode Triodes	750	67	21 (0)	—	5·3 (2·6)
Cold-Cathode Diodes	932	21	2·1	—	2·1
Resistors	5,300	0·7	—	0·4	—
Capacitors	2,700	2·9	2·2	0·7	—
Rectifiers	342	35	—	6	12
Valve Holders ..	1,050	8	—	—	—
Tags	15,000	—	—	—	—
Soldered Joints ..	35,000	0·4	—	0·2	0·06

(Figures in brackets exclude mechanical failures due to handling)

Table 2 gives an analysis of the faults against types of component and the results are given in the form of "Number of faults per thousand components per annum." These rates of failure are derived from the actual faults recorded against each type of component during each of the four six-monthly periods since the start of the trial. The results have been set out in this way to demonstrate how consistently some types of component fail, and how for other components it appears that the unstable samples are gradually being eliminated. The results also indicate that so far there has been no tendency for the fault rate of any component to worsen as the trial proceeds, although many of the components are now more than five years old.

This table also gives the quantities of each general kind of component in the installation, and the results indicate that these numbers are only just about large enough to give satisfactory indications as to their behaviour. It has not therefore been possible to split the general types of components (resistors, valves, etc.) into their individual types (carbon rod, high stability, wattage, tolerance, etc.) as the numbers become too small for the results to be statistically reliable. Tendencies have been observed, however, and these are brought out later in the article in the comments under their several sub-headings of types of component.

In Table 3 the faults have been analysed into causes of failure of the various types of component to illustrate how variable and diverse they are.

TABLE 3
Analysis of Faults into Types

Component	Number of Failures		Cause of Failure	Comments
	1st Year	2nd Year		
Hot Valves ..	3	1	Cracked bases and broken pins.	Considered due to handling.
	3	2	Heater disconnected.	
	5	3	Low emission.	
	—	1	Suppressor cut-off failure.	
	—	1	Grid-cathode contact.	
Cold-Cathode Triodes	8	1	Disconnected and short-circuit electrodes.	Considered due to handling.
	24	1	High striking voltage.	
	1	—	High stabilising voltage.	
Cold-Cathode Diodes	10	1	High strike (NT2).	
	3	3	KD60 reference tube unstable.	Short life now recognised.
Resistors	2	—	Changed by more than 50%.	Type 16 carbon, faulty batch.
	—	1	Burnt out by fault conditions.	
Capacitors	5	—	Insulation less than 5 MΩ.	Standard metallised paper, 150v, 1 μF.
	2	1	Insulation less than 0·5 MΩ.	Miniature metallised paper.
Rectifiers	6	3	Low back impedance.	1/20D falling below 2 MΩ.
Valveholders ..	1	—	Failure to grip valve pins.	B7G old type.
	2	—	Broken-off mounting.	I.O. type.
Soldered Joints ..	2	2	Dry joint.	Apparently good joint.
	3	2	Broken wire or joint.	Handling.
	2	—	Bad soldering.	
Working Party ..	1	—	Tube replaced in wrong holder.	
	1	—	Relay incorrectly adjusted.	
Miscellaneous ..	3	—	RWT.	2 recurred and were cleared.
	2	—	CWL.	1 recurred and was cleared.
	1	—	Broken wire in form.	
	2	—	Relay cover jamming wires.	
	1	—	6·3V lamp disconnected.	
	—	1	Int. fuse holder connection.	Followed severe interference to supplies by working party.
	—	1	C.V. transformer (6V) failure.	
Totals	93	25		

Further comments on these results are given under the various sub-headings of types of component or aspect being studied, and the remainder of this article is devoted to this more detailed study.

Performance of Components and Connections

Hot Valves.

The performance of the hot valves is particularly encouraging, their overall failure rate being less than 3 per cent. per annum. This figure has been maintained very consistently throughout the trial, as will be seen from the results for each six months, given in Table 2. Most of the valves had already had about 8,000 hours life before the start of the trial, so by the end of the second year it is considered that the majority of the valves had seen upwards of 24,000 hours service. All the hard valves are of the miniature type and the majority are of the B7G type (CV 133, 136, 138, 858 and 491), and all have shown similar failure rates.

It is considered that this very good performance of hot valves is attributable to three distinct aspects of the way in which these valves are used; the first is that the valves in general are not required to work to their limits of emission or dissipation; secondly, they are used in switching circuits with generally wide margins of control and operation as compared with amplifying circuits; and thirdly, they are left running continuously with their heaters supplied from constant voltage transformers. This method of supply has a further advantage in that the transformers are arranged to act as current limiters when switching on so as to prevent the heaters from being damaged by the excessive current which is normally taken by the heater elements at this stage. These starting currents may often be four or five times as large as the correct running current, and this may well account for the performance of some electronic computors containing several thousand valves, which have failure rates of 0·5 per cent. of the valves whenever the equipment is switched on.

One type of valve does appear to be suffering from a disproportionate failure rate, but this is undoubtedly caused by the more exacting requirements of the particular circuits in which it is being used. These circuits require, under certain conditions, about 90 per cent. of the normal emission available from the valve at the onset of grid current, and any falling off in emission may give rise to faulty operation of the equipment. The majority of the valves are only called upon to give a maximum current of between 10 per cent. and 50 per cent. of that available.

It is of interest to note that in an electronic computor containing nearly 3,000 hot valves, but using circuits more akin to transmission techniques than the experimental directors, the average valve life has been stated to be only 8-10,000 hours, which is only about one year of continuous service, and so would represent a failure rate of 100 per cent. per annum.

Cold-Cathode Triodes.

The performance of the cold-cathode triodes during the first six months was very disappointing, as it was observed that they were drifting outside their specified limits at a rate of 7 per cent. per annum. However, since then their performance has improved considerably and their failure rate is now only about 1 per cent. per annum.

From the records taken of the behaviour of the tube characteristics it can be shown that during the first six months of the trial the striking voltage of the cold-cathode triodes (CV413) rose by 4-5 volts in general, so that those tubes with striking voltages already near their upper limit (80V) tended to go outside and were then replaced (it was known that some of the circuits were very liable to fail if the striking voltage went more than about 4V outside the limits).

During the second period of six months, it was observed that the striking voltage dropped by 5-6 volts in general, so that those near the lower end approached the lower limit (60V) at a rate such that it appeared that many would soon drift outside. However, towards the end of this period, the striking voltages had ceased to move very much (maybe they were on the point of increasing again) and it was considered unlikely that many would in fact go outside the lower limit.

It was at this stage that the decision was taken to stop the six-weekly tests, firstly because of the damage to the tubes and valves caused by this excessive handling, secondly because the behaviour of the tubes had improved sufficiently, and thirdly to enable the next stage of the field trial to begin, namely, the study of the behaviour of the electronic equipment when left undisturbed.

Those tubes that had drifted outside the specified limits and had been rejected, were subjected to continuous operation in a stepping circuit similar to those used in the field, and it was found that for over half of them (17) the striking voltage returned to within the specified limits and did not again drift outside, while for a number of the remainder it stayed only just outside.

These results indicate that longer preliminary ageing runs, probably of several hundred hours, could be advantageous on this type of tube, as it would enable those tubes likely to give rise to failures to be eliminated.

The results of the tests made on the CC2R type of cold-cathode tube showed that their characteristics did not have the same tendency to drift even at the beginning of the trial. Only two gave rise to faults and were changed, out of a total of 230 used in the installation. They were both changed in the first two weeks, one because the striking voltage was too high, and the other because the stabilise voltage was too low. A third was broken in one of the periodic six-weekly tests.

Cold-Cathode Diodes.

When this circuit was being designed there were no specified limits for the strike and stabilise voltages for the small cold-cathode tubes as they were at that stage being manufactured as indicators. However, tests on several hundreds indicated that they had a very consistent performance and would be suitable for use in gate circuits. Tentative limits were chosen from these results and were used for design purposes. These limits were 65-75V for striking voltage, and 60-70V for stabilise voltage. When a fault on the equipment has occurred and has been traced as being caused by a diode having a striking voltage outside the limits, the tube has been changed and a fault recorded against the diodes. All the diodes which gave rise to faults were changed because of their high striking voltage, but it is not possible to say that the fault was caused by a drift of striking voltage or a drift in other components, as there are no records of the individual striking voltages for each tube. The present limits for design for this type of tube would be at least 60-80V, in which case there would have been only about two tubes which would have been regarded as faulty, instead of eleven.

The KD60 reference tube used in the power supply has had to be replaced regularly. Thus, five tubes out of the six rejected gave a life of between 3,000 and 4,000 hours and the sixth was changed after 1,200 hours as it was becoming erratic. Generally the stabilising voltage remained very steady and constant at 62·5V for about 3,500 hours, then began to rise at about a volt every hundred hours, when it was rejected.

These tubes are run continuously at about 1·5mA which was the original specified value, but the makers now recommend 0·5mA as the steady running current, and thus obtain a very much longer life for the tube.

Resistors.

The 5,300 resistors have given very little trouble, although they are a fair mixture of all the thirteen standard values from 10,000 ohms to 1 megohm, with about ten having values between 2 and 10 megohms. They are also of various types, some being "carbon rod" and others being "high stability", in a mixture of ratings from $\frac{1}{8}$W to 1W, and with specified value tolerance limits from ± 5 per cent. to ± 20 per cent.

The use of the restricted range of standard values not only considerably reduced the numbers of individual components required in construction, but also reduces the stock to be held for maintenance.

Of the three resistors giving trouble, two were from a batch subsequently found to be generally faulty, and it is worth noting that others of the same type but of a different batch have not given any trouble. The third resistor was a $\frac{1}{2}$W type normally carrying about $\frac{1}{8}$W, which was burnt out under a fault condition.

All these faulty resistors were at least three years old and many were more than five, and it is recalled that during the early experimental work on this equipment a few other resistors were changed as they had drifted far outside their limits. It may be considered that the early experimental work constituted a preliminary ageing test of these components, enabling poor or unreliable individual items to be eliminated.

The continued good performance shown by these resistors may also be accounted for by the fact that the majority are working well within their specified limits of load, voltage, temperature and humidity.

Capacitors.

Capacitors in general have given little trouble in this installation, although there are 2,700 in use, mainly of the metallised paper type.

However, in one particular application a 1μF capacitor was subjected almost continuously to a voltage of about two-thirds its maximum rated voltage, and in six cases —once in each register in the same circuit element—the insulation resistance dropped from an initial value in excess of 100 megohms down to about 5 megohms, which caused a big change in the RC timing circuit. These capacitors were changed to some of the same type but having a higher working voltage, so that they were only called on to stand about one third of their rated value, and over the last 18 months no further trouble has been experienced from this circuit element. The possibility of a faulty batch must not be ruled out in this case, as there are many other capacitors, admittedly of lower values, which have continued to work satisfactorily under similar conditions.

Rectifiers.

Practically all the 340 rectifiers used in this equipment are the small copper oxide type (1/20 D) and they gave rise to a number of faults in certain circuit elements. In a particular circuit the rectifiers are subjected to a back voltage of about 2V per plate almost continuously, and it was found that their back resistance gradually dropped from the order of 20 megohms down to less than 2 megohms. This change in resistance was sufficient to alter the bias voltage on a valve and cause a fault in this particular circuit; but in other circuits such a change does not cause faulty operation. It is of interest to note that the copper-oxide rectifiers have behaved in an opposite sense to the selenium type which show a tendency to be deformed when subjected to their full forward current for long periods.

Twelve germanium point contact rectifiers are used in various parts of the equipment, but they have not given rise to any faults.

Valve-holders.

Except for the failure of three valve-holders early in the trial, no trouble has been experienced from this source. Two of the failures were of the International Octal chassis-mounting type, of which 750 are in use. In both cases the complete moulding was pulled out of its chassis mounting because of the very high pressure on the valve pins. The other fault was in a B7G holder giving an intermittent connection between socket and pin. This particular type of valve-holder has now been made obsolete, as a new type has been developed in which each pin socket is fully floating, and the method of making contact with the pins has been improved, so that even slightly bent pins will not cause permanent damage to valve holders, as was the case with the old pattern. However, about 100 of the old pattern are in use on the equipment, and 200 of the new type.

In order not to lose the very important facility of the floating sockets it is necessary to ensure that the wiring is suitably arranged. This often conflicts with the requirements of rapid wiring and appearance. The most usual error occurs in the heater connections on a strip of valves, where two straight lengths of wire are run down the back of the holders and soldered direct on to the tags. This inhibits movement of the valve-holder sockets, and so prevents them from taking their correct position when the valve is inserted, or when expansion takes place either in the valve or wiring. This results in the overstraining of the socket or pin and gives rise to bad connections between them.

As is mentioned later, two connections with valve-holders gave trouble; one was the connection between the wire and the valve tag, and the other was between a tag and a resistor, the other end of which was connected direct to a valve tag. In both cases it is suggested that the continual handling of the valves had fractured what, elsewhere, would have been a good joint.

If the hot valves should continue to show a statistical life of 30 years, as they are doing at present, then it becomes quite feasible to use wire-ended types and so dispense with these plug and socket connections which may never be withdrawn, and so merely represent an added expense and an increased fault liability. As has already been observed the plugs and sockets are not necessary for faulting.

Tags.

As far as is known no trouble has been caused by the very large number of tags, and although they are of very light construction they have not been damaged even as a result of changing a component, because wires are not wrapped round them or clinched onto them after being passed through the tag holes. Even so, tags often introduce an extra soldered joint into the equipment, which is simply another potential fault point, and it is thought that a mounting arrangement whereby the actual wire end of the component can be used as a tag would offer many advantages in the interim period before the use of printed circuit techniques.

Dust is now collecting very thickly on the components and tags, more especially on the high potential points, but although the gap between the tags is only about 1/16 in. no trouble has so far been found arising from low insulation. This quantity of dust would, no doubt, give trouble if the equipment were in a different type of building where a high humidity was likely, unless precautions were taken to keep the equipment warm. In any case, it can well become so objectionable when the equipment has to be handled for locating and clearing faults, that it would be advantageous to prevent dust reaching the components.

Soldered Joints.

During the first year there were seven faults attributed to soldered joints, but the majority were, on investigation, bad joints where the component wire or the tag had not been properly tinned or where the wire was held in a resin block. This number of dry joints was rather surprising as it was thought they had all been eliminated during the preceding engineering trials.

During the second year four faults occurred. One was caused by a wire being fractured at a tag during a demonstration, but the fault did not show up until later. Another was that a wire gradually worked loose from a tag by frequent handling. The remaining two were apparently good joints; the faults were cleared and did not recur when the joints were re-soldered.

No trouble has been experienced from faulty joints on those equipments where care had been taken during assembly to ensure that the wire on the component and the tag had been tinned separately before being joined together with the aid of a hot iron and a minimum of solder.

Although bad joints had apparently been eliminated by the end of the first year, it is considered that even with very good soldering enough troubles still remain to warrant considerable effort being spent with the object of reducing the total number of joints.

Conclusions

The field trial has proved, and continues to prove, a most valuable source of information. It has achieved the object of proving the reliability of certain types of electronic switching circuits and components and has demonstrated the practicability of using this type of equipment in telephone exchanges to give satisfactory continuous 24-hour service with a lower fault-rate than on the best electro-mechanical equipment.

It is of great interest to note how rarely the characteristics of these normal components (i.e., standard items made by the manufacturers of radio components) have drifted in such a way as to combine unfavourably to cause the circuit to fail. Also it will be seen that most of the faults in this trial have been caused by the complete failure of a component and not by a component drifting to its limits. In addition, from a practical point of view, there is a minimum fault rate that can only be bettered at a prohibitive cost as far as telephone exchange equipment is concerned.

The fact that such a high proportion of faults were actually located and given a specific clear could in part be attributed to the close liaison between the circuit designers and the maintenance staff, whereby technical information on the circuits and advice on their behaviour was readily available.

Acknowledgments

The authors wish to thank all the Regional and Area staff who have been involved in either the maintenance or installation of the trial equipment for their willing and helpful co-operation, which has contributed greatly to the success of the trial.

A Tester for the Measurement of Pulse Distortion in Automatic Telephone Systems

S. H. ILES†

U.D.C. 621.317.755:621.395.813:621.395.34

This article describes a measuring set suitable for checking the distortion introduced into signalling pulses, particularly those used in the Signalling System D.C. No. 2 in which loop disconnect pulses are converted to double-current pulses. A cathode ray tube is used as the measuring device, and the circuit arrangements are such that a circular trace is given, the length of which represents the "make" period of the contact under test. Two concentric circular traces are produced when testing changeover contacts.

Introduction

THE increasing demand for dialling over long distances with minimum distortion has created a need for equipment capable of measuring pulse distortion to close limits. The measuring set described in this article has been designed to measure distortion to a high order of accuracy and, in particular, to overcome the problems associated with testing relay sets of the Signalling System D.C. No. 2.[1]

To determine the signalling distortion introduced by a relay set it is usual to compare the pulse output with input, thus eliminating the effect of any inaccuracy in the speed and ratio of the pulse source. In the Signalling System D.C. No. 2, loop disconnect pulses are converted to double-current pulses in the outgoing relay set and vice versa in the incoming relay set. The tester here described is suitable for use with such relay sets, as it is capable of generating and measuring either type of pulses independently. A general view of the tester is given in Fig. **1**.

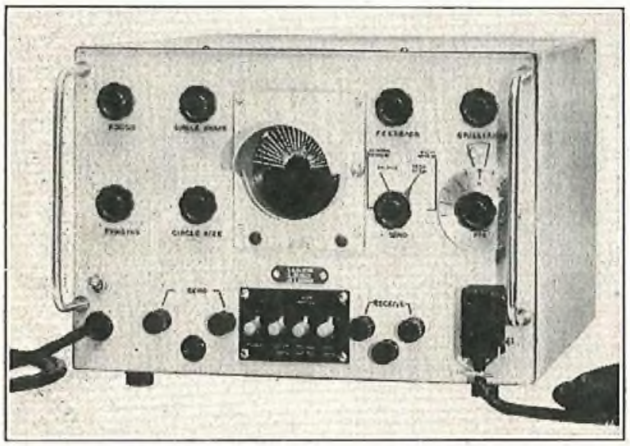

Fig. 1.—The Pulse Generator and Measuring Set.

Principle of the Measuring Set

Continuous pulsing is desirable while the pulse correctors associated with S.S.D.C. No. 2 equipment are being adjusted, and to provide simultaneous monitoring a cathode ray tube is employed as the measuring device. Balanced double-current and 50/50 per cent. break/make ratio pulses are used for this purpose, but a facility for the measurement of $66\frac{2}{3}/33\frac{1}{3}$ per cent. break/make ratio has been included in the set for overall testing of a circuit at normal subscribers' dial ratio.

The electron beam of the C.R.T. is controlled by a rotating electrostatic field to form a circular trace which, by modulation of the grid, can be visible or dark. The modulation is controlled by the contact under test so that the length of visible trace represents the make period of the contact.

The electrostatic field on the plates is caused to rotate twice during one complete pulse period (make and break); thus, a contact pulsing at 50 per cent. make shows on the screen as a complete circle.

For tests on changeover contacts each fixed spring is treated as a make contact, but one spring is made to increase the diameter of the circle to prevent the two displays being superimposed.

For $66\frac{2}{3}$ per cent. break ($33\frac{1}{3}$ per cent. make) pulses, provision is made for the field to rotate three times during one complete pulse period; thus, for distortionless pulses of this type one complete circle is again displayed by the make period.

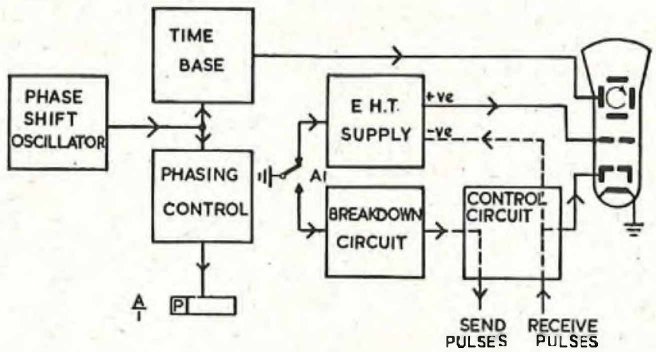

Fig. 2.—Circuit Elements of Distortion Tester.

Fig. **2** shows the circuit elements comprising the complete tester. The phase-shift oscillator supplies the time-base circuit for the rotating field of the C.R.T., and a phasing control circuit. The output from the latter is applied to a polarised relay which acts as a vibrator for the E.H.T. supply and feeds a breakdown circuit to halve (or divide by three) the speed of the pulses for sending purposes. Switching required for the various facilities is carried out in the control circuit. All power requirements, including valve heater and H.T. supplies are obtained from the 50V exchange battery.

For ease of maintenance, one type of valve, the CV 1988 double-triode, is used throughout.

Circuit Details

The Oscillator (*Fig.* **3**).

From the oscillator output are derived both the pulses for application to the equipment under test and the rotating field for the time base; thus, the measuring point does not drift round the displayed circle.

The design of the oscillator meets the following requirements:—

(i) The frequency control is continuously variable to allow testing at any pulse speed between 8 and 12·5 p.p.s., i.e. the oscillator can be set to run at any frequency between 16 and 25 c/s when 50 per cent. break ratio or balance measurements are required, or between 24 and 37·5 c/s when $66\frac{2}{3}$ per cent. break ratio measurements are needed. This also facilitates the measurement of pulses originating from other sources.

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[1] "The Single Commutation Direct Current Signalling and Impulsing System," S. Welch and B. R. Horsfield, *P.O.E.E.J.*, Vol. 44, p. 18.

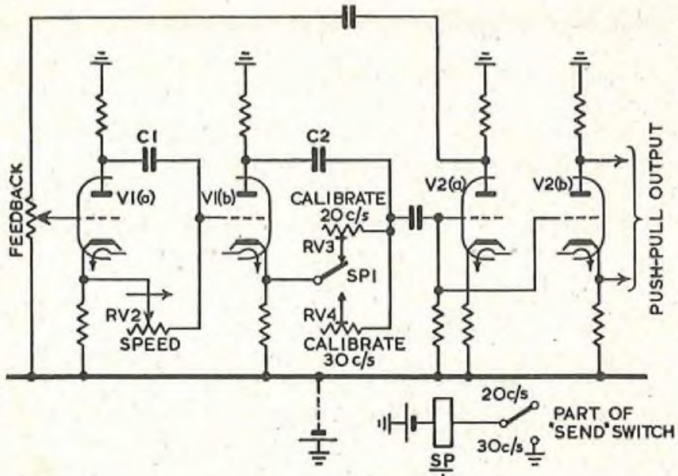


FIG. 3.—OSCILLATOR CIRCUIT.

(ii) Frequency stability is high to avoid the necessity for frequent recalibration of speed. The frequency variation for changes in battery voltage between 46 and 52 is less than 0·2 per cent.

(iii) The generated sine waveform is substantially free from harmonic content. This is necessary since distortion is most noticeable when the output is displayed in circle form on the screen.

(iv) The generated waveform is reasonably constant in amplitude to ensure uniform circle size.

The circuit of Fig. 3 has been developed from selective amplifier circuits described elsewhere[2,3] and employs two frequency-sensitive phase-changing stages, V1(*a*) and V1(*b*), and an amplifying stage, V2(*a*). The loss through V1(*a*), V1(*b*) and associated networks does not change with frequency. Their combined phase shift is 180° at the generated frequency; and due to the 180° phase shift in V2(*a*) the feedback to the grid of V1(*a*) is in the correct phase to maintain oscillations. V2(*b*) is a buffer stage to prevent external conditions affecting the frequency and gives a push-pull output. A feature of the circuit is that it is unnecessary to readjust the feedback control when the frequency is changed.

The Speed control, RV2, is a variable resistor with inverse semi-log grading to give a reasonably uniform speed scale. When calibrating, the control is set to the mean of the range covered, and RV3 and RV4 adjusted to compensate for tolerances in the components. Relay SP connects RV3 or RV4 to produce the different frequencies required for 50 per cent. and $66\frac{2}{3}$ per cent. break ratio measurements.

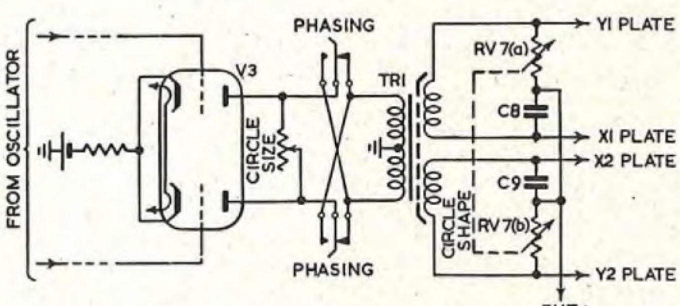


FIG. 4.—TIME-BASE CIRCUIT.

The Time-Base Circuit (*Fig.* 4).

The rotating electrostatic field for obtaining the circular trace on the C.R.T. is obtained from the oscillator output via V3, TR1 and associated components. Two secondary windings are provided on TR1 to enable symmetrical deflecting voltages to be applied to each pair of the X- and Y-plates, thus preventing trapezium distortion and spurious noise pick-up affecting the circle shape.

The two sections of V3 amplify the output from V2(*b*) and feed the primary of TR1 in push-pull. Transformer TR1 has a step-up ratio of 1 : 5 to each of its secondary windings to provide suitable voltages to the deflecting plates, and the windings are so connected with the phase-shifting circuits that a push-pull voltage is applied to the X-plates and a push-pull voltage differing from this by 90° is applied to the Y-plates. The combined effect of these voltages is to cause the electron beam of the C.R.T. to have maximum deflection towards the plates in the order X1, Y1, X2, Y2 at quarter-cycle intervals. At instants of time between the quarter-cycle maxima the beam is deflected partly towards one plate and partly towards the next in sequence.

The resistors RV7(*a*) and (*b*) in the phase-shifting circuits are variable to enable the voltages to be adjusted for correct circle shape. Part of the "Send" switch (not shown in the simplified diagram) is used to switch alternative capacitor values for 50 per cent. break and $33\frac{1}{3}$ per cent. break ratio measurements (20 c/s or 30 c/s at 10 p.p.s.).

The "Circle Size" control shunts the anodes of V3 to allow adjustment of circle diameter by varying the amplitude of the sine wave reaching the primary of TR1.

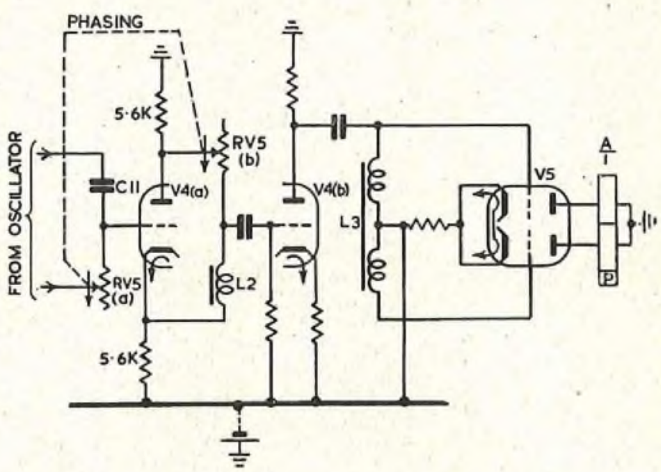


FIG. 5.—PHASING CONTROL CIRCUIT.

The Phasing Control Circuit (*Fig.* 5).

The Send pulses may suffer delay by transmission through equipment under test, and the position, in time, of the received pulses relative to the time-base determines the position of the measuring point on the circular trace. To permit the measuring point to be set to a convenient position, a phasing control circuit is interposed between the oscillator and relay A which drives the breakdown circuit from which the Send pulses are derived.

The grid of V4(*a*) is fed from the oscillator output via a capacitive phase-shift circuit (C11 plus RV5(*a*)), and V4(*a*) is coupled to V4(*b*) via an inductive phase-shift circuit (L2 plus RV5(*b*)).

Considering either phasing circuit alone, the alteration in phase for a given change in resistance is non-linear, but the non-linearity tends to cancel out because RV5(*a*) and (*b*) are connected in opposition. The use of inductance in the second circuit has permitted the interchanging of the reactive and resistive components to make this possible. The result is a controllable overall phase variation of approximately 300° which is sensibly proportional to rotation of the control knob. A further phase-change of

[2] "Tunable A.F. Amplifier," O. G. Villard, Jr., *Electronics*, July 1949, p. 77.

[3] "The Selectoject," O. G. Villard, Jr., and D. K. Weaver, Jr., *Q.S.T.*, November 1949, p. 11.

180° can be obtained by operating the Phasing (reversing) key in the time-base circuit (Fig. **4**).

V4(*b*) is a voltage amplifier, its output being applied via the phase-splitting inductor L3 to the grids of V5, and the voltage considerably over-runs the linear portion of the grid volts/anode current curve of this valve. In consequence, the output from V4(*b*) is severely limited by V5 and squared current pulses are applied in push-pull to relay A. This arrangement gives consistent operation of relay A at all speeds and with normal component tolerances. Contact A1 therefore transmits balanced pulses, their speed being identical to the frequency of the oscillator.

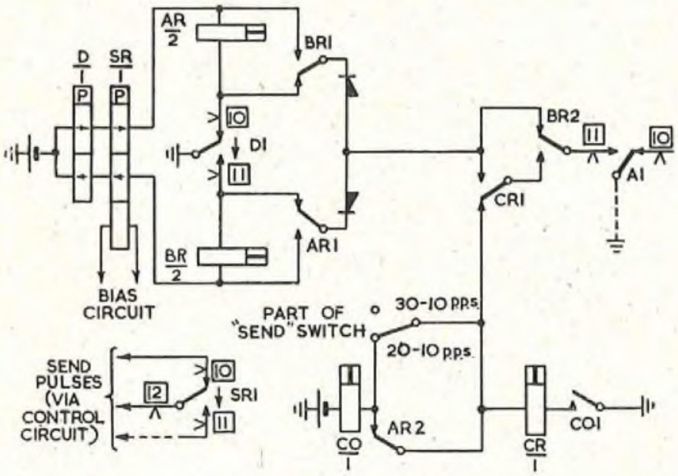


FIG. **6**.—BREAKDOWN CIRCUIT.

Breakdown Circuit (*Fig.* **6**).

As relay A is operating at the oscillator frequency, its contacts cannot be used directly for the Send pulses because the pulse speed required at the Send terminals is one half or one third of the oscillator frequency, depending upon the position of the Send switch. This breaking down in frequency is achieved by relays AR, BR, D and SR for halving, with the addition of relays CO and CR when one-third speed is required. An advantage of this arrangement is that each make (or break) pulse at the Send terminals is comprised of an equal number of make and break pulses of relay A; thus, any unbalance of relay A or its operating circuit has no effect on the Send pulses.

Relays D and SR are polarised and so connected that if current flows (conventionally) in the direction of the arrows then the armature contacts move in the direction shown, and vice versa. Further, both coils of relay D and the two main coils of relay SR have the same number of turns and in the event of opposing currents flowing in the coils, the armature contacts move in the direction of the larger current flow.

When balanced pulses are required, the biasing circuit associated with the third coil of relay SR is arranged to counteract any out-of-balance within its normal adjustment tolerances or associated resistor values.

When make/break ratio pulses are required, only contacts 10 and 12 of relay SR are used and a bias current is deliberately introduced into the third winding so that the break period of these contacts is exactly 50 or $66\frac{2}{3}$ per cent.

When 50 per cent. break ratio or balanced pulses are required a Send pulse speed equal to half the oscillator frequency is necessary. For $66\frac{2}{3}$ per cent. break ratio pulses, the oscillator runs at three times the pulse speed and the armature contact of relay SR is held over to fixed contact 11 for two complete cycles, and over to 10 for one.

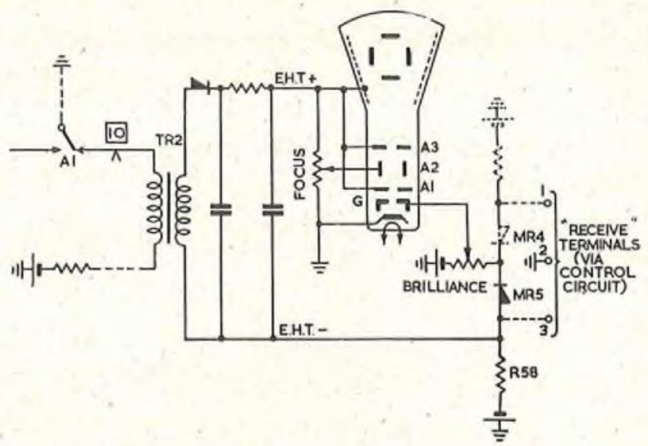


FIG. **7**.—E.H.T. SUPPLY AND C.R.T. CIRCUIT.

E.H.T. Supply and Cathode Ray Tube Circuit (*Fig.* **7**).

The extra high-tension voltage necessary to supply the anodes of the C.R.T. is obtained by contact A1 interrupting current in the primary of TR2. This transformer has a step-up ratio of 1 : 3 and the high e.m.f.s produced in the secondary are rectified and smoothed to produce an E.H.T. supply of approximately 550V D.C.

The positive connection is direct to the C.R.T. anodes, but the circuit from E.H.T. negative to the earthed cathode is via R58 and the —50V exchange battery, or alternatively via an earth pulse connected to "Receive" terminal 3. The resultant voltage between the final anode (A3) and cathode of the C.R.T. may be 500V or 550V, therefore, depending upon the condition connected to Receive terminal 3. If the pulses being measured are connected to Receive terminal 1, they are prevented from affecting the E.H.T. circuit by MR5. The sensitivity of the C.R.T. deflecting plates is inversely proportional to its anode/cathode voltage; therefore, the circle displayed for pulses received on terminal 1 is approximately 10 per cent. larger in diameter than that for pulses received on terminal 3.

Earth pulses on either terminal can flow in the forward direction of MR4 or MR5 to the "Brilliance" control which is set to give a suitable grid bias for the desired brightness of trace. When there is no earth connection to either Receive terminal 1 or 3, the grid is biased to —50V by the exchange battery, which is more than sufficient to cut off the electron beam and darken the trace on the screen.

Interpretation of C.R.T. Traces (*Fig.* **8**).

With the oscillator running at the appropriate frequency, receipt of perfect 50 per cent. make or $33\frac{1}{3}$ per cent. make signals on either of the outer Receive terminals causes the trace to be visible for one complete cycle of the time base and a complete circle to be shown on the screen. With 50 per cent. make signals, one complete cycle of darkness elapses between the make periods (50 per cent. break period) and for $33\frac{1}{3}$ per cent. make, two complete cycles of darkness elapse between the make periods ($66\frac{2}{3}$ per cent. break period), but flicker is reduced by afterglow of the C.R.T. screen. Positive distortion (increase of make) is indicated by overlapping of the trace ends and negative distortion (decrease of make) by a gap between the trace ends. Contact bounce, which results in momentary disconnection(s) after the contact makes, produces gap(s) near the starting end of the trace.

Since the trace starts and finishes at or about the same point on the screen, measurements are not subject to parallax errors.

When the balance of change-over contact units is being checked, the fixed contacts are connected to Receive

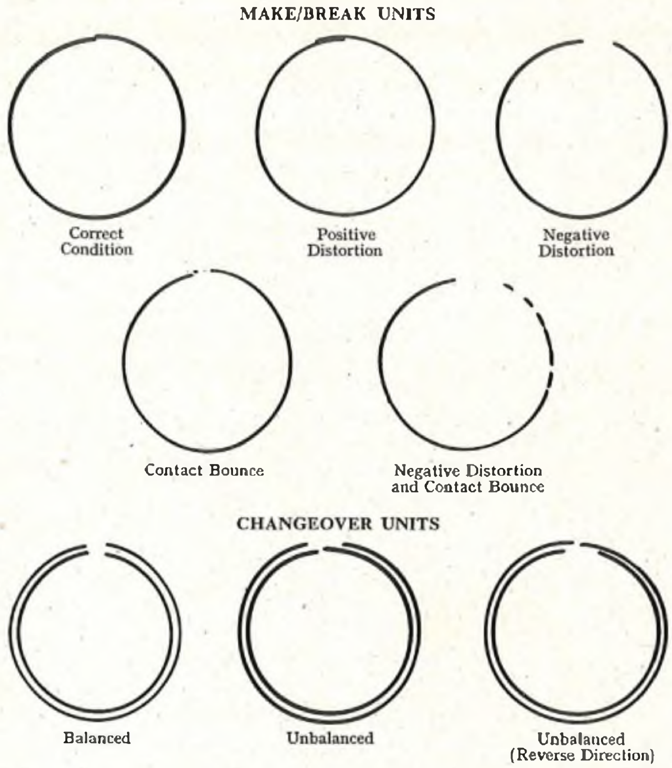


FIG. 8.—TYPICAL C.R.T. TRACES ILLUSTRATING CORRECT AND INCORRECT PULSE CONDITIONS.

terminals 1 and 3, with the armature contact earthed at terminal 2. Due to the circuit conditions already described two concentric traces are displayed alternately, and the make period of either contact may be determined independently. The gap between the finish of the inner trace and the start of the outer trace and vice versa, indicates the transit times in each direction of the centre contact. (The time base rotates in a clockwise direction).

For measurement of distortion two transparent scales are provided for placing in front of the C.R.T. screen where they are illuminated by refraction of the light from two small lamps. The scale intended for use with balanced and 50 per cent. break pulses is marked with radial lines at 7·2° separation (50 per 360°) and that for use with $66\frac{2}{3}$ per cent. break pulses at 10·8° separation ($33\frac{1}{3}$ per 360°). In each case, the line spacing represents 1 per cent. of a complete pulse and this applies for any setting of the Speed control. (At 10 p.p.s., 1 per cent. equals 1 mS).

Control Circuit.

For control of the tester, the Send and Receive terminals are connected to their relative circuits via keys and switches. The main functions are carried out by the Send switch (a multi-way rotary type) which exercises master control. Information concerning the use of the Send switch and control keys given in the following text applies mainly to S.S.D.C. No. 2 equipment for which the tester was originally designed, but by appropriate connection the testing of other pulse-repetition equipment is possible.

The Send switch has four positions:—

(i) "*External or Stand-by.*"—In this position, the sending circuits are connected to jack points for control by other test equipment, such as an automatic tester requiring pre-calibrated pulses. The receiving circuits are connected to other points on the same jack to permit checking while under remote control. Access is by means of a plug and cord.

When the jack points are not in use, this position of the switch leaves the valve circuits switched on with the relays disconnected, and thus may be used as a stand-by position.

(ii) "*Balance.*"—In this position, relay SR (Fig. 6) is arranged to give balanced double-current pulses at the Send terminals. These may be applied to an incoming S.S.D.C. No. 2 relay set and its output (50 per cent. break pulses) measured by connection to the Receive terminals.

(iii) "*Ratio 50 per cent. Break.*"—In this position, relay SR is arranged to give 50 per cent. break pulses directly to the Send terminals which may be connected to the input of a S.S.D.C. No. 2 outgoing relay set. (To measure the balanced output of the relay set the "Receive Balance via Relay" key must be operated—See later.)

(iv) "*Ratio $66\frac{2}{3}$ per cent. Break.*"—In this position, relay SR is arranged to give $66\frac{2}{3}$ per cent. break pulses directly to the Send terminals and the facility is intended for general testing at normal subscribers' dial ratio.

The receiving circuits are controlled by keys whose functions are as follows:—

(i) "*Send Check.*"—Connects the Send pulses to the C.R.T. grid circuit for checking in local.

(ii) "*Receive Balance via Relay.*"—The pulse output circuit of S.S.D.C. No. 2 outgoing relay sets contains too great a series resistance and shunt capacitance to produce a satisfactory trace on the screen, due to the slow change from one polarity to the other. To overcome this, a balanced polarised relay may be connected to the Receive terminals by means of this key. The relay contacts repeat pure double-current pulses into the C.R.T. grid circuit.

(iii) "*Relay Check.*"—To ensure that the relay mentioned in (ii) does not introduce errors, operation of this key enables the relay to be checked for accuracy of balance using the double-current pulses normally available for sending and observing the make period of its contacts on the screen.

(iv) "*Low Impedance.*"—When a pulsing contact shunted by a capacitive spark quench is connected to a relay, the charging current of the capacitor, when the contact breaks, lengthens the apparent make period of the pulses. As the charging current follows a decay curve, the apparent increase is influenced by the type and adjustment of the relay being pulsed. The measuring set has been designed to mask the effect of spark quenches and therefore measure the actual contact time rather than the arbitrary effect upon following equipment.

As shown in Fig. 9, when the Low Impedance key is normal, the contact under test pulses into approximately 3·4kΩ non-inductive battery, which value is sufficiently high to allow appreciable resistance (up to 600 ohms) to be introduced between the contact and the measuring set without undue loss of trace brilliance, and yet sufficiently low to mask the effect of spark quenches up to 0·5 μF + 200 ohms within the required limit of error of 0·2 per cent.

When the Low Impedance key is operated, the input resistance is reduced to approximately 200 ohms and the effect of larger spark quenches (even in excess of 4 μF + 50 ohms) is masked, although in this case the resistance of the connections to the contact must not exceed 30 ohms, otherwise adequate brilliance will not be obtained.

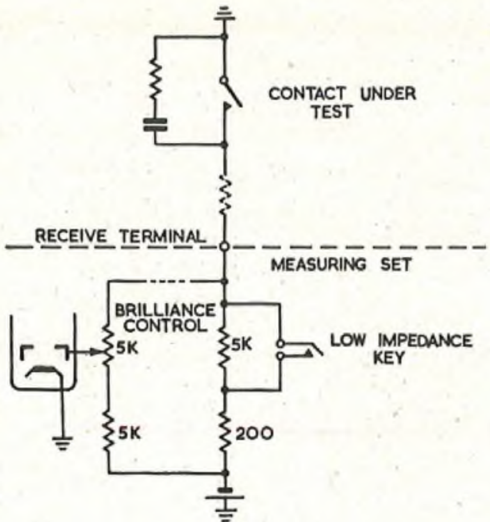


FIG. 9.—LOW IMPEDANCE KEY.

CALIBRATION

Ratio and Balance.

As far as the displays of ratio and balance are concerned, no calibration is required and the measuring set may be regarded as self-checking, since faults in the receiving circuit will show up in ways other than measurement errors. As already described, the sending circuits may be checked on the screen at any time by operating the Send Check key, and the receive relay checked by operating the Relay Check key; pre-set potentiometers are provided in each circuit to enable accurate adjustments to be made.

Speed.

The Speed control can be checked against a standard frequency, preferably a low order multiple of 10 p.p.s. or c/s. If a more accurate source is not available the 50 c/s mains supply may be used provided the calibration is carried out at a time when power conditions are normal.

The method used is to cause the standard frequency to modulate the brilliance of the trace while it is being deflected by the time-base circuit in the measuring set. A series of arcs in circular formation is thus obtained and these appear stationary when the time-base and standard frequency are in exact ratio.

The measuring set is connected as for the measurement of ordinary ratio pulses and the Brilliance control adjusted so that small bright arcs are visible on the screen. Normally, with the Speed control scale set to 10 p.p.s. and the Send switch at Ratio 50 per cent. Break or Ratio $66\frac{2}{3}$ per cent. Break, the appropriate calibrating resistor is adjusted to display stationary arcs, (at 50 c/s, five arcs are displayed in each case). Other calibrating points are available, however, and these may be used for checking the accuracy of the Speed control scale markings, or setting up the tester if extreme accuracy is required at other than 10 p.p.s.

APPLICATIONS

Signalling System D.C.No. 2.

The measuring set has been made as compact as possible to enable it to fit into a trolley-mounted automatic tester. The proposed arrangement is that the automatic tester (at present being designed) will use the pulses from the measuring set during its test cycle and in the event of a pulse distortion fault being indicated, operation of certain keys will transfer the relay set connections directly to the measuring set. This will enable the pulse corrector(s) on the faulty relay set to be adjusted manually before a new automatic test cycle is attempted.

A unit has been developed for connecting the measuring set, and operating appropriate relays and busying in the relay sets, to allow manual checks and adjustments to be made until such time as the automatic testers become available.

Other Typical Applications.

Measurement of Speed of Pulses from other Sources.—The oscillator frequency has proved sufficiently stable to warrant the use of the set for measuring the speed of pulses which originate elsewhere. Any difference between the speed of the received pulses and the setting of the Speed control causes the measuring point to drift round the displayed circle. With the control adjusted to give a stationary display, the speed of pulses between 8 and 12·5 p.p.s. may be read off directly. Higher speeds may be measured by setting the Speed control to a sub-multiple of the received pulses, e.g. 20 p.p.s. pulse machines may be tested with the Send switch at Ratio 50 per cent. Break and the Speed control at 10 p.p.s.

Measurement of Ratio of other Pulse Sources.—Received balanced 50 per cent. break ratio or $66\frac{2}{3}$ per cent. break ratio pulses, between 8 and 12·5 p.p.s., may be measured by the methods already described, and other ratios by regarding them as having wanted distortion; e.g. 80 per cent. break, 20 per cent. make, pulses would be read as negative $13\frac{1}{3}$ per cent. distortion with the tester set up for receiving $66\frac{2}{3}$ per cent. break pulses—or alternatively as negative 30 per cent. distortion when set up for 50 per cent. break pulses.

By suitable interpretation of the display, measurement of pulses at higher speeds is possible.

Tests on other Types of Relay Sets.—Any equipment which contains pulse repeating circuits may be tested for distortion provided they are capable of accepting and repeating continuous pulses.

The operate and release lags of the relays under pulsing conditions may be measured by noting the radial position of the Send pulses when the Send Check key is operated and comparing this with the radial position of the start and finish of make of the relay set output. This is most conveniently done at 10 p.p.s. when the radial lines on the scale are at 1 mS spacing.

Overall Testing of Circuits.—Since the fundamental principle of the measuring set is based on sending perfect signals, and since the oscillator portion has been designed with a view to frequency stability, the Send pulses from one measuring set may be measured on the Receive circuit of another, provided both oscillators are running at the same frequency. If a circuit may be continuously pulsed, its overall distortion, including the line as well as the relay sets at both ends, may be measured by such an arrangement. Difference in frequency between the two oscillators will cause the measuring point to drift, and a slow-motion device has been fitted to the Speed control for ease of adjusting the oscillator frequency of the receiving measuring set.

ACKNOWLEDGMENTS

It is desired to record acknowledgments to officers in Research Branch for the design of suitable transformers and to colleagues in Telephone Branch, in particular, Mr. H. R. Pate of the Circuit Laboratory, for co-operation during the development stages; and Mr. E. C. C. Stevens for assistance in writing this article.

The Platinum-Cored Oxide-Cathode Repeater Valve

G. H. Metson, M.C., Ph.D., M.Sc., A.M.I.E.E.†

U.D.C. 621.3.032.185: 546.92

The life of a conventional nickel-cored oxide-cathode valve may be seriously reduced by the deleterious effect on the cathode of residual gases within the valve envelope. The author outlines experiments in which nickel-core and pure platinum-core cathodes have been artificially subjected to attack by an oxidising gas so as to compare their behaviour under such conditions. It is shown that the use of platinum cores offers certain advantages including higher stability of operating characteristics.

Introduction

A HIGH-SLOPE oxide-cathode valve with a pure platinum core has now been adopted for use in submerged repeaters of the British Post Office shallow-water cable system[1] and it is thought that readers of the Journal may be interested in some of the broad ideas backing this rather novel step. Cathode failure in modern high-performance valves is normally due to one or both of two causes—the growth of interface resistance and deactivation of the emitting cathode by attack of oxidising residual gases. The introduction of pure platinum as a core metal was primarily aimed at the elimination of interface growth and in this it seems to have had considerable success.[2] Platinum-cored pentode valves of the CV138 type have now been running for 18,000 hours without any measurable increase in interface resistance and tests over a period of 13,000 hours under the zero-current condition have shown a similar result. These figures indicate a solid advantage over the conventional nickel core with its dangerous silicon contaminant.

The second requirement of a good cathode is that it must retain its emitting activity in the face of attack by oxidising residual gases which are present to some extent in even the best-prepared repeater valves.[3] The main object of the present note is to compare the relative capabilities of the pure platinum and the conventional nickel cores in meeting and surviving such attacks.

Activators

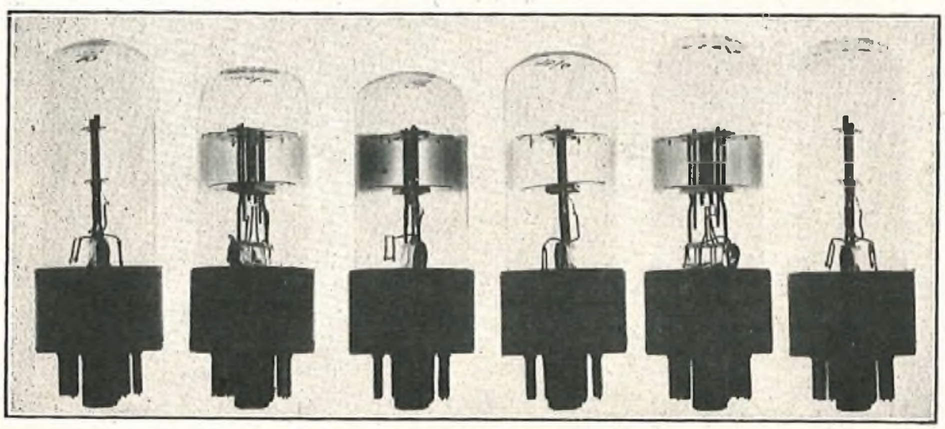
The barium oxide cathode requires an excess of barium metal to give to it the essential properties of matrix conduction and surface emission of electrons. Loss of this excess metal goes on continuously by evaporation, residual gas attack, etc., and the capacity of a cathode to survive is measured by its ability to replace its own barium losses. The conventional nickel core is well placed in this respect by virtue of its active contaminants of magnesium (0·05 per cent.) and silicon (0·05 per cent.) which are able to provide the excess element by a direct reduction process, e.g.

$$Mg + BaO = MgO + Ba$$
$$Si + 4BaO = Ba_2SiO_4 + 2\,Ba$$

The pure platinum-core cathode has no such reducing ability and must rely for its continued activity on other means. This important difference in barium-producing capacity is brought out in Fig. 1 which shows the metallic barium evaporated from various cathodes run at 1,250°K for different periods. Samples 1 and 6 are platinum-core cathodes and show no evaporated barium stain on the envelopes after 200 hours of running. Examples 2 and 3 are the same tube with an active nickel core after 10 and 20 hours of operation. Examples 4 and 5 are similar to 2 and 3 except that the active nickel core is taken from a different supply source. Both of the nickels are typical of those now used in the valve industry. The black stain on the envelopes is almost wholly metallic barium.

In the absence of any effective reducing action the pure platinum-core cathode has to depend for its continued activation on an electrolytic dissociation of its barium oxide. This can only occur under the action of a cathode current and it follows that the cathode continuously deteriorates when run under zero current conditions. Work at Dollis Hill indicates that the rate of barium production is a function of cathode current, but in receiving valves this current is normally limited to about 15 mA/sq. cm. At this current density a platinum-core cathode diode of the type shown in Fig. 1 shows no visible sign of barium stain on the glass envelope after 10,000 hours' operation. Clearly the electrolytic action as a producer of barium is far less effective than the direct reducing action of magnesium or silicon.

Evidence so far considered seems to incline to the active nickel core as the more robust of the pair, but certain side issues of a chemical nature may tend to redress the balance. These actions will now be examined and they centre around chemical actions following an oxygen attack of limited duration on the cathode matrix and core. The platinum case is simple—the only vulnerable constituent is the excess barium of the BaSrO matrix itself. Providing this barium is not totally destroyed then some limited cathode current will pass when the attack is over, and electrolytic reactivation can start its task of rehabilitation. The active nickel-core case is altogether more complex in that the core metal itself is open to oxidation and the products of such



1 2 3 4 5 6

Fig. 1.—Examples of Metallic Barium Production by Active Cathode Cores.

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[1] "Submerged Telephone Repeaters for Shallow Water." R. J. Halsey and F. C. Wright, *Proc. I.E.E.*, 1954, Pt. 1, p. 167.

[2] "Deterioration of Valve Performance due to Growth of Interface Resistance." G. H. Metson and M. F. Holmes, *P.O.E.E.J.*, Vol. 46, p. 193.

[3] "Poisoning Effects in Oxide-Cathode Valves." G. H. Metson, *P.O.E.E.J.*, Vol. 41, p. 204.

action may interfere with both reduction and electrolytic processes when the oxygen attack is withdrawn. The relative robustness of the two cathodes to attack is thus an open question and can only be decided by direct comparative experiment.

Experimental Comparison of the Action of the Two Cathodes under Oxygen Attack

Technique of Comparison.

The making of a comparative study of the two cases is simple in principle, but complex in experimental detail. It will suffice for the present purpose to give a broad outline of procedure and leave the technological description to a later publication. The basis of test is the quantitative comparison of the electrical recovery of two diodes from a common oxygen attack. The construction of the diodes and their treatment are identical in all respects except in the nature of the cathode-core metal. A few practical details will make the experimental procedure clear. The diode used is the G.P.O., 6D15 type with a 2W cathode and 6·3V heater. The collector is a close-spaced molybdenum grid structure and the general appearance of the finished valve is that of Samples 2-5 in Fig. **1**.

The two diodes under comparative test are mounted on a high-grade bench pump and put through a meticulous processing schedule. The electrical characteristics of the two samples are measured and oxygen then injected into the system at some accurately determined pressure for a fixed time. The gas is now cut, the system allowed to pump down again to its ultimate vacuum of about 2×10^{-7} mm. Hg and the valves sealed off the pump. Both diodes are finally subjected to the same recovery process and re-measured for electrical performance.

It will be clear from this description that if recovery is arranged to take place on the pump, then a cyclic succession of gas attack and recovery actions can be studied.

In each of the experiments described below the cathode temperature is maintained at the conventional level of 1,020°K during the attack and the gas used is pure dry oxygen.

Recovery from a Mild Attack.

The first example selected shows the comparative effect of a mild attack. The pressure of oxygen used is 1×10^{-5} mm. Hg for a period of 10 minutes with the cathode temperature of 1,020°K. At the end of the attack the gas is cut and the system pumped down to its ultimate vacuum of 2×10^{-7} mm. Hg. The recovery action takes the following course: the temperature of the cathode is raised to 1,200°K for 30 minutes and a common positive voltage applied to the diode collectors such that the initial space-charge current before attack was around 100 mA/sq. cm.

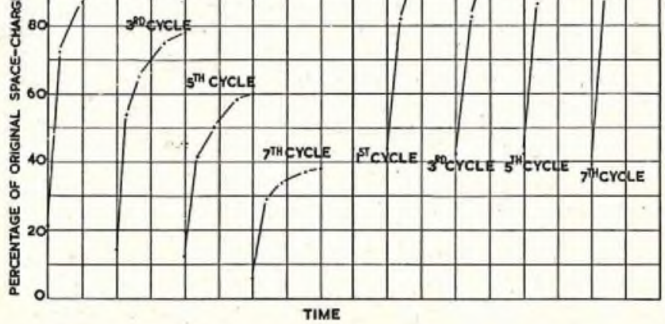

Fig. **2**.—Recovery from a Series of Mild Oxygen Attacks.

The recovery is then assessed as the percentage restitution of the original space-charge characteristic. After the 30 minutes' recovery phase the whole cycle is repeated. Fig. **2** shows the results of seven such cycles with only alternate recovery phases plotted, to avoid constriction of the picture.

It is clear from this result that the platinum core shows a much greater buoyancy than the active nickel core.

Recovery from a Heavy Attack.

In the second example selected the attack is more severe —the oxygen pressure has increased 10 times to $1{\cdot}0 \times 10^{-4}$ mm. Hg and the duration extended to 16 hours. At the end of the operation the system is pumped down to its ultimate vacuum and the valves sealed off the pump.

Recovery in this instance is effected in the same way as before except that the cathode temperature is retained at the common working level 1,020°K and not raised to 1,200°K. The recovery action is allowed to continue until each tube has reached a steady space-charge current—a period ranging from 30 to 60 minutes. The results are set

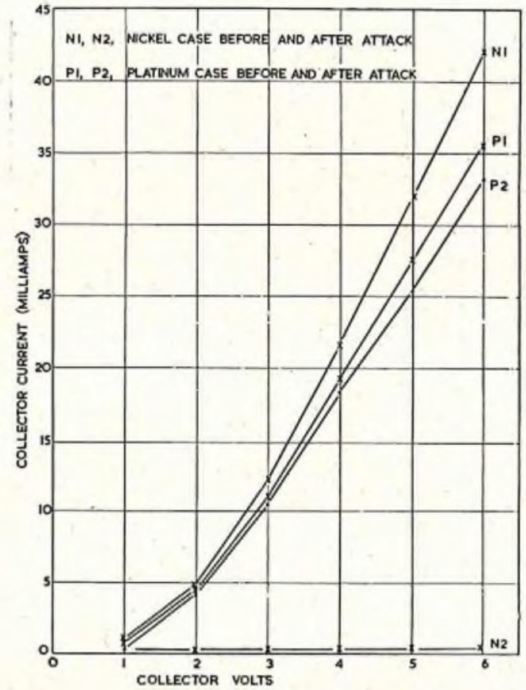

Fig. **3**.—Volt/Amp. Characteristics of Platinum and Active Nickel Core Diodes before and after Oxygen Attack.

out in Fig. **3** and show that the platinum core has almost completely recovered whereas the active nickel core shows no signs of recovery whatever. This result is particularly impressive in respect of platinum, in that no increase in the temperature of the cathode has been necessary to effect the recovery.

Increasing the temperature of the active core case to 1,250°K for 30 minutes produces a negligible further recovery and it seems that an attack of this intensity and time results in irreversible destruction.

Necessary Condition for the Platinum Core Recovery.

The third example has been chosen to give some idea of the nature of the platinum core recovery. The attack in this instance is one of 1×10^{-4} mm. Hg oxygen pressure and 16 hours' duration. The valve has been sealed off the pump for recovery which has been undertaken in two phases; firstly, with zero cathode current, during which the cathode emission state has been explored by a pulse method, and then with a permanently applied collector voltage allowing a continuous current to flow. The results are set out in

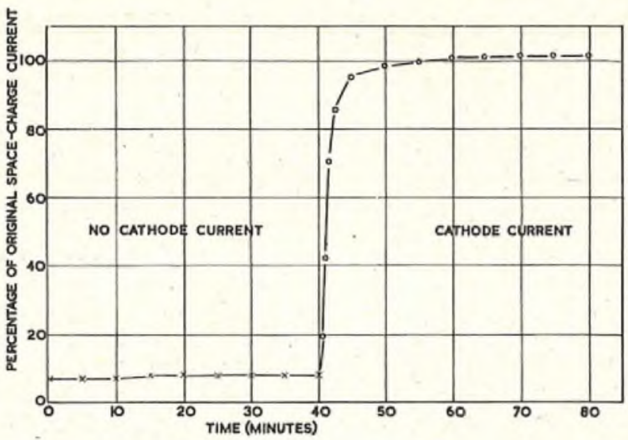

FIG. 4.—INFLUENCE OF CURRENT ON RECOVERY OF A PLATINUM-CORE CATHODE.

Fig. 4 and show that the passage of current is essential to the recovery. In studies of this type the zero current phase has been extended to 250 hours with negligible recovery, followed by complete recovery in 30 minutes under current carrying conditions. It is of further interest to note that increasing the cathode temperature from 1,020°K up to 1,250°K produces no sensible recovery in the zero current condition.

REVERSIBILITY

The work on reversibility of oxygen poisoning in platinum-core valves was started in 1949 and first results gave rise to some astonishment. Since then, however, the experiments have been repeated many times under widely varying conditions and are now accepted as commonplace at the Research Station. What remains more surprising perhaps is the relative vulnerability of the active core cathode and a few comments on this aspect may be of interest.

It seems clear that the BaSrO matrix itself is immune to permanent damage from any reasonable attack of oxygen and that the response of the cathode as a whole is determined by the chemical reactions of the core metal. In the platinum case there is, of course, no action and if the hypothesis of electrolytic reactivation is accepted then the behaviour of the platinum-core cathode is understandable. The attack of oxygen on the active nickel core is far more complex as it involves the oxidation products of nickel, silicon and magnesium. To simplify the problem at this stage, a very pure nickel has been prepared with estimated silicon and magnesium contents around 0·001 per cent. and this has been subjected to comparative tests for reversibility with active nickel. The results show no apparent difference between the samples, and the conclusion is therefore drawn that the element that is primarily responsible for irreversibility is nickel.

The part supposedly played by the nickel is obscure, but it is known that nickel oxide reacts at red heat with barium oxide to form a dark-coloured fusible barium nickelite. That some such action may, in fact, occur is suggested by the following experience. Two batches of diodes with pure nickel cores are processed and one batch subjected to the heavy oxygen attack described previously. After sealing-off the pump both batches are subjected to a steady increase of cathode temperature. Up to about 1,400°K the appearance of both cathode batches is identical—a pure white granular structure. Between 1,400°K and 1,500°K a remarkable reaction occurs on the oxygen-treated batch, their cathodes turn fawn-coloured, then brown to violet and finally fuse to a black matrix. The control batch shows no reaction whatever, even on raising the temperature to 1,600°K. Fig. 5 gives some idea of the magnitude of the reaction.

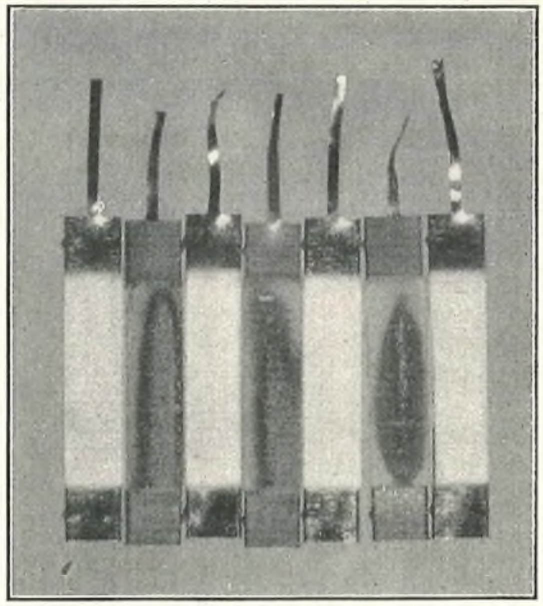

FIG. 5.—FUSING OF THE BaSrO MATRIX AFTER OXYGEN ATTACK ON NICKEL CORE.

Active nickel cathodes give a similar reaction, but in a much less intense fashion and this is probably due to the protection of the nickel from oxygen attack by its overlay of barium orthosilicate.

OPERATION OF PLATINUM-CORE CATHODES IN WORKING VALVES

Too much must not be read into the results described above as they are artificial both as to the nature of the gas employed and in the manner of its application. In working valves the residual gas is likely to be a mixture of oxygen, carbon monoxide, carbon dioxide, water vapour, chlorine, etc.; the pressure range will probably lie within 10^{-6} to 10^{-10} mm. Hg and the time of application be measured in thousands of hours. These overall conditions can only be simulated in a working valve and such is the proper background for practical testing of the platinum core.

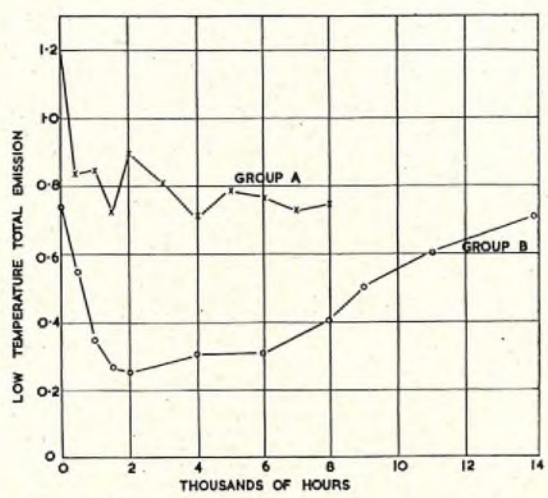

FIG. 6.—EFFECT OF GAS ATTACK ON EMISSION OF GROUPS OF WORKING VALVES.

Fig. 6 shows the low-temperature total emission characteristics with time of two groups of platinum-core valves—the group "A" has components which have been thoroughly processed, whilst group "B" has a component which has been only partially degassed. The second group is, therefore, subjected to gas attack of a type which is probably representative of that occurring in common valves.

The interpretation of the curves can be made in the following manner: the adequately processed group falls in total emission by loss of cathode barium by evaporation and core solution to an equilibrium level depending primarily on cathode temperature and cathode current. The group suffering gas attack falls much faster due to the additive loss of direct barium oxidation. The supply of gas from the offending member is, however, finite and as it tends to exhaustion[4] the forces of deactivation and electrolytic reactivation come into equality. The total emission now ceases to fall and with the electrolytic force in the ascendency the characteristic slowly recovers towards its equilibrium level. This level of around 0·7 mA is of interest —it is measured with 400 mW in a 2W cathode and represents about 1·5 amps/sq. cm. at the normal running temperature of 1,020°K. Such an emission level after a year of operation is as good as any measured at Dollis Hill on active nickel-core valves.

Future of the Platinum-Core Cathode

It may be useful to close on an appreciation of the future of the platinum-core cathode. Within the limitations of present experience it appears to have its own distinctive advantages and shows a greater stability of operating characteristic than the conventional nickel cathode—Fig. 7 shows the "mutual conductance/time" characteristics of groups of the two types which have been prepared under identical conditions.

[4] "Vacuum Factor of the Oxide-Cathode Valve." G. H. Metson, *British Journal of Applied Physics*, Vol. 1, p. 73, March 1950.

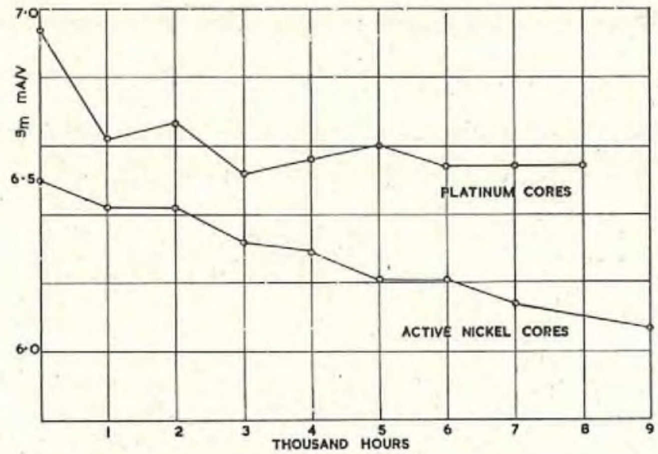

Fig. 7.—Average G_m/Time Characteristics for Two Batches of Long-Life Valves.

Despite these advantages the writer is inclined to think that the future of the platinum core is limited by its necessity for expensive processing. It is, moreover, probable that some of the advantages at present held by platinum will be negated in due course by improvements in the composition of nickel core alloys.

Book Review

"Electronic Measuring Instruments." E. H. W. Banner, T.D., M.Sc., M.I.E.E., M.I.Mech.E., F.Inst.P., M.Cons.E. Chapman & Hall. 395 pp. 186 ill. 45s.

Electronic measuring instruments are finding uses in so many sciences, in so many industries and by so many professions, that they deserve a book or two on their own, rather than chapters here and there in books on radio engineering, atomic energy, acoustics, etc. If the books are to be directed to scientists and engineers they must contain critical chapters on design, facilities and accuracy; if to non-specialist users, broader descriptive writing is permissible, as used by the author—who nonetheless directs his book also at instrument engineers in general and students with some knowledge of electronics. The book is apparently a collective effort; some chapters are more forcibly written than others, but there is no overlapping.

After a brief chapter (Part I) on indicating instruments, a quarter of the book (Part II) is devoted to the electronic devices used in measuring instruments, generally in very simple terms almost devoid of formulae and symbols. Catering for readers with and without prior knowledge of electronics makes the author's task difficult, particularly in the face of many adequate books on most electronic devices. The Part is wrong or misleading in places, sometimes admittedly only typographically. Two important advantages of push-pull working in amplifiers are not mentioned: better linearity and easing of the design of any output transformer. The diagram of the basic circuit of a cathode follower shows two valves; the selenium photocell is said to have a "spectral response more nearly approximately that of the eye than that of any emission type," whereas the Figs. 4/3 and 4/5 contradict the statement. The figure showing the forward characteristic of a selenium rectifier contains two broken curves which mean little if anything. There is loose writing in the section on crystal rectifiers. "Some silicon p-n junctions have a reverse characteristic considerably greater (?) than that for thermionic valves and which (what?) are less temperature dependent than similar germanium rectifiers." The radiation and particle detectors are well described, even though halogen quenching is only briefly mentioned.

Part III, nearly half the book, is devoted to the instruments. Presumably because test gear for radio engineering is deliberately excluded there is no mention of radio sondes, navigational aids or altimeters. Several voltmeters are described, including two for clinical medicine, with some advice implied on the best choice for different purposes. Cathode ray instruments are less adequately dealt with; the versatility of modern units is not made sufficiently obvious. A longer chapter on photoelectric measuring instruments deals more satisfactorily with several photometers. But instruments for measuring α, β and γ (including X) radiations receive the best treatment in a chapter of nearly 50 pages. The choice of instrument here must depend not only on the type of radiation to be measured, but the terms in which it is to be expressed, e.g., number of particles producing ionisation or the total ionisation produced. The radiation thickness gauge is adequately described in a chapter on its own; only the first row of Table II is necessary however.

Part IV, the final fifth of the book, deals with "quasi-electronic" instruments. Some non-electronic counters are briefly described and compared with electronic counters. In a chapter on instruments using electromechanical transducers for the measurement of non-electrical quantities, the strain gauge has pride of place, but inductive thickness gauges, a vibration pick-up, accelerometers and proximity meters receive attention. Thermo-variable resistors, the magnetic amplifier, vacuum gauges and moisture meters receive mention, along with a few recording instruments, in final chapters.

The book is very well produced even though a few of the photographs could have been omitted with little loss and the captions and lettering of a few diagrams could usefully be revised. It is difficult, however, to recommend the book strongly to any one group of readers, e.g., those who would study, design, operate, incorporate or even sell electronic measuring instruments, though it contains something—perhaps not enough—for each group. The price is reasonable. J. R. T.

Short-Wave Directional Aerial-Systems*

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Part 1.—Basic Considerations; Arrays of Resonant Dipoles

U.D.C. 621.396.677.029.58

This article discusses in simple terms the principles underlying the design of short-wave aerials and their application to specific aerial arrangements. Part 1 introduces the subject with a statement of the conditions to be fulfilled and gives a summary of the more important design considerations. The aerial system using arrays of resonant dipoles is then described. Part 2 will include a description of travelling-wave and other types of short-wave aerial, and will consider ground effects and impedance matching.

Introduction

LONG-DISTANCE point-to-point radio communication around the curved surface of the earth by means of short-waves is possible only because of the existence of layers of ionised gases and free electrons located in that region from 80 to 450 kilometres above the earth's surface, known as the ionosphere. The two significant layers for short-wave radio communication are the E-layer, discovered by Heaviside, which is located at about 80 kilometres above the earth's surface, and the F-layer, discovered by Appleton, which is at a height varying from 250-350 kilometres. The variation of electron density within these layers is such that high-frequency radio waves penetrating the layers are refracted to a degree which depends on several factors, including the frequency of the wave itself. Under certain conditions the refraction is such that the path of the radio-wave is deviated downwards until it returns to the earth's surface at a point perhaps two or three thousand miles away from the transmitter. The wave is said to be reflected from the particular layer concerned—the process is illustrated in Fig. 1, where T

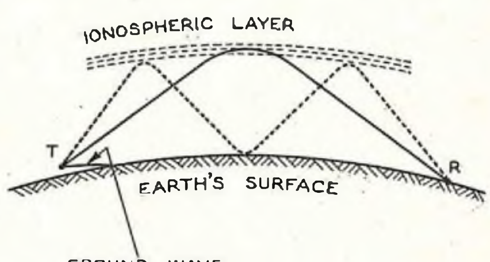


FIG. 1.—PRINCIPLE OF IONOSPHERIC PROPAGATION (SINGLE AND TWO-HOP PATHS).

represents the position of the transmitter and R that of the receiver. The signals can be transmitted from T to R by reflection from the ionosphere using transmitter powers which would be entirely inadequate if the signals were transmitted horizontally along the ground from T. In practice, at high-frequencies such a ground-wave is attenuated so rapidly with distance from the transmitter that signals due to this mode of propagation are negligible beyond a hundred miles or so.

In setting up a short-wave point-to-point circuit it is clearly desirable that as high a proportion as possible of the signal power available at the transmitter shall be transmitted to the receiving station, in order to reduce to a minimum the total power requirements at the transmitter. The extent to which this is achieved depends on the extent to which the following conditions are fulfilled:—

(*a*) The maximum amount of power shall be transferred from the transmitter into the transmitting aerial system.

(*b*) The maximum amount of power transferred into the transmitting aerial system shall be radiated, i.e., dissipation in the aerial system shall be a minimum.

(*c*) The radiated power shall be directed in the correct *azimuthal* direction, i.e., along the great circle path between the transmitting and receiving stations.

(*d*) The radiated power shall be directed in the optimum *vertical* direction, such that the propagation path so determined between the transmitting and receiving stations offers the minimum possible path attenuation—such a path may involve one, two or more reflections from E or F layers.

(*e*) The design of the aerial shall be such that the radiated power shall be concentrated as much as possible in the particular direction whose azimuth and zenith are determined by (*c*) and (*d*) above.

Similar conditions apply in principle to the aerials at the receiving station, although in this case they can best be regarded as a measure of the sensitivity of the aerial to the wanted transmission relative to unwanted signals, including noise.

It is relevant at this point to consider a little further the factors affecting the propagation of short-waves. The degree to which a radio wave is reflected from an ionospheric layer depends on the frequency of the wave, the angle of incidence and the ionic densities present in the layer. The angle of incidence is a function of the separation of the transmitting and receiving stations, the nature of the path, i.e., whether one, two or more "hops," and the height(s) of the layer(s) concerned, which depends on the time of day. The ionic densities are a function of time of day, time of year, time of sunspot cycle, geographical location and incidence of such phenomena as ionospheric disturbances. Thus, a frequency of transmission which is satisfactory for transmission at one time of day or year may be useless at another time, and to provide a continuous service it is necessary to have available a number of frequencies with associated aerial systems suitable as regards both operating frequencies and optimum vertical angle. For example, the frequencies required on the London-New York circuit range from 4 to 25 Mc/s, and the optimum vertical angles range from 30° to 10° approximately, depending upon frequency, time of day and season of the year.

Basic Aerial Considerations

It is not intended to describe all the various types of short-wave aerials in use to-day, for they are legion, but to discuss in simple terms the principles underlying the design of short-wave aerials in such a way that the application of these principles to any specific type of aerial can be understood.

Radiation.

The term radiation, as applied to radio aerials, is used to denote the process whereby electromagnetic energy generated by a transmitter is transferred to free space in the form of electromagnetic waves. The aerial is thus the

* This article reproduces the Paper read before the London Centre of the Institution in May, 1954.

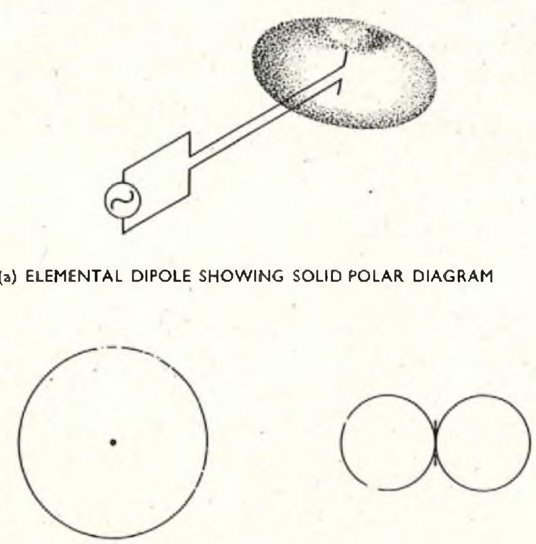
† The authors are, respectively, Senior Executive Engineer, Executive Engineer and Assistant Engineer, Radio Experimental and Development Branch, E.-in-C.'s Office.

medium used for launching such waves. If an aerial is to act as a reasonably efficient radiator it must possess a high degree of coupling with free space, and this condition obtains when the size of the aerial is of the same order as the wavelength of the radiated wave. Hence, due to practical limitations as to the size of supporting structures, it is easier to set up an efficient aerial at high frequencies than at low ones.

Radiation from an aerial must give rise to a loss of power, and the effect this has on the transmitter is equivalent to a similar amount of energy being dissipated in a resistance appearing as a component of the input impedance of the aerial. This resistance is proportional to the degree of coupling between the aerial and free space, and so serves as an indication of the radiating ability of an aerial. The power radiated by the aerial is equal to the product of this resistance value and the square of the current flowing in it. Not all the power supplied to an aerial is radiated, some being dissipated in ohmic losses in the wires, and some in the surrounding media, particularly the ground. For simple short-wave aerials, however, these losses are so small as to be negligible, and this implies that the resistive part of the input impedance is virtually that due to radiation resistance alone. Typical figures for the radiation resistance of short-wave aerials lie between 40 and 600 ohms, depending upon the structure and arrangement of the aerial.

Elemental Radiator and Polar Diagram.

The factor of greatest interest in the transmitting case is usually the field strength produced at a distant point. Clearly, this will depend upon the magnitude of the distance, the quantity of power radiated, and the distribution of energy in space around the aerial. Electromagnetic fields set up by an aerial can be divided into induction and radiation fields. The former predominates in the near vicinity of the aerial, but decreases inversely with the square of distance and rapidly becomes of little or no significance; the latter, however, decays only inversely with distance, and persists at long distances making possible radio communication. Considering the distribution of energy about an aerial, it is convenient for theoretical studies to use the concept of an aerial which radiates energy equally in all directions, and hence is termed an isotropic radiator, but which has no practical form. From an engineering standpoint a more useful elemental aerial is the dipole. This consists of two conductors arranged colinearly with small spacing between the adjacent ends, which are connected to a balanced generator, as shown in Fig. 2(*a*). A dipole radiates equally well in all directions in the plane perpendicular to the line of the conductors, but in the plane containing the conductors the radiation in any direction is nearly proportional to the sine of the angle which the direction makes with the line of the conductors. Hence for directions in line with the conductors the radiation is zero, rising to a maximum for directions perpendicular thereto. The dipole is thus a simple form of directional aerial, and its performance can conveniently be delineated by plotting for any desired plane the relative strength of the radiated wave against angular direction; the resulting diagram is termed the polar diagram for the particular plane considered. For a simple dipole only two planes need be considered, the one perpendicular to, and the other containing, the line of the conductors. As shown in Figs. 2(*b*) and 2(*c*) the polar diagram in the former is a circle, and in the latter is a figure-of-eight comprising two circles tangential to the line of the conductors. It should be noted that the total radiation is three-dimensional, and is most truly expressed as the solid polar diagram shown, which is the solid figure delineated by rotating the figure-of-eight about the line of the conductors. However, such solid polar diagrams are difficult to depict, and the same information is normally presented in the form of two polar diagrams in two mutually perpendicular planes.



(a) ELEMENTAL DIPOLE SHOWING SOLID POLAR DIAGRAM

(b) POLAR DIAGRAM IN PLANE PERPENDICULAR TO LINE OF DIPOLE i.e., EQUATORIAL PLANE

(c) POLAR DIAGRAM IN PLANE OF DIPOLE

FIG. 2.—RADIATION DUE TO A DIPOLE.

The solid polar diagram, or alternatively the two plane polar diagrams, indicate the directional distribution in space of the energy radiated from the dipole. The same amount of energy radiated from an isotropic radiator would be distributed equally in all directions, so that the corresponding solid polar diagram is a sphere; the corresponding plane polar diagrams are single circles in each case. It can be seen that, since along the line of the conductors the dipole radiates less of the total energy than the isotropic radiator, it must necessarily radiate more in some other directions, and particularly so at right-angles to the line of the conductors. In this latter direction, therefore, the radiation from the dipole is greater than from the isotropic radiator for equal total radiated powers, and the ratio of these two quantities is referred to as the "gain" of the dipole relative to the isotropic radiator (in the plane perpendicular to the line of the conductors).

Half-wave Dipole.

If the two conductors or elements of a dipole are increased in length there is little change in the shape of the polar diagram in the plane of the conductors, provided the length of each element does not exceed a quarter of a wavelength. A dipole consisting of two elements each exactly an electrical quarter-wavelength long, i.e., a half-wavelength dipole, possesses an important property in that its input impedance is purely resistive and is always 73 ohms irrespective of the actual wavelength. As discussed earlier, therefore, this also represents the radiation resistance, and hence the radiated power can be ascertained very simply since the current entering the dipole terminals is also that flowing through the radiation resistance. This property of the half-wave dipole, and also the relatively simple nature of its polar diagram, has resulted in the widespread use of this aerial as a practical reference against which to compare the performance of other aerials, particularly those of a complex nature, the performances of which are not always accurately predictable.

Input Impedance.

The input impedance of an aerial is not always purely resistive and can contain large reactive components; such components do not in themselves impair the efficiency of the aerial as a radiating medium, but they do so indirectly in that they make impedance matching to the transmitter very difficult, especially where high-power operation is involved. To quote a typical instance, the input impedance of a wire dipole with elements one-tenth of a wavelength long is about $10 - j\,3{,}000$ ohms; to give conjugate matching with a resistive 10-ohm generator by the provision of inductive reactance is not readily possible without the introduction of a significant amount of resistance, which could dissipate some of the available output power and thus reduce the amount radiated. Care is taken therefore in the design of aerials to promote input impedances which are nearly or wholly resistive, a condition which is usually realisable with most types of short-wave aerials.

Although the input impedance of a half-wave dipole is purely resistive at its design frequency, at frequencies both above and below this the impedance has large reactive components which, as shown above, seriously affect the performance of the aerial. In consequence this type of aerial is narrow-band in its operation, being restricted in use to a band ± 10 per cent. on either side of its design frequency. (A further cause of restriction is that the polar diagram begins to become more complex at frequencies above the design frequency.)

Full-wave Dipole.

The full-wave resonant dipole is used mainly as the unit aerial in array systems, for the reason that its resistive input impedance can be controlled by simple means over wide limits without affecting its radiating properties, thus facilitating impedance matching. Control is effected by varying the diameter of the elements, and values of input resistance realisable in practice range from 600 ohms for large diameter tubular elements to 10,000 ohms for thin wire elements.[1] This input resistance does not, however, represent the radiation resistance as in the case of the half-wave dipole. The radiation resistance of a full-wave dipole is 196 ohms, and can be regarded as being located half at the centre of each element, and undergoing impedance transformation between these points and the dipole terminals.

Polarisation.

An electromagnetic wave radiated from a dipole comprises two components, an electric vector lying in the plane containing the elements and the direction of propagation, and a magnetic vector in the plane perpendicular to the elements and containing the direction of propagation. It is conventional to regard the plane containing the electric vector as the plane of polarisation of the wave—thus a dipole with the line of the elements vertical radiates a vertically polarised wave, and a horizontal dipole radiates a horizontally polarised wave.

Reciprocity.

So far, only the transmitting aspect of aerials has been considered, but the properties of an aerial when used to abstract energy from a radio wave can be regarded as the same as when acting as a radiator. The relative response to waves arriving from different directions is the same when receiving as the relative values of field strength radiated in the same directions when transmitting, for the same aerial. The reciprocal relations make it possible to deduce the performance of receiving aerials from transmitting tests, and vice versa.

[1] "Theory of Antennas of Arbitrary Sizes and Shape," S. A. Schelkunoff, *Proc.I.R.E.*, Vol. 30, p. 493, 1942.

Arrays of Resonant Dipoles

"Broadside" Arrays.

The half-wavelength dipole aerial provides little directivity in itself, but directivity may be obtained by the use of suitably designed arrays of dipoles. Fig. **3** illustrates the principle involved. Points A and B represent two identical aerials (for simplicity, isotropic aerials, i.e., point sources) spaced a distance d apart and energised in phase.

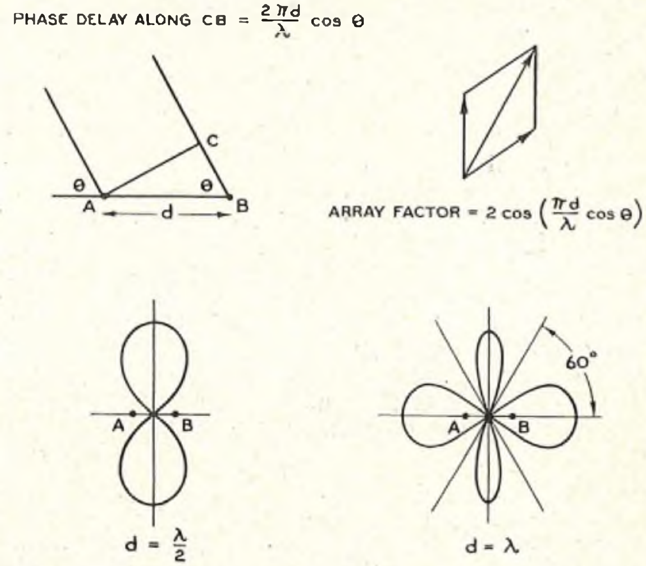


Fig. 3.—Horizontal Radiation Patterns of Two Spaced Isotropic Aerials energised in Phase.

In the direction perpendicular to AB the signals from the two aerials are always in the same phase and are therefore additional. On the other hand, in a direction at angle θ to AB, as shown, the signal from B will lag behind the signal from A by

$$\frac{CB}{\lambda} \times 2\pi \text{ radians, i.e., by } \frac{2\pi d}{\lambda} \times \cos\theta$$

Thus the vector sum of the two signals will vary with angle θ, being zero when $\frac{2\pi d}{\lambda}\cos\theta = \pi$, when complete cancellation of the two signals is realised. A typical array design uses a spacing between aerials of one half-wavelength, i.e., $d = \lambda/2$, and it can be seen that in this case cancellation, i.e., zero radiation, occurs in the direction $\theta = 0$. For a spacing of one wavelength, i.e., $d = \lambda$, zero radiation occurs when $\cos\theta = 0{\cdot}5$, i.e., in the direction at 60° to the line AB. In this case for the direction along AB the signals add in phase, being 2π radians apart in phase. Diagrams of the horizontal radiation patterns for these two spacings of two aerials are shown in the lower part of Fig. **3**.

In the above cases, consideration of the vector diagram shows that the array factor, i.e., the factor by which the polar diagram of the unit aerial is multiplied, is given by $2\cos\left(\frac{\pi d}{\lambda}\cos\theta\right)$. For n equally spaced aerials energised in phase the array factor is given by the general expression

$$|A| = \frac{\sin n\phi/2}{\sin\phi/2},$$

$$\text{where, } \phi = \text{constant phase difference} = \frac{2\pi d}{\lambda}\cos\theta$$

(Substitution of $n = 2$ in this expression can be seen to give the formula already quoted.)

This expression always has a maximum when $\theta = \pi/2$ and $3\pi/2$, i.e., the maximum field is in the direction at right-

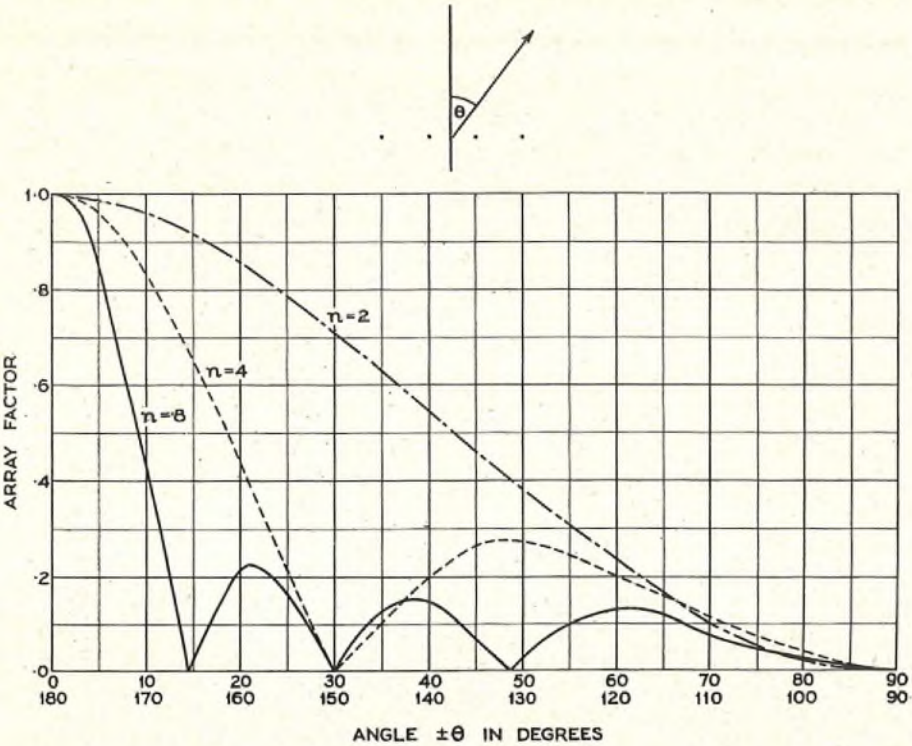


FIG. 4.—ARRAY FACTOR FOR n ISOTROPIC POINT SOURCES OF EQUAL AMPLITUDE SPACED $\lambda/2$ APART.

angles to the line of the array. This arrangement of in-phase sources is termed a broadside array, and the array factors for broadside arrays containing 2, 4 and 8 sources respectively are shown in Fig. **4**. It should be appreciated that the array factor, and the consequential directivity, applies only in the plane containing the line of the array and the direction of shoot—thus a horizontal broadside array results in improved directivity in the horizontal plane only, while a vertical array gives vertical directivity. The resulting polar diagram of the array is then determined by multiplying the polar diagram of the unit aerial by the array factor.

It will be seen from considerations of symmetry that such arrays in their simplest form are bi-directional; however, if an array is required to be unidirectional the energy transmitted in the unwanted direction can be reflected by locating a similar array one-quarter wavelength behind the main array. The second array, which is not energised, is termed a parasitic reflector. Energy reaching the reflector is re-radiated with a phase change of 180° and, since the two arrays are identical, complete cancellation of the original and re-radiated energy occurs in the backward direction; in the forward direction the re-radiation phase change of 180°, taken in conjunction with the half-wavelength total path length from driven array to reflector and back to driven array, ensures that the re-radiated transmission reinforces the original transmission. A widely used broadside array is the Kooman's array.[2] A typical Kooman's array as shown in Fig. **5** might consist of two bays, each comprising four horizontal full-wave-length dipoles arranged in vertical stack with half-wavelength spacing in the vertical plane, the two bays being side by side in the plane of the elements with one wavelength spacing between centres. An identical pair of bays spaced a quarter-wavelength behind the driven bays serves as a reflector. In each bay the four dipoles are fed by a transmission line in which transpositions take place between dipoles so that all the dipoles are energised in phase. In such an array the impedance of each dipole would be about 4,800 ohms, giving an impedance of 1,200 ohms for each bay, so that the two driven bays connected in parallel offer a good impedance match to a 600-ohm transmission line. Fig. **6** gives a general view of a typical Kooman's array operating on about 15 Mc/s, with principal dimensions shown. Such an array would have a gain of about 12 db. relative to a half-wave dipole over a frequency band of about 1·5 Mc/s. It is of interest to note that such

[2] "Beam Arrays and Transmission Lines," T. Walmsley, *J.I.E.E.*, Vol. 69, p. 30, 1931.

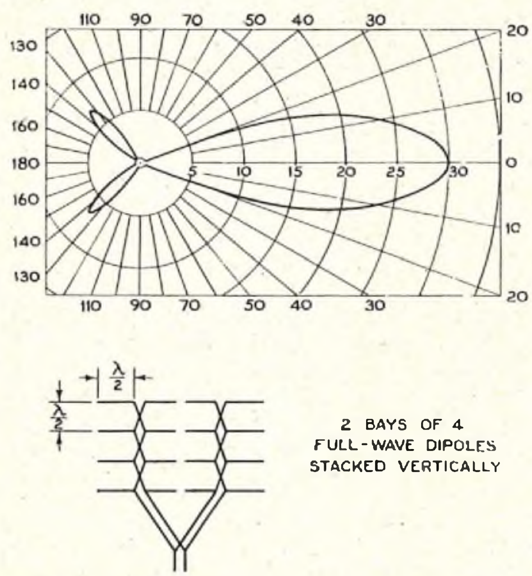


FIG. 5.—HORIZONTAL POLAR DIAGRAM OF KOOMAN'S AERIAL WITH REFLECTOR.

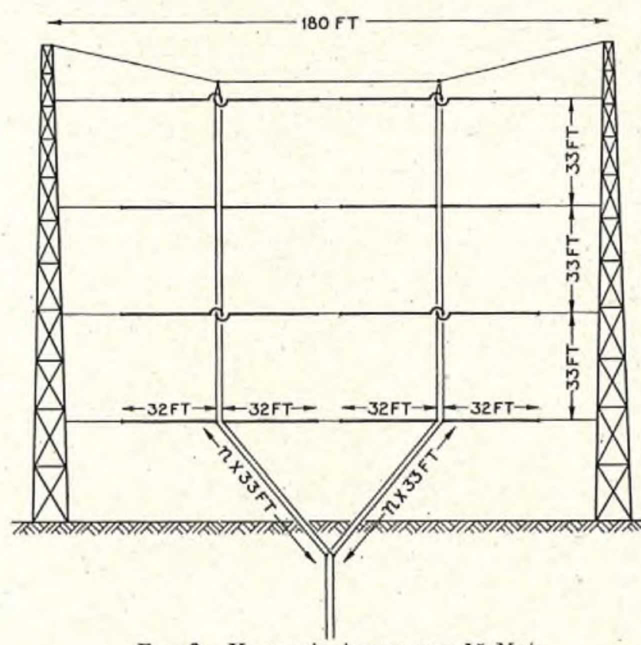


FIG. 6.—KOOMAN'S ARRAY FOR 15 Mc/s.

an array as that just described can be reversed in its direction of transmission by reversing the roles of the driven array and the reflector. Furthermore, the aerial can be "slewed horizontally," i.e., off-course, by altering the phase relationship of the two bays of the driven array from the normal in-phase condition.

"End-Fire" Arrays.

Another method of building up an array of dipoles is illustrated in Fig. 7. Points A and B represent two point

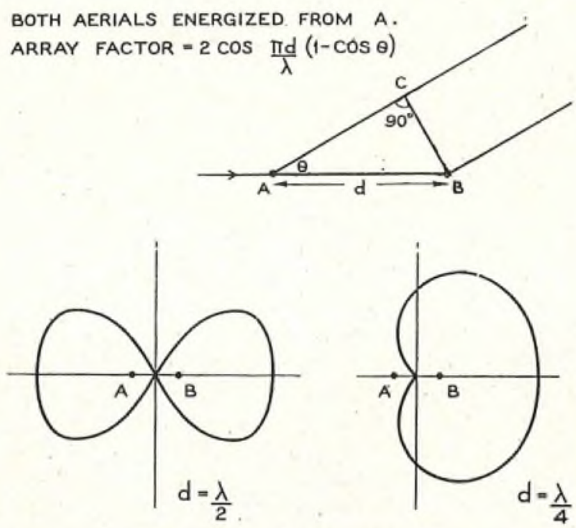


FIG. 7.—HORIZONTAL RADIATION PATTERNS OF TWO SPACED END-FIRE FED ISOTROPIC AERIALS.

source aerials spaced a distance d apart and connected by a transmission line. Energy for both aerials is applied at A, so that B lags behind A in phase by an amount $2\pi d/\lambda$. It can be seen that, assuming the velocity along the transmission line is the same as that in free space, the signals from the two aerials are always in phase in the direction AB.

In a direction AC at angle θ to AB, signals from aerial B will lag in phase behind those from A by an amount $\frac{2\pi d}{\lambda}(1 - \cos\theta)$. Thus the vector sum is a maximum when $\theta = 0$, i.e., along the direction A to B as stated above, and is zero when $\frac{2\pi d}{\lambda}(1 - \cos\theta) = 1$. For a spacing $d = \lambda/2$, this occurs when $\theta = \pi/2$ and $3\pi/2$, corresponding to zero at right angles to the line of the array. For a spacing $d = \pi/4$ zero radiation occurs when $\frac{2\pi d}{\lambda}(1 - \cos\theta) = 1$, i.e., $\theta = \pi$, corresponding to zero radiation along the direction B to A. Diagrams of the horizontal radiation patterns for two-unit end-fire arrays with spacings of $\lambda/2$ and $\lambda/4$, respectively, are shown in the lower part of Fig. 7.

For these cases where only two aerials are considered the array factor is, $2\cos\frac{\pi d}{\lambda}(1 - \cos\theta)$. For n such equally spaced aerials the array factor is given by

$$|A| = \frac{\sin n\phi/2}{\sin\phi/2}, \quad \text{where } \phi = \frac{2\pi d}{\lambda}(1 - \cos\theta).$$

When $d = \lambda/4$ an array of point sources has a unidirectional polar diagram. A feature of the end-fire array is that the array factor and the resulting directivity applies equally to the horizontal and vertical planes.

A typical end-fire array of dipoles used for reception, known as the H.A.D. array, consists of two bays, each comprising 10 full-wave dipoles, spaced a quarter wavelength apart along a horizontal terminated transmission line. The array is shown in schematic form in Fig. 8,

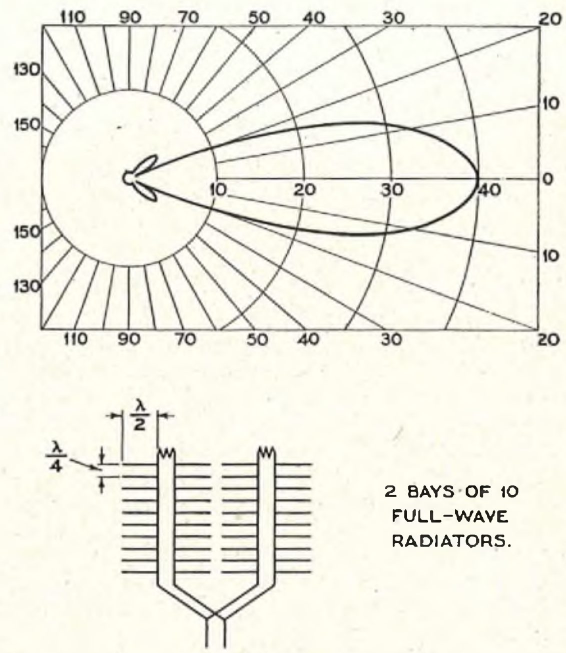


FIG. 8.—HORIZONTAL POLAR DIAGRAM OF STANDARD H.A.D. ARRAY.

together with the horizontal free-space radiation diagram. If required this type of array can be double-ended, in which case the terminations are removed and the two bays paralleled at each end, both ends being connected to feeders.

Such an array for operation on 16 Mc/s would have a gain of about 15 db. over a frequency range of 5 or 6 Mc/s.

(*To be continued.*)

Book Review

"Direct-Current Circuits." 2nd Edition. Earle M. Morecock. McGraw-Hill Publishing Co. Ltd. 388 pp. 40s.

An outstanding feature that is common to all the publications by the McGraw-Hill Company is the first-class finish and presentation given to their books. The second edition of "Direct-Current Circuits" is splendidly produced, with illustrations that are up to the standard of the rest of the text.

The book is based on a lecture-series at the Rochester Institute of Technology and so its lay-out follows American teaching practice. For example, only a very limited knowledge of mathematics is assumed, with no calculus and very little trigonometry; so that, as physical aspects of D.C. engineering are discussed to a standard just beyond that of Grade II in Telecommunications Principles of City and Guilds of London Institute examinations, a number of unproved statements must be accepted by the reader. This gives an air of simplicity to the subject that may prove the undoing of new students.

This is not a book for serious students intending to advance well into the realms of electrical engineering. It is more suitable for those who make their first entries into electrical engineering when their normal school-days are over, and a volume that is easy to read in an armchair is more welcome than a heavy text demanding concentration. There are numerous worked examples throughout each chapter to keep them awake. C. F. F.

The Transistor

H. YEMM, B.Sc., and J. I. CARASSO, B.Sc.†

Part 4.—The Making of Transistors

U.D.C. 621.314.7: 546.289

Although the underlying principles of point-contact and junction transistors are the same and the preparation of suitable germanium or other semiconducting material is common to all types, the physical forms of the point-contact transistor on the one hand, and of the several types of junction transistor on the other, are so different that the making of the units involves the solutions of different sets of problems. The main problems and the solutions commonly adopted are discussed.

The Point-Contact Transistor

THERE are four main stages in the making of point-contact transistors:—

1. The preparation and surface treatment of the germanium.
2. Making the point-contact whiskers.
3. Assembly of the germanium pellet and whiskers.
4. Electrical forming to produce desirable electrical characteristics.

Preparation of the Germanium.

The methods employed in the preparation of the germanium and in cutting it into suitably sized pellets have been described in Part 3.[1]

The germanium used may be either n-type or p-type. Although double the bandwidth can be obtained with p-type than with n-type germanium, the current gain, α, (dI_c/dI_e) is much smaller and it is customary therefore to use n-type germanium for point-contact transistors.

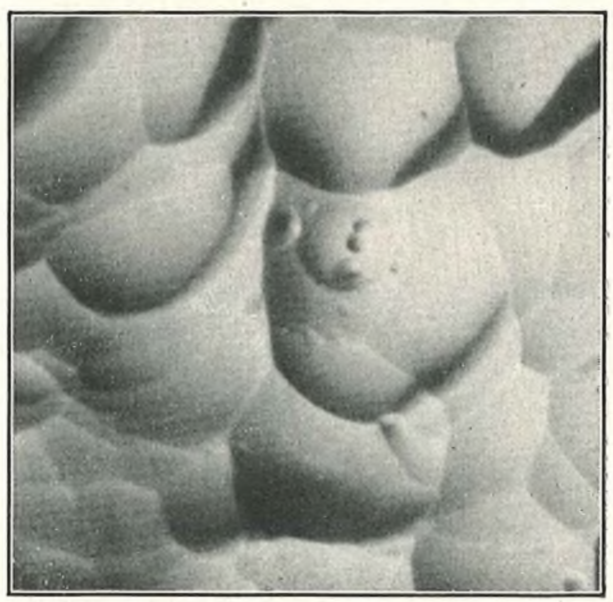
Values of α approaching the maximum value of about three (at values of I_e greater than 1 mA) can only be obtained if the lifetime, τ_p, of the minority carriers (holes in n-type germanium) is sufficiently long that there is negligible loss of holes by recombination with electrons during their passage between emitter and collector. Experimental evidence shows that if τ_p is greater than about 5 μsec. values of α greater than 2·5 can be obtained, even with point-contact spacings as large as 0·1 mm. If, however, the transistor is to be used for switching purposes, e.g., in trigger circuits, the time taken for the holes to recombine may limit the speed of switching and it may become necessary to use germanium of shorter lifetime. To maintain the value of α it would then be necessary to use smaller point-contact spacings.

The choice of the value of the resistivity of the germanium is governed by the following considerations. High resistivity material enables (*a*) the collector to withstand a high voltage, and (*b*) a high hole-emission efficiency at the emitter to be obtained, helping to provide large values of α. There is also some evidence that a larger bandwidth can be obtained with high resistivity material. But, because the base resistance r_b (dV_e/dI_c, I_e constant) is then large, there is less margin against instability; further, the maximum useful working temperature of the transistor is reduced. A compromise in the value of the resistivity has therefore to be made. Although point-contact transistors have been made using germanium of resistivity between 1 ohm-cm. and 20 ohm-cm., material of resistivity of about 5 ohm-cm. has been commonly used for general-purpose units.

Germanium pellets of suitable size have an area of about 1 sq. mm. and a thickness of about 0·5 mm. The larger the area or the smaller the thickness, the smaller is that part of r_b contributed by the bulk resistance of the germanium pellet. The part of r_b arising from the non-uniform current flow close to the point contacts, increases with decrease of point spacing and can predominate for closely-spaced point contacts.

The pellet is soldered to the base-connecting wire with a tin or tin-lead solder. The solder should contain enough donor impurity (e.g., 2 per cent. of antimony) to over-compensate any p-type impurities in the solder. A non-hole-injecting base connection is thus ensured, which is of small resistance if the area of germanium wetted by the solder is relatively large. Wetting of the germanium with solder by the use of a soldering iron (temperature of the bit about 350°C) cannot be satisfactorily achieved even with the use of permitted fluxes. Fluxes containing metals are liable to cause degradation of the electrical characteristics of the germanium surface, and the contamination is not readily removed after the soldering. Satisfactory wetting of clean germanium (cleaned by light etching) is obtained with the use of a vacuum furnace operated at about 500°C for a few minutes.

Good transistor action depends on the surface treatment of the germanium. The aim of the treatment is to produce a surface which, having a low rate of recombination of holes, enables high values of α to be obtained. After completing the soldering operation, the surface is first lapped on glass with a fine-grade emery powder and is then etched. At least two satisfactory methods of etching are known. In one method etching is done by immersing the pellet in "CP4" for 1 to 3 minutes at room temperature (about 20°C); the pellet is then washed with distilled water and dried with alcohol or acetone. In the other method the pellet is immersed in boiling H_2O_2 for about 5 minutes before washing and drying. The appearances of the surfaces obtained by the two methods are distinctly different, as shown by Figs. **10** and **11**. The light etch with CP4 gives a glassy finish which at high magnification shows a mosaic structure, with deep etch pits superimposed, as seen in

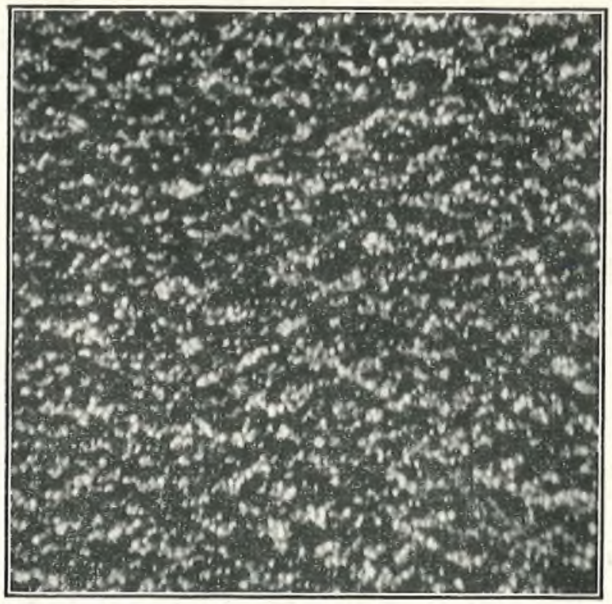


(Scale: 1·7 cm. = 100 microns)

FIG. **10**—SURFACE OBTAINED BY ETCHING WITH "CP4."

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

[1] *P.O.E.E.J.*, Vol. 47, p. 166.



(Scale: 1·7 cm. = 100 microns)

FIG. 11.—SURFACE OBTAINED BY ETCHING WITH H_2O_2.

Fig. **10**. This structure is believed to be related to one or more types of dislocations emerging from the underlying crystal. The H_2O_2 etch gives a matt finish which at the same magnification shows the fine-grained structure reproduced in Fig. **11**.

Making of the Whiskers.

Although many metals and alloys are suitable for the emitter whisker, one very commonly used with n-type germanium is beryllium-copper. One theory and some experiments suggest that the material of the collector with n-type germanium should contain a donor impurity; phosphor-bronze wire (phosphorus being a donor), which is readily obtainable, is generally used, but the proportion of phosphorus is known to be very variable and difficult to control.

In order to obtain a close and well-defined spacing between emitter and collector contacts (necessary for good frequency response) it is desirable to shape the whisker tips so that the areas of contact between whiskers and germanium are approximately elliptical. The minor axes of the whisker tips should be in line and should be small compared with the spacing. The whisker tips can be shaped as shown in Fig. **12**, by cutting the wire in a guillotine and polishing the cut surface with fine-grade emery paper. The finish of the tip should be such that the area of contact determined by the load and the hardness of the metal is well defined. The load is determined by the deflection of the whisker as a cantilever or spring, the stiffness of which increases rapidly with increase of diameter of the whisker wire. Small diameter wire is desirable for producing areas of contact having small minor axes, but the use of too fine a wire leads to insufficient stiffness with a consequent lack of mechanical stability. A compromise has therefore to be made. Wire of about 0·1 mm. diameter is commonly used.

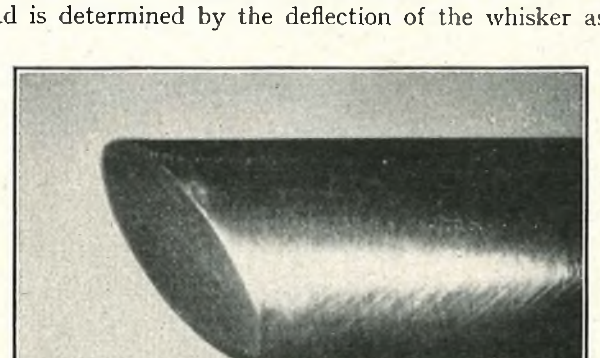


FIG. 12.—SHAPE OF WHISKER TIP.

Two shapes of whisker in general use are shown in Fig. **13**, and are made by bending the wire in suitable jigs.

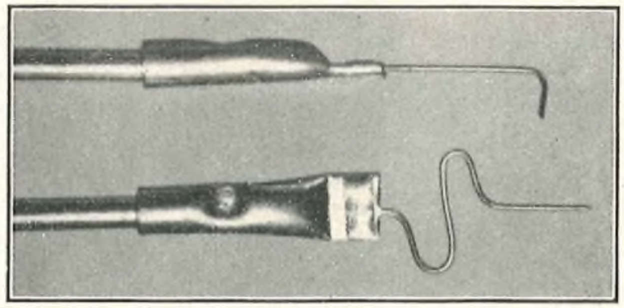


FIG. 13.—TWO SHAPES OF WHISKER IN GENERAL USE.

The whiskers are either crimped, welded or soldered to the emitter and collector leads.

In order that the whiskers shall be stiff they should be as short as possible. For comparable sizes the "S" type whisker is less stiff for sideways deflections than the "L" type. Even with whisker lengths as short as 2 mm. (shorter lengths become difficult to handle) it has been found that the stiffness of either type of whisker is not enough to allow the transistor to be dropped on to a hard surface from a height of only 2 ft. without displacement of the contact points. Increased mechanical stability can, however, be obtained by embedding the whiskers and the germanium pellet in a suitable plastic. The embedding technique is described later.

Assembly.

The collector and emitter leads are either held in a jig or fitted into a body of suitable material. The separation of the whisker points is then adjusted, by bending the leads with the aid of a jig, to the approximate spacing required, observation being made through a microscope. The etched surface of the germanium is now brought into contact with the two whisker points (see for instance Fig. **1** of Part 1[2]), which in the previous adjustment have also been positioned so that contact with the advancing germanium is made simultaneously. The whiskers are now deflected by further advancing the germanium until there is sufficient force (e.g., 1 to 10 grams) between the whisker contacts and the germanium to ensure good electrical contact. During the adjustment of the whisker deflection, sliding of the whisker contacts on the surface of the germanium occurs. Whereas the sliding with the L-shaped whisker is small, that with the S-shaped whisker can be considerable. A further adjustment of the contact separation is thus necessary. This part of the assembly is a very delicate operation and demands particular care if units with very small separation (e.g., 0·02 mm.) are desired in order to ensure very large bandwidths, e.g., 40 Mc/s (bandwidth is approximately inversely proportional to the cube of the effective separation). Pieces of mica, about 0·02 mm. thick, placed between emitter and collector contacts have been used in one design to ease the adjustment of the spacing. Even so, great care is necessary in the positioning of the whiskers, to ensure that a line joining the two contacts is approximately

[2] *P.O.E.E.J.*, Vol. 47, p. 92.

normal to the plane of the mica sheet, and that the whisker contacts are in contact with the mica. The whiskers and the germanium, together with a small portion of their associated lead wires, are then embedded in a thermosetting resin which serves to bond the unit and render it relatively stable against mechanical shock. Transistors made as described can withstand repeated dropping from a height of 6 ft. or more on to a hard floor without showing any detectable changes of their electrical characteristics. The increase of volume of some types of resin at temperatures 10°C-20°C in excess of the curing temperature is sufficient to lift the whiskers off the germanium. It is therefore necessary that the curing temperature should be sufficiently in excess of the maximum working temperature of the transistor. If the contact separation is to be adjusted at room temperature and maintained up to the curing temperature, the coefficients of linear expansion of the materials of the jigs or of the transistor body must be approximately the same as those of the whisker materials.

Water vapour can diffuse through the resin in sufficient quantity to alter considerably the surface conductivity of the germanium, and degradation of the electrical characteristics may result. A more important effect is that absorption of water vapour causes the resin to swell and thus to lift the whiskers off the germanium. Hermetic sealing of the unit is therefore necessary if transistors are to be stored or used in damp situations, but the problems associated with such an operation have yet to be satisfactorily solved.

Forming.

The power gain, which it is desired to make as large as possible, is proportional to $\alpha^2 r_c$ (r_c is the collector resistance). In general, unformed transistors do not provide sufficiently large values of $\alpha^2 r_c$. For use in switching circuits α should be greater than 1·5 and preferably not less than 2, and I_{c0} (the collector current when $I_e = 0$) should be as small as possible. In unformed units α is usually considerably less than 0·5, and, with 5 ohm-cm. germanium, r_c is about 100kΩ and I_{c0} is less than about 0·1 mA at a collector voltage of −10V.

Forming of the collector causes considerable changes of the above parameters, resulting in transistors suitable for amplification and switching. Forming is achieved by intensely heating the germanium in the vicinity of the collector contact. This is usually done by discharging a capacitor (of up to 0·1 μF) charged up to 150-350V, between the collector and base or between collector and emitter, the collector being connected to the negative terminal. The degree of forming can be varied by controlling the values of the capacitor and the voltage. Whereas the value of α increases as forming is increased, until a maximum of between two and three is obtained, the value of r_c decreases to about 10kΩ-25kΩ, with, however, a net increase of $\alpha^2 r_c$. Further forming results in the reduction of r_c without a corresponding increase of α, (so that $\alpha^2 r_c$ decreases) until finally a crater is formed in the germanium and the unit is destroyed. Although the bandwidth may increase about ten times, the value of I_{c0} also increases with increase of forming. The operator has to try to form the transistor to obtain the parameters within specified ranges, success depending to a large extent upon his individual experience and judgment.

Even now the action of a formed point-contact collector is little understood. It has been established, however, that during forming some melting of the collector contact and of the germanium in its vicinity occurs. It has been suggested that copper from the whisker diffuses rapidly into the germanium and thereby forms a p-type layer of germanium and that the phosphorus forms an n-type layer of germanium on the surface. The two layers so formed constitute a "p-n hook" which theoretically could account for the current gain of greater than unity. At least one other theory has also been proposed.

p-n Junction Transistors

The properties of p-n junctions which make them suitable for incorporation into crystal devices have been described in Part 2[3] of this series. From a metallurgical standpoint, such junctions may be defined as regions in an otherwise homogeneous crystal lattice in which a more or less abrupt change in the relation between the concentrations of donor and acceptor impurities takes place: simple contact between a piece of p-type material and a piece of n-type material will not produce a good p-n junction.

The robustness of a p-n junction renders it mechanically far superior to a point contact for diode and transistor construction, and the more complete understanding of its electrical performance permits a better control in terms of the production processes involved. Because of the very high internal impedance of the p-n junction under reverse bias the apparent characteristics of a junction device may be seriously modified by surface leakage and the utmost care is required in surface treatment, and in encapsulating the unit.

In the following paragraphs three methods for the production of p-n junction diodes or transistors will be discussed.

Diffused Junctions.

A theoretically simple method of producing a p-n junction consists of allowing a "p-type impurity" to diffuse, at elevated temperature, from the surface into an n-type semi-conductor, or vice versa. Under these conditions, if the temperature is uniform and the diffusion is stopped after a time t, the concentration of the diffusing substance is given by $C = C_o \, erfc\left(\frac{x}{2\sqrt{Dt}}\right)$ where $erfc$ is the gaussian error function complement of the argument $x/2\sqrt{Dt}$, x is the distance into the semi-conductor and D is the relevant diffusion constant (depending on the nature of the diffusing substance, and the temperature at which diffusion is carried out).

A transition from p- to n-type will take place at the point where the concentration of diffusing acceptors just equals that of the supposed uniformly distributed donors (Fig. **14**). Within limits it is theoretically possible to vary both the location and the differential impurity concentra-

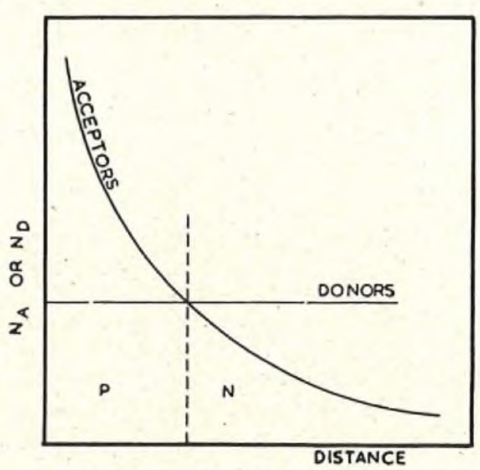


Fig. **14**.—A Diffused Junction.

[3] *P.O.E.E.J.*, Vol. 47, p. 94.

tion gradient by appropriate choice of initial surface concentration and time of diffusion, but the method has been found to have serious technological limitations. The chief of these is the low diffusion constant of those impurities which are of interest, even at temperatures close to the melting-point of germanium, except for copper and nickel, which, however, are subject to precipitation on subsequent cooling and moreover behave electrically as both acceptor and recombination centres.

Grown Junctions.

In this method a crystal is grown by the seed-pulling method, using donor or acceptor doped material, and the conductivity type of the crystal is changed abruptly, during growth, by addition to the melt of an impurity of the opposite type to that originally present in the melt, in an amount exceeding that required to compensate the effect of the originally present impurity. This method of preparation results initially in a step junction (Fig. **15**), but diffusion

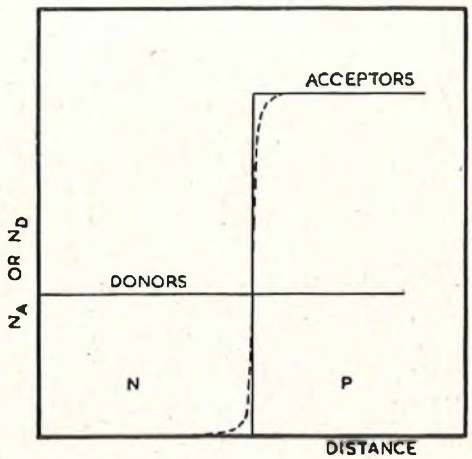


FIG. 15.—A STEP JUNCTION.

of the added impurity can be important at the temperature just below the melting-point, and results in a more or less gradual transition as shown dotted in the figure. The method lends itself very well to the production of more complex structures of controlled geometry and resistivity values, such as n-p-n transistors and p-n-p-n transistors with a p-type emitter and p-n hook collector, but the accumulation of added impurities in the melt sets a limit to the number of junctions which can be introduced into one and the same crystal.

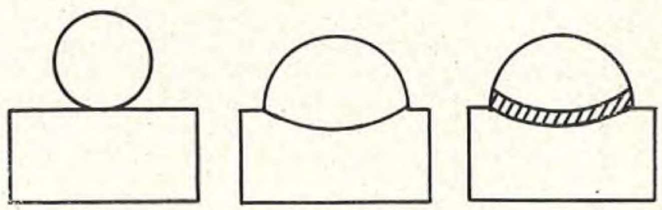
The amount of doping impurity necessary to convert the growing crystal to the required resistivity of the opposite type is readily calculated on the basis of the segregation behaviour of the two impurities used, but the practical success of the method requires stringent control of the growing conditions. In particular, the stirring must be efficient to ensure that the pellet of impurity is distributed throughout the remaining melt in as short a time as possible; the timing of the successive additions of impurity, the temperature control, and the control of the pulling speed must all be accurate to yield a structure of controlled geometry. An alternative method of producing grown-junction devices relies on the fact that the segregation constants of certain donor impurities (antimony, in particular) depend on the growing rate much more markedly than do those of acceptor impurities (e.g., gallium). Thus, the value of the segregation constant of antimony in germanium increases from 0·003 at a growing rate of 1 in./hr. to 0·010 at 9 in./hr. This enables the concentration of antimony in a crystal grown from an antimony-doped melt to be increased approximately three times simply by increasing the pulling speed. If, in addition to antimony, the melt contains gallium in an amount sufficient to introduce into the crystal a concentration of acceptors intermediate between the two donor concentrations in question, and since the segregation constant of gallium does not vary appreciably with pulling speed, it is evident that the crystal will exhibit n- or p-type behaviour according to whether it is pulled at the higher or the lower speed. The required variation of growth rate can be achieved either mechanically, by the use of suitable gears, or by modulating the heat input to the furnace. Among its other advantages, this method enables a large number of p-n junctions to be incorporated into a single crystal: up to 100 have been claimed.

Grown-Junction Transistors.—The prepared crystal is sectioned into rods approximately 1 mm. square by 3 mm. long, each of which usually consists of two n-type regions separated by a thin (approximately 0·03 mm.) p-type region. Ohmic soldered contacts are applied to both ends; the rod is etched, rinsed and thoroughly dried, and an ohmic contact is next applied to the thin base layer. This rather delicate operation is carried out by probing the surface of the transistor with a fine pointed gold wire until contact to the base region is established (as shown by electrical tests) and lightly welding the wire in position by discharging a condenser through the point contact. The transistor is then encapsulated to protect it from moisture and other forms of atmospheric contamination.

Alloy Junctions.

This process is being used to a greater extent, at the present time, than the previous one. It is based on the fact that if certain relatively low melting-point metals are melted in contact with germanium, germanium will dissolve to an extent determined by the liquid solubility of germanium in the molten metal at the temperature in question. Then, on resolidification, the germanium will precipitate out, not in a pure state but doped with the other metal to an extent determined by the solid solubility of the latter in germanium at the alloying temperature.

The successive steps are shown diagrammatically in Fig. **16**. A bead of a metal, such as indium, which acts as an acceptor impurity in germanium, is placed in contact



(*a*) (*b*) (*c*)

FIG. 16.—THE FORMATION OF AN ALLOY p-n JUNCTION.

with a block of n-type germanium (Fig. **16**(*a*)). When the combination is heated to above the melting-point of indium (155°C) the molten indium dissolves a certain amount of germanium (Fig. **16**(*b*)) depending on the amount of indium and the alloying temperature used. On cooling back to room temperature germanium, contaminated with indium, and hence electrically p-type, is deposited on the underlying n-type material which acts as a seed for its crystallisation (Fig. **16**(*c*)).

This junction, even more than the grown junction, is step-like, since diffusion is negligible at the low temperature used for alloying (about 500°). The resistivity of the p-type layer can be controlled, within limits, by selecting a suitable alloying temperature, but only a restricted range of resistivities is in general available, since the choice of the alloying temperature is also determined by the depth of penetration required. In spite of this limitation, the method has made possible the production of many useful types of device.

Alloy-Junction Transistors.—p-n-p junction transistors can be made by alloying two droplets of indium on opposite faces of a thin wafer of n-type germanium, to one end of which an ohmic soldered contact is also made (Fig. 17).

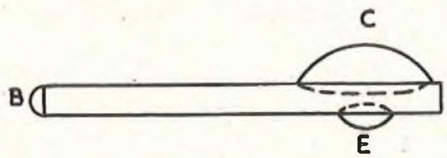


Fig. 17.—A p-n-p Alloy-Junction Transistor.

The width of the base-layer is determined by the thickness of the germanium wafer (approximately 0·1 mm.) and by the depth of penetration of the molten indium, which is a function of the amount of indium used and of the solubility in it of germanium at the alloying temperature. The collector diameter (approximately 1 mm.) is made larger than the emitter diameter (approximately 0·5 mm.) to ensure that most of the holes leaving the emitter can reach the collector. The fired unit is etched, rinsed and dried; emitter, collector and base leads are applied by means of a low melting-point solder, and the transistor is encapsulated.

Most of the transistors made by the alloy-junction process have been of the p-n-p type. Some n-p-n units have been made by an appropriate modification of the process but the superiority in high-frequency performance (due to the fact that the minority carriers in the base region are electrons) has so far been achieved at the cost of deficiencies in other directions.

Surface Barrier Transistors

Both the grown and alloy-junction triodes contain three different regions of germanium, and the control of the thickness of the intermediate layer, the base, presents a severe manufacturing problem, particularly in units designed for wideband use, when the base has to be made especially thin. Among the solutions proposed for wideband units is one involving only one type of germanium bounded by two metallic layers, one acting as emitter and the other as collector. The complete unit is called a surface barrier transistor and its manufacture seems to present no new severe problems.

The two faces of a thin slice of monocrystalline germanium are etched by two fine jets of electrolyte (indium sulphate has been used) through which current is passed, initially so as to cause germanium to go into solution. The two jets are accurately directed and two depressions form in the germanium directly opposite one another. At some controlled stage in the process, when the base thickness has been reduced to, perhaps, 0·005 mm., the current through the electrolyte is reversed and the metal of the salt in the electrolyte is deposited in the depressions. When sufficient metal has been deposited to enable robust connection to be made, the process is stopped, the unit lightly etched, the leads made to the two metallic regions (that to the germanium base is already made) and the unit encapsulated. The surface barrier transistor may not have a high value for $\alpha/(1-\alpha)$, because of the low value of the emitter injection ratio, though 10 seems easily possible, but its bandwidth may be 40 Mc/s. This type of unit has not yet been manufactured in more than experimental quantities.

Conclusions

It has been seen that the main problems involved in the making of point-contact transistors are (*a*) the mechanical one of maintaining the precise positions of the point contacts on the semi-conductor surface, and (*b*) the electrical one of "forming" the collector contact in a consistent manner to give the desired current gain and impedance. Neither of these problems exists for junction or surface barrier transistors, although the establishment and maintenance of the base connection on the grown-junction transistor presents somewhat similar mechanical difficulties.

Junction and surface barrier transistors, on the other hand, require close control of the thickness of the base region and they are very susceptible to direct electrical degradation due to humidity and certain other gas and vapour contamination. Truly vacuum-tight encapsulation appears to be essential for all types of transistor if their performance is to be maintained over a long period. The achievement of such encapsulation without damage to the active portions of the unit or undue sacrifice of its maximum performance is a basic problem in the making of transistors: a number of solutions are being developed by manufacturers in this country and abroad.

(*To be continued.*)

Book Review

"The Oscilloscope at Work." A. Haas and R. W. Hallows. Iliffe & Sons, Ltd. 171 pp. 320 ill. 15s.

As its title implies, this book deals entirely with the cathode ray oscilloscope and it was first written in French by A. Haas. Mr. R. W. Hallows has largely rewritten the original to produce this version in English.

The cathode ray oscilloscope is so much taken for granted as a laboratory tool nowadays that it is difficult to understand how earlier experimenters in the electronics field managed to do their work without one. It is almost certainly true to say that without the cathode ray oscilloscope in the laboratory, progress in electronics generally over the last 20 years would have been very much retarded, and its field of application now is so wide as amply to justify the devotion of a whole book to the subject.

The book opens with a chapter describing the general characteristics of cathode ray tubes and the circuitry associated with their use in oscilloscopes. This is followed by a description of the ways in which oscilloscopes may be used to measure the basic electrical quantities—voltage, current, impedance, frequency, phase and so on. Subsequent chapters deal with the application of the oscilloscope to measurements on various items of electronic equipment such as amplifiers, oscillators, modulators, etc.

Faults commonly met with in cathode ray oscilloscopes are dealt with in a rather brief chapter, and an even briefer one, surprisingly, is devoted to the testing of television receivers. However, it is pointed out that the latter subject is dealt with adequately elsewhere and only a brief outline is given in this book.

The concluding chapter of the book describes some of the latest improvements in cathode ray oscilloscopes including post-deflection acceleration and the use of electronic switches to give multiple beam facilities. The book is profusely illustrated and includes over 200 oscillograms photographed from the screen; it should prove a very useful addition to the laboratory worker's reference library.

T. K.

Light, Colour and Colour Television

F. J. M. LAVER, B.Sc., M.I.E.E.†

Part I.—The Measurement of Light and Colour

U.D.C. 535.65:621.397.5

This article, to be published in two parts, outlines the principles used in the specification and measurement of light and colour, with particular reference to colour television. Part 1 deals with the measurement of light and colour. Part 2 will describe the graphical representation of colour, and those characteristics of human vision that influence the design of colour-television systems.

Introduction

THE study of colour-television systems requires some knowledge of the terms and physical principles used in the measurement of light and colour. Several books and papers have recently been written on these topics,[e.g., 1–5] and the object of this article is to present a summary account of light and colour measurements based on this literature. The terms used are those recommended and defined by the Physical Society.[6]

Light and Human Vision

Light is radiant energy which can stimulate the human eye causing the sensation of vision: in round figures it includes those electromagnetic radiations having wavelengths between $0{\cdot}4\mu$ and $0{\cdot}7\mu$.* It is accepted that there are in the human retina two types of light receptors, known as "rods" and "cones." The rods operate when the eye is adapted to low levels of illumination (scotopic vision), and vision is then in monochrome. The cones operate at higher levels of illumination (photopic vision), and give colour vision. The distribution of rods and cones varies over the retina; the central area, or fovea, covering about 1° to 2° of the visual field, is tightly packed with cones alone; but with increasing distance from the fovea the proportion of cones steadily falls, and at its periphery the retina has only rods. Thus, visual acuity and colour discrimination are very high in the central area and low at the periphery of the retina.

The rods and cones differ in spectral sensitivity, as is illustrated in Fig. **1** which shows the relative visual sensitivities for each wavelength in the visible spectrum.

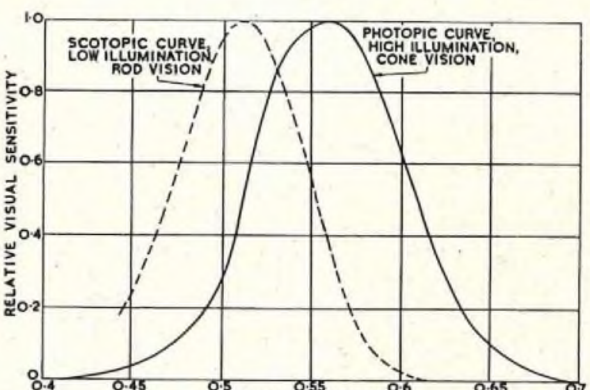


Fig. 1.—Relative Spectral Visual Sensitivity of the C.I.E. Standard Observer.

The difference between the two curves accounts for the changes that are observed in the relative brightnesses of differently-coloured surfaces as the illumination is reduced—notably a darkening of reds and oranges relative to blues and greens. This phenomenon is known after its discoverer as the Purkinje effect. Colour measurements are usually made in the range of illuminations corresponding to photopic vision.

The Measurement of Light

Light can, of course, be considered simply as electromagnetic energy and the strength of a beam of light can be specified in terms of the rate of flow of energy through unit area of its cross section, e.g., in terms of its radiant flux in watts per square centimetre. Such a specification takes no account of the varying sensitivity of the eye to lights of different colours, and while it would be satisfactory for comparing the visual effects of two beams of identical spectra, it would be inconvenient in general use. It is, therefore, usual in photometric work to measure the "amount of light" in a beam, i.e., its "luminous flux," by a visual comparison with that radiated by a standard source. The internationally standardised source is commonly known as the "candle," although its recommended international name is the "candela." One candela corresponds to $\frac{1}{60}$th the luminous intensity of one square centimetre of a black body at the melting point of platinum (2,046°K). It replaced, on 1st January, 1948, a sensibly equal unit, the International Candle, which was defined in terms of a standard pentane lamp. The unit of luminous flux is the "lumen" and equals the flux radiated in unit solid angle (one steradian) by a uniform source having a "luminous intensity" of one candle. The total luminous flux from such a source is therefore 4π lumens. For light of given spectrum there is a fixed ratio between the luminous and radiant fluxes which depends upon the visual sensitivity: the maximum photopic visual sensitivity is 680 lumens per watt, and is obtained with monochromatic light of wavelength $0{\cdot}555\mu$ (see Fig. **1**). A statement that a given light beam has a luminous flux of n lumens does not mean that it would produce a visual sensation n times as intense as that produced by a flux of one lumen, for there is no way of assessing the ratio of intensities of two sensations. The correct interpretation is that a flux of one lumen would need to be increased n times to equal the visual sensation produced by the n-lumen beam.

The "illumination" at a point on a surface is measured as the surface density of the luminous flux falling upon it. The metric units are 1 lumen/sq. metre = 1 Lux, and 1 lumen/sq. cm. = 1 Phot. The British unit is "one lumen per square foot," and can be visualised as the illumination of the inner surface of a sphere of one foot radius surrounding a uniform source of one candle power: it is therefore equivalent to the older, but not now preferred, unit, the "foot-candle." Some typical values of illumination are: 0·02 lumens/sq. ft. for moonlight, 5 to 10 lumens/sq. ft. in a well-lit living room, and 10,000 lumens/sq. ft. for direct sunlight. The intensity of the light radiated from an illuminated surface is commonly called its brightness; but the term brightness is also used to distinguish differing degrees of colourfulness, as in the contrast between bright and dull colours, and for this reason the term "luminance" is preferred for photometric brightness. Luminance can be measured in either of two ways. First, treating the surface as a source of light its luminance can be stated in candles per square foot, the area being the projected area of the surface normal to the direction of observation. The metric unit, 1 candle/sq. cm. = 1 stilb, is found to be useful for expressing the luminances of intense sources of light such as arc lamps.

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* 1μ = 1 micron = 1/1000th millimetre.

Alternatively, where diffusing surfaces are viewed by reflected light they can be dealt with in terms of a "reflection factor" which is the ratio of the reflected to the incident light. A freshly-prepared magnesium oxide surface has a reflection factor approaching 100 per cent. The product of the illumination in lumens/sq. ft. and the reflection factor gives the luminance in "Foot Lamberts." A transparent surface transmitting light can be similarly treated in terms of its "transmission factor." The name Foot Lambert is a somewhat misleading one, for it is not a compound unit like foot-lb.; the word "foot" serves to distinguish the unit from the "Lambert" which corresponds to lumens/sq. cm. A spherical source of π candles and one foot radius has a projected area of π sq. ft. and so a luminance of 1 candle/sq. ft.; and its surface illumination is π lumens/sq. ft., which for unity transmitting factor gives a luminance of π ft. Lamberts. Hence the relation 1 candle/sq. ft. $=$ π ft. Lamberts. The highlights of the images on the screens of typical British television receivers have luminances of about 20-25 ft. Lamberts, American receivers work with highlight luminances up to 60-100 ft. Lamberts, and in cinemas the highlight luminances are about 8-10 ft. Lamberts.

Colour and Human Vision

The process of "seeing a coloured light" can be divided into three groups of related phenomena, namely:

(*a*) the physical events associated with radiation of given intensity and spectral distribution falling on the observer's eye;

(*b*) the physiological events in his eye, optic nerve and brain consequent upon (*a*) that makes up his visual sensation; and

(*c*) the psychological events in his mind consequent upon (*b*) that are his perception of "a patch of coloured light."

Colour enters only at Stage (*c*) of this process, and although for a given observer only one colour perception arises from a given radiation, the converse is not true. Thus, it has long been known that most colours can be matched by mixtures of three differently-coloured lights, and that these mixtures need not have the same spectral-energy-distributions as the colours they match. This fact is used for the specification and measurement of colours in terms of three standard sources, which are commonly red, green and blue in colour. When a colour is matched by a light source of identical spectrum the colour match holds for all observers. However, when a colour is matched by a mixture of three or more differently-coloured lights the proportions of each chosen by different observers will usually differ slightly, owing to differences between the spectral sensitivities of their eyes. These differences between observers with normal colour vision are a source of error in colour measurement, though not a serious one; their effect can be reduced by taking precautions and by averaging. Observers who differ widely from the average are said to be colour blind.

Coloured lights may be mixed by combining the beams optically, or by presenting each light in turn to the observer in a sequence sufficiently rapid to prevent the appearance of flicker. Instead of adding coloured lights, a given colour can be matched by subtracting appropriate amounts of coloured light from a beam of white light by passing it through a series of coloured filter glasses. However, in practice each filter cannot be made completely transparent to the radiations absorbed by the other filters, and so the filters do not operate independently. This is the principal difference between additive and subtractive colour mixing, and is why additive mixing is used for colour measurement. The usual subtractive primary colours are magenta, a bluish-green called cyan, and yellow; these are also the paint-box primaries, for pigment mixing is a subtractive colour process.

Three independent attributes can be distinguished when perceiving the colour of a luminous source, and these are commonly classified as hue, saturation and intensity or luminosity.

Hue distinguishes red, green, blue, yellow, purple, etc., from one another, and so enables the eye to distinguish between different parts of the spectrum. Table 1, below, shows, very approximately, the hues usually associated with the parts of the visible spectrum.

TABLE 1

Wave-length (μ)	0·40–0·45	0·45–0·48	0·48–0·51	0·51–0·55	0·55–0·57	0·57–0·59	0·59–0·63	0·63–0·70
Hue	Violet	Blue	Blue-Green	Green	Yellow-Green	Yellow	Orange	Red

Saturation determines the purity of the colour, that is the extent to which it is free from dilution with white. Thus red is a saturated and pink a desaturated colour; the saturation of spectral colours is 100 per cent. and of white, zero. In ordinary speech, saturated colours are described as vivid, bright, rich or deep, and desaturated colours as pastel, pale or dull.

Luminosity is the subjective judgment of the intensity of a visual sensation: the corresponding objective measure is luminance. Achromatic sensations differ only in luminosity according to the scale: white, light greys, dark greys, black. The term "brightness" is often used instead of luminosity, but has the disadvantage that it is used also to refer to degrees of colourfulness; bright colours are necessarily saturated, but bright lights may, or may not, be saturated.

Hue, saturation and luminosity are the attributes that are most commonly used to describe a source of coloured light although they are not the only possible ones; but whatever system is used three parameters are necessary and sufficient to describe a colour.

An additional feature is associated with the appearance of reflecting surfaces, namely, "lightness," which distinguishes between surfaces reflecting greater and lesser proportions of the incident light. Lightness is not the same as luminosity, for a white object in shadow may have a higher lightness but a lower luminosity than a grey object that is more strongly illuminated.

The physical composition of a beam of light corresponds with the visual perception it produces in an observer insofar as the hue is broadly determined by the wavelengths of any predominant radiations, and the saturation depends on the degree to which those radiations exceed the rest. Subjective tests, however, have shown that the judgment of hue depends, to some extent, on other factors besides dominant wavelengths. Thus, increasing the luminosity within the photopic range, changes the hues of all except four invariable colours. The invariable colours are blue ($\lambda = 0{\cdot}478\mu$), green ($\lambda = 0{\cdot}505\mu$), yellow ($\lambda = 0{\cdot}573\mu$) and red ($\lambda = 0{\cdot}674\mu$). All other colours become increasingly like blue or yellow and decreasingly like green or red: this effect is known as the Bezold-Brucke phenomenon.[2] Again, increasing saturation causes hues near blue-green ($\lambda = 0{\cdot}488\mu$) to differ increasingly from that radiation, and hues near yellow ($\lambda = 0{\cdot}577\mu$) to become increasingly like that radiation, an effect known as the Abney phenomenon.[2] Moreover, the saturation of surface colours appears to increase as the angle subtended at the eye by the surface increases up to about 15°, a phenomenon that is well known to dressmakers who match hanks of thread and not isolated strands. On the other hand a decrease in the angle subtended below about 10′ causes a yellow surface to appear white or grey and a blue surface to appear grey or black. At still smaller angles a similar loss of colour is observed for red or green surfaces.

Changes in the total energy of a beam of light can occur in different ways, which do not lead to identical changes in appearance. Thus, for objects viewed in isolation the greater the energy emitted per unit area, the greater is the luminosity. However, under normal viewing conditions most scenes contain a variety of diffusely-reflecting surfaces whose appearance is judged almost entirely by comparison with surrounding surfaces, and their appearances change very little with changes in the general level of illumination, once the eye has adapted itself. Again, the amount of light reflected from a surface can be reduced by a strictly neutral "blackening," which does not change the spectrum of the reflected light. If a white surface, viewed among other surrounding surfaces, were blackened so that it became, say, $\frac{1}{10}$th as effective a reflector, its appearance would change from white to dark grey. On the other hand if the surface had been kept white and the general illumination had been reduced to $\frac{1}{10}$th, the surface would have continued to look white. Blackening produces familiar changes in the appearance of coloured surfaces, viewed among others, e.g., orange to brown, green to olive green, and it is an interesting fact that many common colours, brown for instance, only manifest themselves as contrasts with other lighter colours. If the reader doubts this, let him ask himself if he has ever seen an intense brown light.

The Measurement of Colour

The measurement of colour, i.e., colorimetry, depends on the principles listed below, which summarise the results of many experiments.

(1) Most colours can be matched by a mixture of not more than three differently-coloured lights. These are commonly red, green and blue, and the components of a mixture of coloured lights cannot be resolved by the eye.
(2) A colour match made at one level of illumination holds over a wide range of levels.
(3) The luminance of a mixture equals the sum of the luminances of its components.
(4) Colour matches are additive; thus if colour A matches colour B, and colour C matches colour D, then the mixture of A and C matches the mixture of B and D.
(5) Colour matches obey the law of subtraction: this follows from (4).
(6) Colour matches are transitive; thus if A matches B, and if B matches C, then A matches C.

Colour matches can be conveniently expressed as equations by using "=" for "colour matches," and "+" for "additively mixed with." Thus:

$$C = uR + vG + wB \qquad (1)$$

states that colour C is matched by an additive mixture of u units of light of colour R, v units of G and w units of B. If R, G and B are specified, and if the units for measuring the amounts of R, G and B are stated, then the equation gives a precise specification for the colour (apart from the differences between observers mentioned above). The three colours R, G, B used in any system of colour specification are called the primary colours of that system. Any colours can be used as primaries, and the choice between them is solely a matter of practical convenience. In 1931 the *Commission Internationale de l'Eclairage* (C.I.E.) standardised three spectrum colours as primaries, namely: red ($\lambda = 0{\cdot}7000\mu$), green ($\lambda = 0{\cdot}5461\mu$) and blue ($\lambda = 0{\cdot}4358\mu$). The amounts of R, G and B can be measured in any convenient way, e.g., as energy, luminous flux, luminance, etc., and the coefficients u, v and w in the colour equation are known as the "tristimulus values" for that system of colour specification. Thus, the colour equation:

$$L_C(C) = L_R(R) + L_G(G) + L_B(B) \qquad (2)$$

states that the specification for a beam of light of colour C having a luminous flux of L_C lumens is L_R lumens of R, L_G of G and L_B of B.

When lights of the three primary colours are mixed in the correct proportions to match a source of white light it is usually found that the separate luminances of the three components are far from equal. Nevertheless, white is commonly regarded as a neutral colour in which none of the colours red, green or blue predominates; and it is preferable for colour specification to adopt a system of units for measuring the amounts of R, G and B which expresses this fact, since their measurement in terms of luminance does not. Units, known as trichromatic units, are accordingly chosen so that equal numbers of trichromatic units of R, G and B are needed to match white light from some reference source. The precise white chosen is of not great importance, and the C.I.E. has in fact standardised three "white" illuminants, known as standard sources S_A, S_B and S_C. S_A represents average artificial light and is a gas-filled tungsten lamp at a colour-temperature of 2,848°K. S_B, colour temperature 4,800°K and S_C, 6,500°K, represent two grades of daylight. S_C is the reference white of the American colour-television system. There are, however, theoretical advantages to be gained by using for colorimetric calculations an equal-energy white source S_E having a uniform distribution of energy over the whole visible spectrum. Suppose that the colour-matching instrument, the colorimeter, has three apertures controlled by iris diaphragms calibrated in equal increments of aperture area from 0 to 1, each diaphragm being used to control the light from one of the three primary-colour sources. This instrument could be calibrated in trichromatic units by setting the three aperture scales to equal readings, and then independently adjusting the luminous fluxes from the primary sources until a match with an equal-energy white source was obtained. Colour matches thereafter could be read off directly in trichromatic units from the aperture scales. The trichromatic unit readings are thus direct measures of the luminance of each primary, but the scale units are different for each, and chosen so that equal numbers of units of each primary are needed to match the reference white.

Using a colorimeter calibrated as described above, a colour match for a certain quantity, c units, of a colour C might be obtained with r′, g′ and b′ trichromatic units of primaries R, G and B respectively. The corresponding colour equation is:

$$c(C) = r'(R) + g'(G) + b'(B) \qquad (3)$$

in which

$$c = r' + g' + b' \qquad (4)$$

and r′, g′ and b′ are the tristimulus values of the colour in terms of trichromatic units.

It is found in practice that colour calculations are considerably simplified when the quantity of light (in lumens or trichromatic units) is treated separately from its colour quality. The quantity factor can be removed by dividing both sides of equation (3) by "c" to obtain:

$$1{\cdot}0(C) = r(R) + g(G) + b(B) \qquad (5)$$

where:

$$\left.\begin{aligned} r &= r'/(r' + g' + b'), \\ g &= g'/(r' + g' + b'), \\ b &= b'/(r' + g' + b') \end{aligned}\right\} \qquad (6)$$

Equation (5) is known as the "unit trichromatic equation" for colour C, and its coefficients r, g and b are called the "chromaticity co-ordinates" of the colour. Since from (6), $(r + g + b) = 1$, it follows that when any two of the chromaticity co-ordinates are known the third is fixed, and so two of them are sufficient to specify the colour quality, or "chromaticity" of a light source. Chromaticity corresponds to the subjective attributes hue and saturation; although the two co-ordinates that express it do not correspond to separate measures of these two attributes. A source of coloured light can thus be completely specified by three numbers, namely, its two chromaticity co-ordinates measured with a colorimeter as above, and its luminance in candles/sq. ft. or ft. Lamberts measured with a photometer.

The chromaticity co-ordinates of reference white are, clearly, (1/3, 1/3, 1/3) and those of the three primaries are (1, 0, 0), (0, 1, 0) and (0, 0, 1). The chromaticity co-ordinates

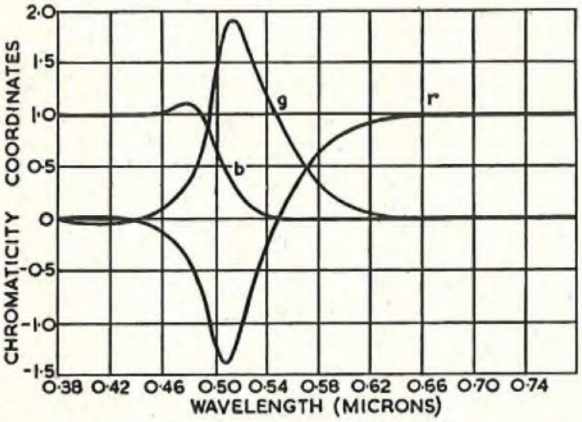

FIG. 2.—CHROMATIC CO-ORDINATES OF SPECTRAL COLOURS FOR THE STANDARD OBSERVER (C.I.E. PRIMARIES).

of the spectrum colours in terms of the C.I.E. spectrum primaries are shown in Fig. 2. It will be noted that some of the co-ordinates shown are negative, and a negative amount of light has no physical meaning. The negative quantities arise from the fact that some of the spectrum colours cannot be matched by mixing the three C.I.E. primaries R, G and B. However, these colours can be matched by two of the primaries when they are themselves mixed with the third. The colour equation, in trichromatic units, is then of the form:

$$c(C) + r'(R) = g'(G) + b'(B) \quad \ldots\ldots\ldots\ldots (7)$$

which can be written:

$$c(C) = -r'(R) + g'(G) + b'(B) \quad \ldots\ldots\ldots (8)$$

and this is how negative chromaticity co-ordinates arise and are to be interpreted.

(*To be continued*)

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[6] Report on Colour Terminology. *The Physical Society*, London, 1948.

Joint Committee for the Co-ordination of the Cathodic Protection of Buried Structures

THE above Committee has been formed for the purpose of co-ordinating the application of cathodic protection to buried structures. Evidence of the increasing use of the method in this country is provided by the fact that, although the records are not yet complete, information has already been received on some 200 installations which are either in operation or projected.

Installations by impressed current or reactive anodes are in use on water, gas, oil and sewage pipes, telephone and electricity supply cables and structures such as oil tanks and jetties.

The need for co-ordination arises largely from the fact that current circulating in the soil due to a cathodic protection installation may accelerate the corrosion of nearby structures. Methods of assessing the probability of damage in particular cases are being studied. One method of preventing such harmful interaction is to extend the cathodic protection to neighbouring structures by connecting them to the protected structure, with suitable safeguards where necessary, either directly or through resistors or other devices. It is, therefore, necessary to consider the conditions under which such interconnection of buried structures is permissible.

Membership of the Committee has been confined to representatives of organisations or industries responsible for buried structures through ownership or otherwise. At present the following organisations are represented:—

The British Electricity Authority,
The British Transport Commission,
The Gas Council,
The General Post Office,
United Kingdom Pipelines,
The Water Research Association.

Since it will ultimately be necessary to make the findings of the Committee generally available in the form of a Code of Practice, a Technical Panel has been set up having the following terms of reference:—

"to study cathodic protection with a view to the eventual drafting of a Code of Practice, with special reference to the possibility of cathodically protected systems endangering adjacent buried structures, and to joint protection schemes."

The membership consists of one representative of each of the organisations listed above, together with Dr. F. Wormwell, representing the Department of Scientific and Industrial Research, who is Chairman of the Panel.

Arrangements have been made to ensure liaison with the British Cast Iron Research Association, the British Electrical and Allied Industries Research Association, the British Iron and Steel Research Association and the British Non-Ferrous Metals Research Association.

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

B. B. GOULD†

Part 3.—Description of a Register-Translator Equipment

U.D.C. 621.395.636

Part 2 stated the requirements of a system designed to enable non-director exchange subscribers on the fringe of a director area to dial subscribers within a radius of 15 miles. The present article, concluding the series, gives a general description of a prototype electromechanical equipment which would provide the facilities required.

Design Considerations

The main requirements of the register-translator, as stated in Part 2[1] are:—

(i) To recognise any one of the 900 three-digit codes which may be dialled by a subscriber connected to a fringe area exchange.

(ii) To translate the 3-digit code into a metering digit and routing digits.

(iii) To provide various special facilities which are appropriate to some of the codes dialled, e.g., to condition the register to expect only three numerical digits on a call to a U.A.X.12 or 13.

For the London fringe area a minimum of 400 translations is required. The routing arrangements require 200 of the translations to be 4-digit and the remaining 200 to be 3-digit. In both cases an additional digit is required for metering discrimination.

Expressing these requirements in terms of cross-connection points on the translation frame of each register-translator, the number of points required is 900 for code identification, $(200 \times 5) + (200 \times 4)$ for translation digits and 400 for special facilities, making a total of 3,100 points. Equipment having a capacity of 3,100 points could be provided by four 800-point motor-uniselectors in each register-translator.

The translation frame and motor-uniselectors would be the principal items in the cost of such a register-translator. Considerable economy can therefore result if this equipment is made in the form of a common translator and shared by a number of registers. The number of registers per translator depends upon the relative holding times of register and translator. In the scheme to be described the holding time of the register would be approximately 20 seconds and that of the translator approximately 300 mS. A traffic study of the London fringe area shows that one translator per exchange would be sufficient for present and estimated future requirements.

In practice it would be necessary to provide a standby translator in order that maintenance could be carried out without interruption to the service. Two translators are therefore necessary, and the registers are divided into two groups with one translator per group. Although both translators are normally in use, arrangements are made for either to serve both groups of registers whilst the other is out of service.

The design of the translator is such that 900 translations, each comprising a metering digit and five routing digits, could be provided without any increase in equipment over and above that which would be required to provide the minimum 400 translations. With the increase in routing digits the need for intermediate registers, referred to in Part 2, may be avoided in some cases.

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[1]*P.O.E.E.J.*, Vol. 47, p. 162.

*In Part 2 the code digits were designated CDE, but in order to avoid confusion with the normal designation MCDU of numerical digits the code digits will be referred to as cde.

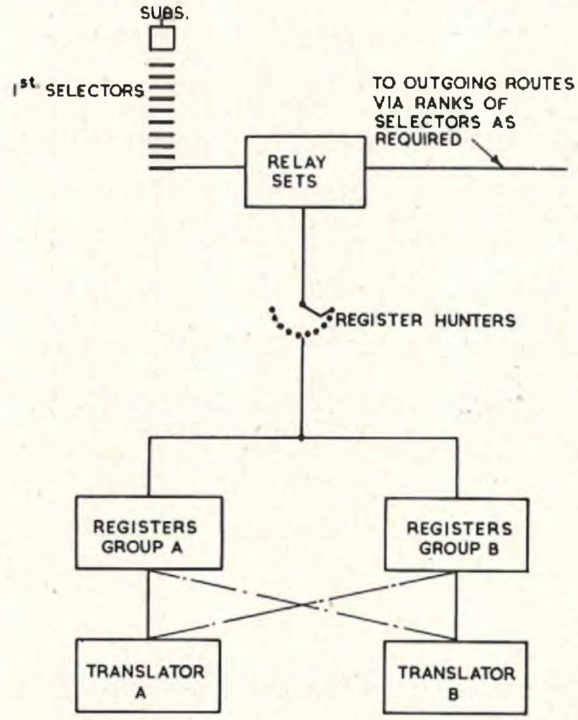

Fig. 1.—Trunking of Register-Translator Equipment.

A further advantage of the common translator is that in comparison with individual register-translators routing changes can be made more quickly and at less cost, since only two cross-connection fields are involved.

A suitable trunking arrangement is shown in Fig. **1**. (The dotted connections are only brought into use when one translator is serving both groups of registers.)

Outline of Circuit Operation

Relay Set.

On seizure from level 1 of the first selector (see Fig. 1), the relay set causes its register-hunter, which is non-homing, to search for a free register. Full availability of outlets to both groups of registers would normally be given.

The first digit dialled into the relay set, the c* digit, is stored on a uniselector and when a free register is found the digit is transferred to the register. The uniselector then drives to contact 11 of the bank, from which it is subsequently stepped when the metering discrimination digit is pulsed in from the register. Having seized the relay set, the calling subscriber may therefore continue dialling without having to wait for a free register to be found, thus obviating the need for dial tone which otherwise would have to be given on seizure of a register.

The subsequent digits, code and numerical, are repeated to the register as they are dialled. When the cde code has been translated into a metering discrimination digit and routing digits these are pulsed out from the register into the relay set. The metering digit is transmitted as earth pulses to step the uniselector, previously used for c-digit storage, to a contact in the range 12-24 of the uniselector bank and thus determine the metering facility required. Table I shows the metering facilities available and the corresponding position of the uniselector wipers. Charge

TABLE I

Metering Facility	*Bank Contact*
1 fee	12
No fee	13
1 fee Manual	14
2 fee	15
3 fee	16
4 fee	17
Charge Step D*	18
,, ,, E*	19
,, ,, F*	20
,, ,, G*	21
,, ,, H*	22
,, ,, J*	23
Beyond dialling range	24

*Charge steps D-J refer to calls beyond the 15-mile range.

steps D-J, which apply to calls beyond the 15-mile range, are not required for the scheme described, but could be used if the range of dialling were extended, in which case a call timer could be associated with the relay set if tariff requirements should demand it. C.C.B. barring can be provided as required on all calls other than 1 fee and No fee.

The routing digits followed by the numerical digits are then pulsed out via the relay set as loop-disconnect pulses. On completion of pulsing-out the register is released by the relay set which then acts as a transmission bridge between the calling subscriber and the forward equipment.

On receiving the called-subscriber-answer signal the relay set effects metering as determined by the position to which the c-digit storage uniselector has been stepped by the metering discrimination pulse train.

If all registers are enga ed the register hunter continues to hunt until the second digit, the d digit, is dialled. Busy tone is then returned to the caller and hunting ceases.

Register.

Having received the cde code the register immediately applies for a translation. If the translator is engaged the register waits until it becomes free.

The translator can be arranged to deliver the maximum of six translation digits simultaneously, but in order to reduce costs, in terms of apparatus and mounting space, the register here described is equipped to store only three translation digits simultaneously. To obtain the full translation information the register has therefore to make two demands on the translator.

On receiving the first demand from the register the translator delivers, in code form, the first three translation digits consisting of the metering digit and two routing digits. Successively the register stores the translation, disconnects itself from the translator, pulses out the first three translation digits, cancels the stored translation and applies to the translator for the remaining translation digits. The sequence of operations described above is then repeated, but in respect of the 4th, 5th and 6th translation digits. The translator is able to discriminate between a first and second demand made by a register and thus supply the appropriate translation digits.

If less than six translation digits are required the register receives a Digit Cut-Off Signal from the translator in place of each spare translation digit.

If the code dialled indicates that a special facility is required the information relating to this is transmitted to the register simultaneously with the first three translation digits. The normal function of the register is to send the metering and routing digits followed by the four numerical digits. The information relating to special facilities causes the register to depart from its normal function and to act according to the specific requirements of the call in hand.

These requirements may be to:—

(*a*) Omit the numerical digits.

(*b*) Send the cde code in addition to the other requirements of the call.

(*c*) Release after sending only three numerical digits instead of four, where the exchange code indicates a 3-digit number.

(*d*) Bar calls as required by the routing arrangements.

After sending all the stored digits the register transmits a Send-Finish signal to the relay set, which in turn releases the register.

Forced Release of the register is given under the following conditions:—

(*a*) If dialling at any stage is delayed for a period greater than 18-36 seconds.

(*b*) If the register fails to obtain the translator within 6-12 seconds of the cde code being received.

(*c*) If a spare code is dialled.

In each case NU tone is connected to the calling subscriber's line.

Translator.

Since the translator is common to a number of registers simultaneous demands may be made on it. In order to separate these demands a register-finder is incorporated in the translator. It consists of a P.O. No. 2 uniselector to whose banks a marking wire from each register is connected. On receiving a start signal from one or more registers, on a common start wire, the register finder, which is non-homing, hunts for the calling register. The register seized is the first which the finder encounters in its drive round the bank. This is not necessarily the first to make a demand. However, the holding time of the translator (300 mS) is such that under normal conditions the delay in finding any register is small. Calculations show that for all exchanges in the London fringe area not more than one call in one hundred would experience a delay greater than one second.

Having seized the register, the translator accepts the information relating to the cde code. The c digit is used to select one of nine motor-uniselectors, and the d and e digits, which together provide 100 combinations, are used to mark the test banks of all nine motor switches. The switch corresponding to the c digit drives until the d and e marking is found, so that the uniselector is positioned with respect to the cde code. The remaining banks of the motor-uniselector are occupied by translation wires which are cross-connected to translation code relays as required. Contacts of the translation code relays connect the translation information to the register and at the same time a signal is sent to the register causing it to release from the translator after sufficient time has been given for storage of the translation. The motor-uniselector then drives to its home position and the translator is free to accept further demands.

If it is necessary to take a translator out of service a change-over key is operated. This disconnects all registers from the translator which is out of service and connects them to the other translator. If either translator is engaged when the change-over key is operated, change-over is delayed until both become free.

Circuit Elements

Transfer of c Digit from Relay Set to Register.

Referring to Fig. 2, the c-digit pulse train, dialled into the relay set, steps the cRA uniselector wipers to a bank

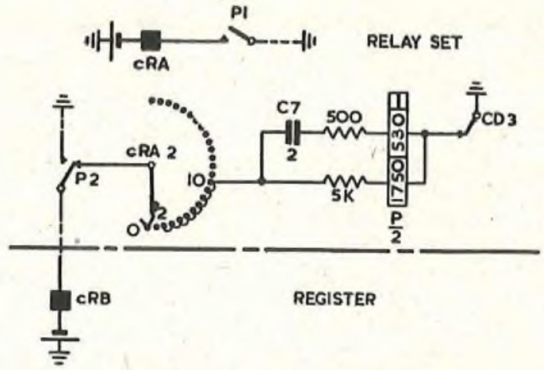

FIG. 2.—CIRCUIT ELEMENT FOR TRANSFER OF c DIGIT FROM RELAY SET TO REGISTER.

contact in the range 2-10. Only c digits 2-0 are used for working codes and if 1 is dialled as a c digit NU tone is connected to the calling subscribers line. Relay CD releases at the end of the c-digit pulse train. On release of contact CD3 current flows through both coils of relay P, the current in the 1750Ω coil remaining steady whilst that in the 530Ω coil decreases as capacitor C7 charges. Relay P is differentially connected and the initial flux in the 530Ω coil therefore delays the operation of the relay. Contact P1 operating energises the cRA uniselector magnet while contact P2 disconnects the operate circuit of relay P and energises the cRB uniselector magnet. Capacitor C7 now discharges through both coils of relay P, the current being in such a direction as to prolong the release of the relay. Contacts P1 and P2 releasing cause the uniselectors each to take one step. P2 re-establishes the operate circuit of relay P and the cycle of operations is repeated. With the values of resistance and capacitance shown in Fig. 2, relay P, which is of the high-speed type, pulses at approximately 20 p.p.s. The c digit is not transmitted to the register in alphabetical sequence with regard to the d and e digits and this speed of transmission ensures that the c digit is always stored in the register before the e digit, this being a requirement of the register circuit. When the cRA2 wiper reaches contact 11 the circuit of relay P is disconnected; thus the number of pulses transmitted to the cRB uniselector is equal to (11 — number of pulses in the c digit dialled). When the c-digit information is presented to the translator this inversion is corrected and the translator receives the actual c digit dialled.

It will be seen that the circuit element described allows two uniselectors remote from each other to be pulsed in synchronism at high speed over a single-wire connection. In this case the connection is via the arc of the register hunter and for reasons of cost it is therefore necessary to reduce the number of connections to a minimum.

Storage of Digits in Register.

In order to economise in apparatus and mounting space, arrangements were made for three of the register's uniselectors each to perform more than one function.

The uniselector which accepts the e-code digit is also used to control sending. A second uniselector stores both M and C digits and a third stores the D and U digits and in addition acts as digit distributor. The principle used is the same in each case. Storage relays are connected to the banks of the uniselectors as shown in Fig. 3 for the e digit. The five storage relays shown have to provide ten combinations, one for each e digit. The relays are therefore operated two at a time, giving (4 + 3 + 2 + 1) combinations, making a total of 10.

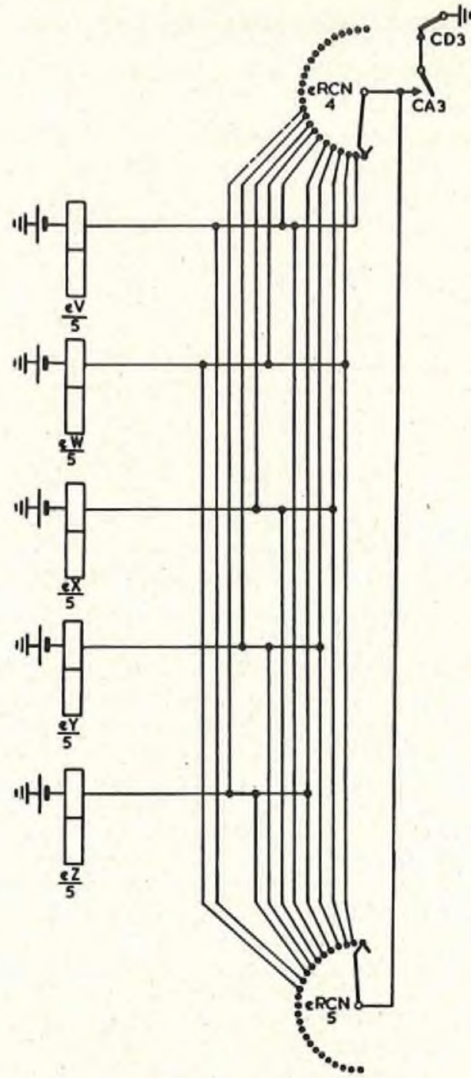

FIG. 3.—CIRCUIT ELEMENT FOR STORAGE OF e DIGIT.

Referring to Fig. 3, relay CD releases in the inter-train pause following the e digit and in turn releases relay CA, which is slow to release. The relays are therefore operated by earth at CD3 connected during the release of CA3.

On release of relay CA, the uniselector is then driven to contact 11 of the bank. Contacts 11 to 24 are then used to control storage of the translation digits and sending of all digits.

The M digit is stored on relays connected to the first portion of a uniselector bank, as shown for the e digit. The uniselector then drives to contact 11. From this position the wipers are stepped by the C digit, which is then stored by marking the latter half of the uniselector bank. The storage of the D and U digits is performed in the same way as that of the M and C digits.

Transmission of cde Code from Register to Translator.

Referring to Fig. 4 a total of 26 wires are used for transmission of the cde code from the register to the translator. The c-digit information is transmitted over one of nine wires (arc cR3) corresponding to the working c digits 2-0. Though the d digit, whose range is 1-0, would normally be transmitted over one of 10 wires, in this case the information is sent on two wires out of seven. This reduction in the number of wires is obtained by connecting the wires corresponding to digits 1-5, respectively, to those corresponding to digits 6-0, as shown on the dR2 arc. Thus a marking on one of these five wires from the dR2 arc indicates that the d digit is either 1 or 6, 2 or 7, 3 or 8, etc. The marking on either the dR3 or dR4 arcs indicates whether the d digit is in the range 1-5 or 6-0. Collation of the two markings will therefore determine the actual d digit.

The e-digit information is transmitted over one of 10 wires corresponding to e digits 1-0.

Identification of Code by Translator.

The marking of the de code is common to all nine motor switches and occupies two arcs of each. The 50 points of one arc commoned in five sets each of 10 points. Each set is connected to one of the d-digit wires (1, 6) (2, 7), etc., as shown in Fig. **4**. The 10e- digit wires are multipled in five appearances on the other 50-point arc. A high-speed relay is connected across the two arcs. Earth connected to the c-digit wire TK1 drives the appropriate motor switch until battery is encountered on the e-digit arc and earth on the d-digit arc, when relay TK operates, contact TK1 cutting the drive. Since the motor switch driven is selected by the c digit and the marking is particular to two d digits, one in the range 1-5 and one in the range 6-0, and one e digit, the position of the motor switch wipers is therefore particular to two cde codes. The motor switch arcs carrying the translation wires are therefore divided into two sets, one carrying translation wires for cde codes whose d digit is in the range 1-5, and the other translation wires for those whose d digit is in the range 6-0. Earth connected via the dR3 or dR4 arcs operates one of the relays CSA, CSC, CSB or CSD. Contacts of these relays connect earth to the wipers of the translation arcs. Operation of CSA or CSC indicates that the d digit is in the range 1-5, while operation of CSB or CSD indicates the range is 6-0. The actual translation wires marked are therefore particular to only one cde code.

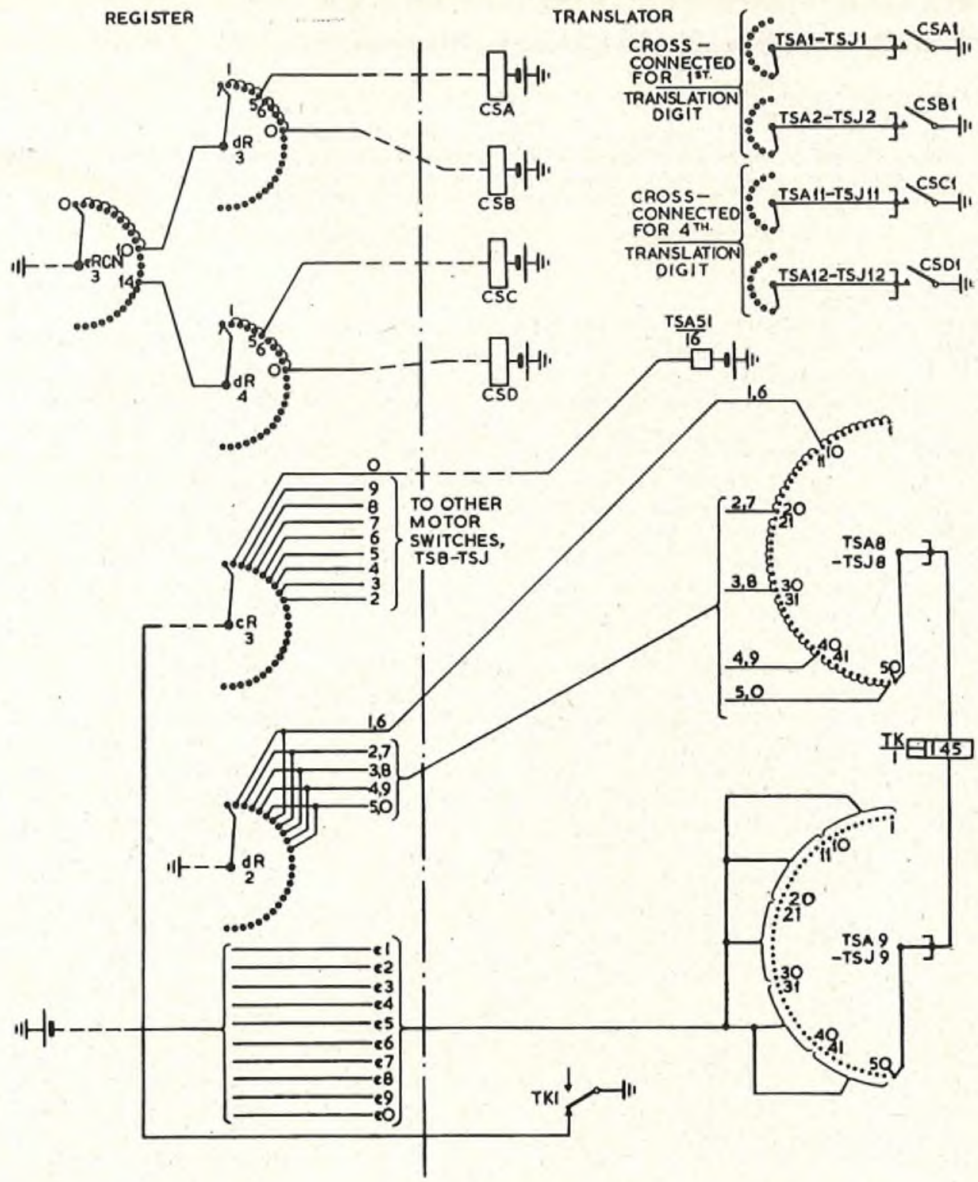

Fig. **4**.—Circuit Elements for Transmission of cde Code from Register to Translator.

Discrimination between First and Second Demands of a Register.

The dR3 and dR4 arcs in combination with the eRCN3 arc (Fig. **4**) enable the translator to distinguish between a register's first and second demands for translations. If the register is making its first demand the eRCN wipers will be on a contact in the range 1-10. Earth via eRCN3 and dR3 operates relay CSA or CSB, depending on whether the d digit is in the range 1-5 or 6-0. Similarly, for a second demand, the eRCN3 wiper will be on contact 14 and relay CSC or CSD is operated. Contacts of these relays connect earth to the appropriate translation wipers of the motor switch. The connections shown in Fig. **4** refer to the 1st and 4th translation digits. The 2nd, 3rd, 5th and 6th are similarly connected.

Conclusion

The register-translator described provides one solution to the problem of recognising large numbers of dialled codes and translating them into charging and routing information. Though primarily designed for fringe area dialling within a range of 15 miles, a register-translator of this type could equally well be used for other purposes where a 3-digit register would be required.[2]

Acknowledgments

The author wishes to acknowledge the help received from members of Telephone Branch and of the General Electric Co. Ltd.

[2] "Subscriber Trunk Dialling in the United Kingdom." D. A. Barron. *I.P.O.E.E.* Printed Paper No. 203.

A Portable Telephone Cabinet

H. M. WELLS, M.I.E.E.†

U.D.C. 621.395.721.2:725.92

The author describes a telephone cabinet, designed and constructed in the Home Counties Region, for temporary installation in hotel foyers to meet the needs of delegates and Press during conferences. The cabinet is of lightweight construction and the component parts are designed to pack flat in crates. Because of ease in transport, assembly and dismantling, it is claimed that, in spite of the higher initial cost, service can be provided more cheaply than when using standard cabinets.

Introduction.

WHEN conferences, union gatherings, etc., are held at hotels an augmented telephone service is usually required for the duration of the meeting. Thus, for a comparatively short time it may be necessary to provide in the building additional telephones in silence cabinets, to give both Press and delegates adequate communication facilities. In the past the practice has been to obtain a number of wooden cabinets and assemble them in suites at the selected hotel. Sometimes, cabinets in a far-from-new condition have had to be brought in from distant Areas, at considerable transport cost, in order that an adequate number of telephones could be installed at the required point.

Considerable thought was therefore given in the Home Counties Region to the question of producing locally a cabinet which would be easily transportable and also possess a pleasing appearance harmonising with the modern styling of the typical hotel foyer.

After a detailed survey of the problem had been made the following design points were decided upon:—

(*a*) The production of a lightweight cabinet which could easily be erected and dismantled by local staff.

(*b*) Cabinets to be built in pairs, as the majority of requirements call for a double cabinet.

(*c*) Transport crates to be provided to eliminate damage in transit.

(*d*) The completed cabinet to match the counter of the Travelling Post Office.

The following paragraphs describe the main constructional features of a cabinet designed to meet the above requirements, and a completed double cabinet is illustrated in Fig. **1**.

FIG. 1.—THE COMPLETED DOUBLE CABINET.

Outline of Construction.

An experimental side-member of the cabinet was made utilising differing forms of construction with a view to obtaining data on strength/weight ratios. Finally, a design was decided upon which was constructed from 2 in. by 1 in. aluminium channel. This took the form of a rectangular framework suitably braced with cross-struts. In assembling these members it was found that employing an aluminium brazing technique yielded a stronger frame than when normal welding procedure was followed.

Having determined the form and materials to be used for the component walls and doors, attention was directed to the floor and roof.

For the roof, as no great strength is required, a fairly light form of construction was adopted using aluminium channelling of similar dimensions to those employed for the side-members. The floor, however, requires to be very robust as it forms the foundation upon which the pair of cabinets is erected. The floor members are accordingly manufactured of $2\frac{1}{2}$ in. by $2\frac{1}{2}$ in. angle-iron, giving adequate strength and lowering the centre of gravity of the completed unit. For ease of erection the base is constructed in two parts, divided so that each half serves as a floor for its own cabinet. The two halves are bolted together before erection to produce a particularly substantial erecting base for the assembly.

General Assembly Details.

In view of the fact that in the majority of installations the cabinets would be erected by staff unfamiliar with the erection routine, it was decided to shape the component parts and position the fixing bolts so that incorrect assembly would not be possible. In the event of the proper part not being offered up to the remainder of the assembly the bolt holes will not register and further assembly is prevented.

The Side, Back and Doors.

As already mentioned, the vertical members of the assembly are constructed of aluminium channelling, with cross-braces positioned to give the greatest strength whilst not obstructing windows. Fig. **2** shows, in elevation and section, the final form of construction adopted. A rectangular frame dimensioned to give standard kiosk size is formed of the channelling, with the flat face on the outside edge. Cross-braces, including those to form the window frame, are then brazed in position. As in its final form the assembly is boxed in by the outside and inside covering, provision was made for a series of captive nuts to be mounted inside the channel to receive the bolts used in assembly. These nuts are made of $1\frac{1}{2}$ in. by $\frac{1}{2}$ in. iron strips with a nut welded in the centre. The strips are secured to the channel and suitable holes drilled through the aluminium to allow the bolts to pass through and into the nuts.

The outside of the framework is covered with 9-ply wood having an external surface of olive ash veneer. This is secured in position by wood screws which pass through holes in the sides of the channelling. The face of the

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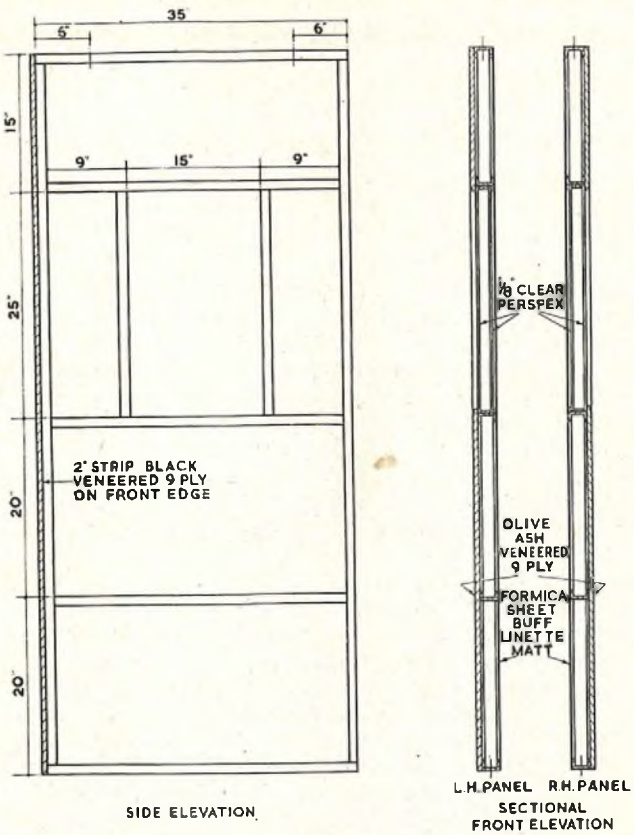


FIG. 2.—FRAMEWORK FOR SIDE PANELS.

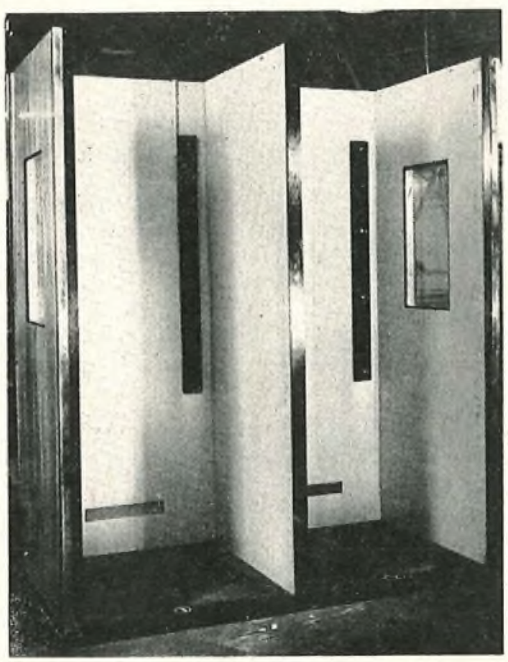


FIG. 3.—DOUBLE CABINET PARTIALLY ERECTED.

frame forming the interior of the cabinet has buff linette Formica sheeting cemented to it by means of an impact adhesive; thus, no screw holes mar either the exterior or interior of the cabinet.

Fig. 3 shows some of the main sections in position for the erection of a double cabinet.

For the purpose of acoustic insulation the space between the plywood and Formica is filled with glass wool. To give an idea of the efficiency of this arrangement, when the construction of the cabinets had been completed in the workshop a fairly noisy pillar drill standing some 3 ft. away was started up. Inside the cabinet with the door shut the level of noise was insufficient to interfere with speech.

The windows are of double Perspex, $\frac{1}{8}$ in. thick, held in position by black wooden frames. For rapidly removing the Perspex in order to clean the interior surfaces or to replace a complete pane, the inside retaining ledge of the window is held in by spring clips which are easily removable.

For easy assembly the door and door frame are constructed as one unit. The frame is of aluminium channelling suitably reinforced at lock, hinge points, etc., and holds the door by chromium hinges. The construction of the door follows the same practice as the side-members, namely, cross-braced channel formation. Double Perspex windows and sound insulation are as already described. A chromium "both-sided" door handle and spring lock are fitted, and a retaining chain prevents the door being opened too wide.

Roof and Floor.

The roof is of hollow construction, being channel covered on both sides with 16 S.W.G. sheet aluminium. Lighting is provided through an aperture cut in the inner roof into which are mounted two 15-W sign-type lamps. A ground Perspex cover is fitted over this aperture, thereby giving a flush lighting fitting which does not decrease the effective height of the cabinet and also reduces the possibility of damage to this component during erection operations. Fig. 4 shows the arrangement.

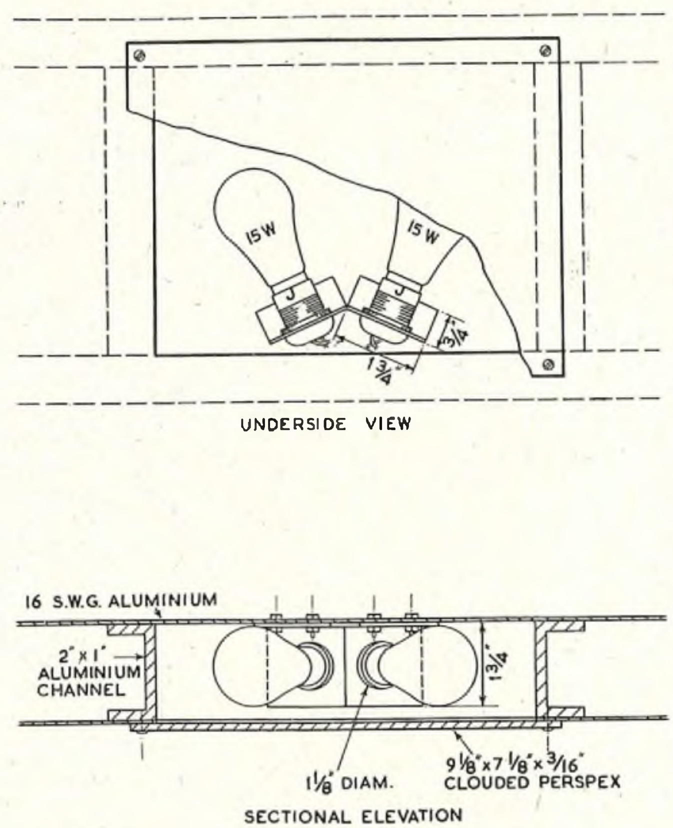


FIG. 4.—DETAILS OF LIGHTING FITTING IN ROOF SECTION.

The floor, of mitre-welded angle-iron, provides a steady base on which to build the cabinet. Prior to erection, the two halves of the base are first bolted together to form a foundation plate through which assembly bolts pass into the side panels and door frames. The actual flooring consists of 9-ply wood covered with cork lino. This rests on the angle-iron, making a snug fit with the sides of the cabinet and concealing all assembly bolt heads.

Ventilation.

Ventilation is achieved by two louvres in each cabinet. One is cut through the rear wall just above floor level and consists of an aperture 14 in. by 3 in. covered on both sides with expanded aluminium, the outside presenting a gilded finish to match the olive ash facing, and the inside being of natural aluminium which blends well with the Formica lining. These grilles are recessed to give a flush finish both on the outside and inside.

A similar vent is provided in the roof and is also fitted with external and internal covers of expanded aluminium.

Provision for Telephone.

The rear wall of the cabinet has a number of blind bolt holes provided so that any standard kiosk back-board can be mounted without the necessity for further drilling. These holes are protected with steel plates at the bottom of the threads so that, even if a bolt longer than that supplied with the cabinet is inadvertently used, no damage to the outside surface of the cabinet can result as a result of over-penetration.

The leads to the instrument are brought in at the top of the cabinet (similarly for the electric lighting feed) and drop down to the coinbox through aluminium tubing mounted on the surface. By this means a straight run is possible which makes threading the lead-through an easy matter. It was considered that if conduit were embedded in the interstice between the plywood and Formica it would necessarily have a sharp bend in it which might become jammed by a misplaced lead. As the Formica is cemented on it would not be possible to expose the conduit to allow clearing operations to proceed; hence a straight run was considered more practical.

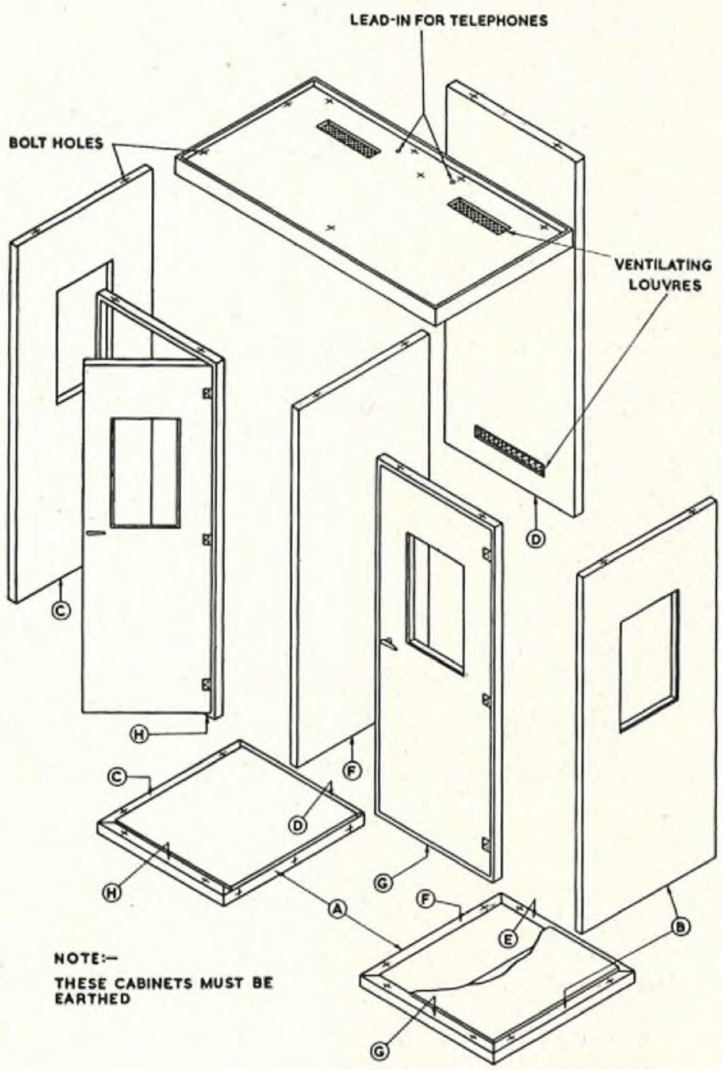


FIG. 5.—SPECIMEN OF ERECTION DRAWINGS.

External Finish.

As the portable cabinet is to be used adjacent to the Travelling Post Office counter the finish and fixtures have been designed to match up with this larger piece of equipment as far as possible. The external finish of olive ash is similar, and the lettering, in Post Office red, also matches. The lettering and crown are cut from Perspex sheet and cemented to the black surround at the top of the cabinets.

Black wooden lintels are also fitted at the extremities of the channelling to conceal end sections, etc. Polished aluminium corner pieces round off the corners and also give a measure of protection to the edges of the cabinet.

Carrying Crates.

The three crates into which the component parts of the cabinet fit are strongly constructed of wood with felt-lined divisions to ensure that no damage occurs during transit. The lids are held in position by wing nuts threading on to bolts anchored to substantial plates on the sides of the crates. When screwed down, the lids lock the contents of the crate into position and no internal movement is possible. Castors are fitted to the crates to facilitate transportation.

Erection.

A full set of erection drawings is furnished, of which Fig. 5 is a specimen. These, together with the non-reversible features incorporated in the various component parts, make incorrect assembly practically impossible.

With regard to the time taken to prepare the cabinet on site, an average team of three can complete erection in under an hour. This time does not, of course, include fitting the telephone. The cabinet can be completely dismantled and packed in the crates in 30 minutes.

Conclusions.

From a purely financial consideration it appears that these cabinets will amply justify their construction. Admittedly more expensive than the present standard cabinet, they will save an appreciable amount of money each time they are used as, being lighter than the standard cabinet, transportation costs will be lower. Time will be saved in erection and also it will not be necessary to redecorate the cabinets locally, as is usually necessary when assembling a number of second-hand standard cabinets.

Perhaps not the least important point is that the enhanced appearance of the cabinets creates a much better impression when used in the surroundings for which they are intended.

A Novel Type of Saw for the Economical Cutting of Quartz Crystals or Other Materials

J. E. THWAITES, M.I.E.E., and C. F. SAYERS†

U.D.C. 621.93:549.514.51

The saw consists of a thin metal annulus charged with diamond powder on its inner edge and clamped at its outer edge to the face of a cup or chuck in such a fashion as to hold the thin metal annulus in radial tension. The chuck is fixed on a spindle which rotates at high speed. The saw combines rigidity and thinness and cuts accurately and economically.

Introduction

UP to now, piezoelectric quartz vibrators have been made chiefly from Brazilian natural quartz, and it is only recently that the production of suitable raw quartz crystals by an artificial growth process has become a practical possibility. At present it appears that small crystals can be grown artificially much more easily than large ones, and it therefore seems likely that if the artificial material were to be used, small vibrators such as high-frequency overtone-mode plates would be fabricated from small crystals. Indeed, whether artificial or natural quartz is used, the greater availability of small crystals favours the use of such crystals for the production of vibrators of small dimensions. A cutting technique particularly suited to small crystals should combine accuracy with minimum wastage in saw-cuts, and the saw described in this article represents what is thought to be a novel approach to the problem.[1]

The cutting of raw crystals into plates or bars of the desired form and size to become piezoelectric vibrators is generally done with a circular saw which consists of a metal or plastic disc, charged with diamond particles on its periphery, and which is rotated at a high speed. The crystal is pressed against the edge of the saw, either by gravity or by a feed screw, and the cut is copiously sprayed with oil or other liquid to cool the work and carry away swarf. The cut surfaces are invariably damaged to a certain depth, being penetrated by minute cracks. To render the pieces, or elements, suitable for the purpose in view, the damaged regions must be removed by lapping and the pieces have therefore to be cut oversize to allow for the removal of the saw-damaged portions.

The elements must be cut at a precise orientation with respect to the axes of the crystal and, unless the saw cuts quite truly in the intended direction, the elements must be cut with a sufficient allowance on dimensions to provide for correction of their orientation by subsequent lapping. Such correction is not easy, and it is desirable to maintain accuracy of cutting by mechanical stability of the cutting machine and by the inherent rigidity of the saw itself. In the conventional type of quartz saw, sufficient rigidity can be obtained by making the saw blade fairly thick and by clamping it concentrically over as large an area as possible, consistent with the required depth of penetration of the saw into the work. For the large preliminary cuts into the raw crystal, to produce blocks or slabs, the saw may be as thick as 2·5 mm., and for slicing its thickness is rarely less than 1·0 mm. and produces a saw-cut of the order of 1·2 mm. wide. Slices are rarely cut less than 1·0 mm. thick even when the required final thickness of the quartz plate is perhaps only 0·2 mm., owing to the risk of breakage.

The general trend of development in radio communication has been towards the use of higher frequencies, and this has made itself felt in crystal cutting and processing laboratories by a demand for much thinner and smaller vibrators than had previously been required. Whereas oscillator-plate dimensions have in the past been largely of the order of 15 mm. square and from 0·5 to 0·15 mm. thick, plates as small as 5 mm. in diameter and 0·15 to 0·05 mm. thick are now being demanded. This reduction in size of quartz elements concurrently with the increase in cost of large raw crystals has rendered attractive the utilisation of the smaller, more plentiful and less expensive stones. The use of such stones would in itself constitute an economy, but to reap the full benefit of the reduction in the size of quartz elements required, it is necessary to be able to cut thin slices. If these slices are but little damaged by the saw, thus requiring to be cut only a small amount oversize, and if they can be cut accurately with a thin saw, the maximum economy of both material and labour will be achieved.

The normal type of saw or cutting disc is shown in Fig. **1**. It is mounted between two rigid flanges on a spindle so that its plane is truly perpendicular to the axis of rotation. It must be perfectly flat and circular, and must have sufficient unclamped radial dimension to cut the required depth. When used in an accurately aligned machine, it will cut accurately and freely so long as it penetrates the work-piece in a direction truly parallel to the direction of feed, provided of course that the cutting edge itself is in a satisfactory condition.

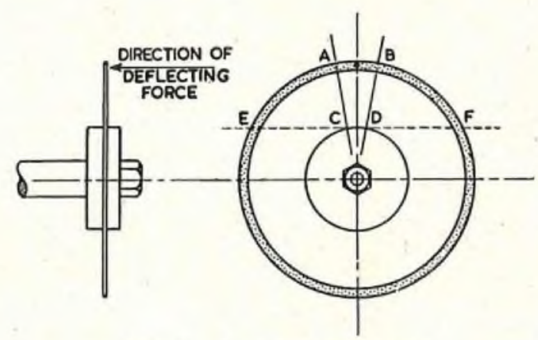


Fig. 1.—The Disc-type Saw.

When the saw thickness is reduced, two difficulties are encountered. First, it is very difficult to produce a thin disc which is sufficiently flat. Secondly, a thin saw lacks the rigidity necessary to resist deflection as it penetrates a work-piece, particularly when the work-piece is of irregular shape. If the active part of the saw edge, AB in Fig. **1**, be considered to be the end of a cantilever supported rigidly in the flanges between C and D and partially supported in the region near the lines CE and DF, the deflection of the disc with a given side thrust rapidly increases, as the thickness of the disc is reduced, in the manner characteristic of cantilever systems. The lower practical limit of the ratio thickness/diameter for mild steel discs seems to be about 1/150—for example, a 6-in. saw of thickness 0·040 in. held between 4-in.-diameter clamping discs is fairly satisfactory—so that a reduction in thickness below 0·040 in. must generally be accompanied by a reduction in diameter below 6 in. Objections to this reduction of diameter are that (i) the depth of the work that can be accommodated

†The authors are, respectively, Senior Executive Engineer and Executive Engineer, Radio Experimental and Development Branch, E.-in-C.'s Office.

[1] British Provisional Patent Specification No. 14514/52.

is reduced; (ii) there is a reduction of peripheral speed, which may necessitate an increase of spindle speed beyond an economic and practical value determined by such considerations as the effective application of coolant and machine design and maintenance; (iii) the total active cutting surface available in the saw is reduced; and (iv) for any given size of work-piece the arc of contact of the saw with the work is increased, and the coolant has less ready access to the cut to wash away swarf and to cool the work. To sum up, the normal type of circular saw is subject to severe limitations when accuracy combined with economy of cutting is sought.

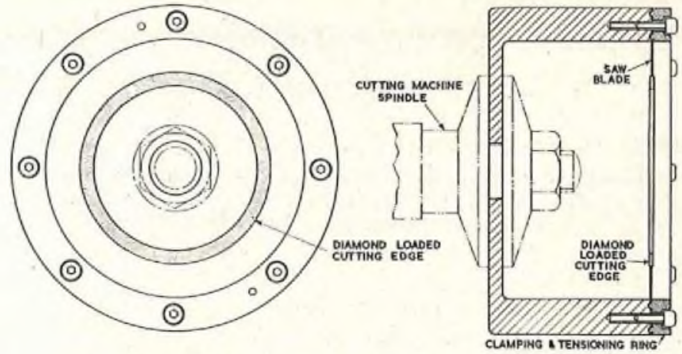


FIG. 3.—MOUNTING DETAILS FOR ANNULAR SAW.

DESCRIPTION OF NEW SAW

The new type of circular saw, shown diagrammatically in Fig. 2, takes the form of a thin metal annulus, clamped

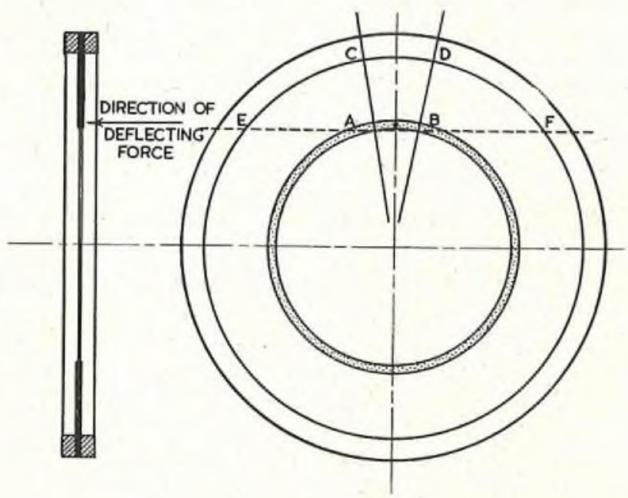


FIG. 2.—THE TENSIONED-ANNULUS SAW.

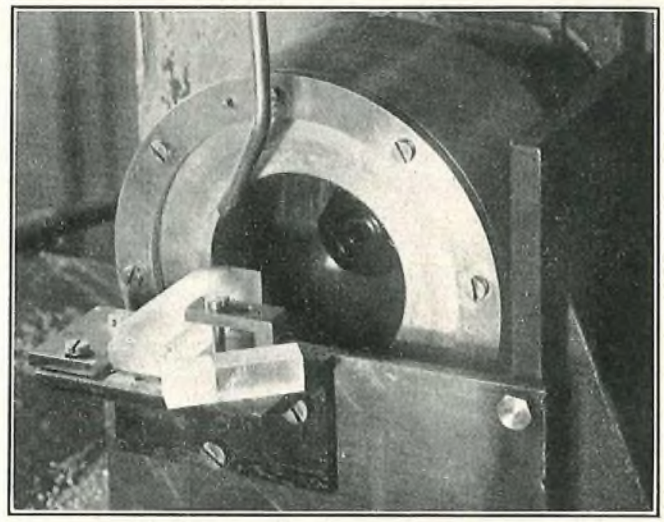


FIG. 4.—EXPERIMENTAL COPPER SAW, 0·01 IN. THICK, SLICING QUARTZ BLOCK.

round its outer edge so as to tension the metal, and charged on its inner edge with the cutting agent, which may consist of small particles of diamond pressed into the metal or attached to it by other means. It will be seen from Fig. 2 that the active part of the saw edge AB is directly supported along a wide root or base, CD, and derives some additional support from the clamping of the periphery on the arcs CE and DF. Due to the radial tension applied to the annulus there is a state of tension between E and F. The tensional stresses, which are completely absent from the normal type of circular saw, hold the cutting edge in the desired plane and produce a restoring force if the edge is deflected. It is thus possible to construct a thin annulus possessing considerable rigidity.

The experimental saws were half-hard copper annuli, of inner and outer diameter 3 in. and 6 in., respectively, and thicknesses from 0·006 in. to 0·016 in. They were charged with diamond powder, of 170 to 200 mesh, on the inner annular edge by first notching the edge with a razor blade to a radial depth of 0·020 in., then coating the notched edge with a paste of a diamond powder and grease, rolling the diamond into the notches with a steel rod and afterwards closing the sides of the notches by pressing the blade with the rod on a flat surface. In use the saw is clamped to the annular face of a cup or chuck as shown in Fig. 3, the clamping ring being formed with annular projections of semi-circular cross-section which correspond with annular grooves in the face of the chuck. To produce the radial tension the saw blade is placed between the chuck face and clamping ring and the latter is pressed home by a set of clamping screws, which pass through suitable holes in the clamping ring and saw blade and engage in tapped holes in the chuck body. The chuck is held on a spindle substantial enough to permit it to be rotated at speeds up to 3,000 r.p.m.

The crystal to be cut is mounted on a suitable fixture in front of the saw, as shown in Fig. 4, and protrudes through the central aperture. The holding fixture is attached to a table which is moved horizontally by gravity or by a feed screw so as to press the crystal against the saw. When a slice is cut off it will, unless prevented, fall into the chuck and be carried round on the internal surface thereof, and may thereby suffer damage. If, however, the work-piece is wrapped with Cellophane tissue before cutting, the slices are held in position by the tissue and may be removed either one by one as cut, or at the end of the operation.

PERFORMANCE OF SAW

With a spindle speed of 2,400 r.p.m., the surface speed of the cutting edge is 1,900 ft. per minute and at this speed satisfactory slices can be cut with a feed rate of $12\frac{1}{2}$ in. per hour; or expressing the rate differently, a slice $\frac{5}{8}$ in. square can be cut in three minutes. The method of charging the experimental saws produces a cutting edge which is slightly thicker than the saw, so providing clearance in cutting. This clearance is very desirable since it reduces heat due to friction, permits free access of coolant, allows swarf to escape, and reduces the chances of damage to the slices. The width of the saw-cut is some 0·005 in. greater than the web thickness of the saw blade, and can be as small as 0·014 in.

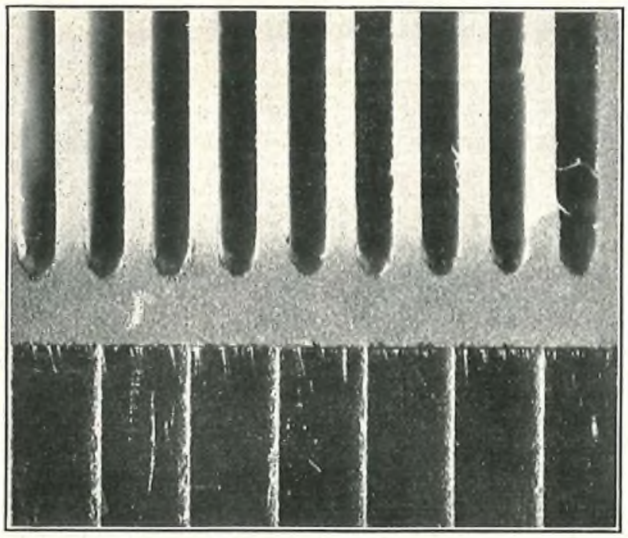
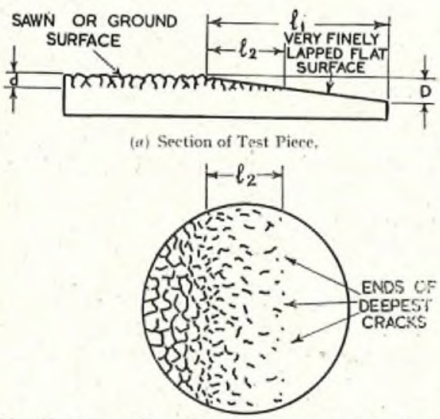


FIG. 5.—EXAMPLE OF SAW CUTS, SHOWN AGAINST MILLIMETER SCALE.



(a) Section of Test Piece.

(b) Magnified View of Test Piece at Junction of the Two Surfaces.

Notes.—1. The two surfaces are inclined at approx. 1° to each other.
2. Specimen is etched in dilute H.F. acid for 2 hrs. to reveal full extent of fine cracks.
Depth of Surface Damage (i.e. extent of penetration of fine cracks produced in cutting or grinding) $= d$
where, $d = D \times l_2/l_1$.

FIG. 6.—METHOD OF DETERMINING DEPTH OF DAMAGED LAYER ON SAWN OR GROUND SURFACES.

With the experimental saws as many as 20 successive slices, of edge dimensions 18 × 14 mm., can readily be cut in the form of a comb such as that shown in the foreground of Fig. **4**, and in greater detail in Fig. **5**. The thickness of the slices and the width of the saw-cuts can each be made as small as 0·35 mm (0·014 in.). The taper of the slices is of the order of 0·01 mm. The depth of the saw damage produced by the experimental saw, determined by the method shown in Fig. **6**, is approximately 0·015 mm.

One very important aspect of cutting thin slices is the accuracy of orientation of the slices. If there is consistency of cutting (i.e. if a particular cut is repeated with accuracy), the achievement of a particular target angle is mainly a matter of the design of the holding device. The repetition accuracy, as shown by measurement of the orientation of successive slices, may be influenced by:—

(i) Imperfection of the slices in respect of flatness and taper.
(ii) Difficulty of X-ray measurement of thin plates.
(iii) Deflection of saw blade.
(iv) Lack of linearity of feed mechanism.

With the latest machine adapted for the use of the annular saw, X-ray measurements of the orientation of slices in a batch cut from a single block, with one setting of the work-piece, have shown a scatter of about four minutes, measured in the direction of feed, and two minutes measured at right-angles to the direction of feed.

In the initial arrangement, illustrated in Fig. **4**, the oil coolant collected in the interior of the chuck, where it was held as a liquid annulus during rotation until it flowed over the cutting edge of the saw. The pressure exerted by this oil on the saw blade caused the latter to bulge slightly and consequently to alter its cutting direction, but this pressure was readily released by providing holes in the chuck wall for the oil to escape. The depth of the oil could be controlled by suitably placing these holes. In a later arrangement an outer shell or bowl was fitted, attached to and rotating with the chuck. The oil escaping from the chuck into this bowl was automatically collected by a scoop and returned to the supply tank.

CONCLUSION

It is thought that the saw described in this article may be usefully applied to the slicing of quartz, germanium, silicon and other substances when the samples are small and accurate cutting is required.

Book Review

"Ferromagnetic Domains." K. H. Stewart, M.A., Ph.D. Cambridge University Press. 176 pp. 77 ill. 25s.

As this book is one of the Cambridge Monographs on Physics, the engineer must not expect it to guide him in the practical application of his materials. It so happens, indeed, that some of the practical cases (e.g., low flux densities or high-permeability materials) are the hardest to discuss from the physicist's point of view.

The book gives an excellent critical account of the theoretical background, and explains how far the theory is or is not borne out when tested on suitably chosen materials. The purely experimental side of the subject, however, is treated less fully than in Bozorth's "Ferromagnetism". Magnetic annealing is dismissed in seven lines, with no entry in the Index; this is disappointing in view of its interest both in theory and in practice.

Dr. Stewart's interest in practical materials is limited; their names do not appear in the Index, and some mistakes about them have crept in—for example, in Fig. 22 Permalloy (of unspecified composition, but in fact it was 78·5 per cent. nickel) is shown saturating at about 1000 gauss, and on page 91 40 per cent. nickel-iron is said to be easily magnetised along the cube diagonals. "Mumetal" is *not* merely 78 per cent. nickel-iron with small additions of copper (for the last 10 years, at least, it has contained molybdenum as well), but Dr. Stewart is not the only recent author to be wrong about this.

These criticisms may be irrelevant, for Dr. Stewart has certainly achieved what he set out to do—to gather up the available information about the physics of domains. But users of magnetic materials will regret that the scope of the book was not widened to show how far the physics applies to everyday materials as well as to the special materials chosen to illustrate particular theories.

A. C. L.

Sir W. Gordon Radley, C.B.E., Ph.D.(Eng.), M.I.E.E.

THE appointment of Sir Gordon Radley as Deputy Director General, just three years after becoming Engineer-in-Chief, is a fitting recognition of the outstanding services, ability and versatility of a colleague who has never been content to follow precedent. A product of Faraday House, his studies were interrupted for nearly three years by military service in the 1914-18 war. After a year at Bruce Peebles, Ltd., he joined the Post Office in 1920 as a Temporary Inspector in the Research Branch, and in 1922 he was successful in the first post-war competition for Old-style Assistant Engineers. During his early days he was engaged on a variety of problems associated with materials and specialised in spectrographic techniques including X-ray diffraction; in 1929 he was awarded the Silver Medal of the Institution of Post Office Electrical Engineers for a paper entitled "X-rays and the Structure of Some Engineering Materials".

When the electricity grid was under construction he became concerned with the problem of interference with communication circuits and worked in co-operation with the Electrical Research Association, carrying out many field experiments to confirm theoretical studies; it was for a thesis on this subject that he was awarded a Ph.D. degree by London University in 1934. By this time his primary interest had moved to corrosion problems and here again he came right to the forefront; in 1937 he addressed a conference on this subject in Washington.

His work as an Assistant Engineer and as an Executive Engineer having been so specialised it is somewhat surprising to find that, when, on appointment as Assistant Staff Engineer, he found himself in charge of development of the 2V.F. signalling system, he was soon in complete command of the principles and details of long-distance signalling and dialling and made personal contributions to the art. This versatility and ability to specialise in widely differing fields are characteristic and have been evident at all stages in his career. He represented the Post Office on three C.C.I.F. Study Groups dealing respectively with protection and interference, corrosion and switching.

Promotion to Staff Engineer, Research Branch, in 1939, brought a further widening of responsibility and all the difficulties and problems of the war years. During his 10-year term of office he became the first Controller of Research (1944) with a status which was subsequently raised to that of a Deputy Engineer-in-Chief. He established himself as an authority not only on telecommunications but on allied problems involving research and development, and served as Chairman of the Materials Committee of the Radio Research Board and of a committee formed to advise the Medical Research Council on deaf aids and on audiometers for assessment of individual needs. He was a member of the Radar and Signals Advisory Board of the Scientific Advisory Council (Ministry of Supply) and Chairman of its Line Communication and Electro-Acoustics Sub-committee. As Chairman of an earlier war-time sub-committee on Electro-Acoustics he advised the Ministry on communication in armoured fighting vehicles. Always a staunch supporter of the I.E.E. he has been awarded premiums on three occasions; he became a Vice-President in 1951.

In 1949 he was transferred to Alder House as Deputy Engineer-in-Chief. Here he tackled staff and organisation matters with characteristic zeal and this gave the additional background necessary to enable him to take over as Engineer-in-Chief on the retirement of Sir Archibald Gill in 1951; in this post he worked unsparingly throughout his term of office. For some years previously he had been greatly interested in the development of repeatered submarine cable systems and, in particular, the possibilities of a transatlantic telephone cable. His new office gave him the opportunity to further this work and it is due to Sir Gordon, more than anyone else on this side of the Atlantic, that the ambitious project, which is due to mature in 1956, was put in hand. Although he has now crossed "over the road" to Headquarters he has, at his own request, retained technical responsibility for this project; we all hope that it will serve for very many years to remind us of his efforts. He was honoured with a knighthood early in 1954.

Sir Gordon's new duties as Deputy Director General cover the field of telecommunications; sound broadcasting and television remain, for the present, with Sir Ben Barnett. Sir Gordon is no stranger to these duties as he carried them out for some months during Sir Ben's illness in 1952. One thing is certain: he will set about his new job with that thoroughness and tireless energy which we know so well and, with all his new preoccupations, his colleagues, old and new, engineers and administrators, can be sure of a willing, helping hand when they need it. The Engineering Department wishes him well and looks with pride to his achievements, past and to come.

Some may regard Sir Gordon's move as a triumph for the engineer as such. While this may be true to some extent it is, above all, a triumph of the man himself, of qualities which just had to take him to the very top.

R. J. H.

Brigadier L. H. Harris, C.B.E., T.D., M.Sc., F.C.G.I., M.I.E.E.

BRIGADIER L. H. HARRIS, who succeeds Sir W. Gordon Radley as Engineer-in-Chief, has had a very wide experience of men and of Headquarters and Regional work.

A simple unpremeditated action started him on his distinguished Army and Post Office career. In March 1914, he left London for Australia to learn farming, but war broke out and as soon as he was 18 he joined the Australian Imperial Forces. One day, volunteers for training as signallers were called for, and when a young telegraphist from the Australian Post Office stepped forward, he did the same; a short step, but the first on the road to Engineer-in-Chief of the British Post Office.

He went to Egypt as a signaller in the 32nd Infantry Battalion and later to France after transfer as a sapper to the 5th Australian Divisional Signals.

After the war he studied at the City and Guilds Engineering College and entered the Engineering Department on the Open Competitive Examination as an Assistant Engineer in 1923, spending the next 10 years in the Research Branch, during which he obtained his Master of Science degree. For his papers read before the Institution of Post Office Electrical Engineers he has twice been awarded the Silver Medal. In conjunction with F. O. Morrell and E. H. Jolley, he presented an historic paper on "Modern Telegraph Developments" at the Institution of Electrical Engineers.

In 1932, he was promoted to Executive Engineer in the Telegraph Branch and to Assistant Staff Engineer in 1936, where he was concerned with the development of the original teleprinter automatic switching scheme, the equipment of which was lost when the Central Telegraph Office was burned during the London blitz.

Leaving behind, temporarily, the sphere of Research and Development where his work was to have a widespread influence on future telephone and telegraph practice, he became Superintending Engineer in the Midland District in 1938.

In 1939, he went to France as a Company Commander of the 44th (Home Counties) Divisional Signals, the unit he had joined as a Territorial subaltern early in his Post Office career.

After evacuation from Dunkirk, he was appointed Lines Officer at G.H.Q. Home Forces and then commanded G.H.Q. Signals until his promotion to Colonel in 1942, when he was engaged in the planning and organisation of the cross-channel and continental communications designed to cover any operational plan for the invasion of North-West Europe which might be ultimately decided upon. This early preparation of coastal installations, mobile equipment, cable and teams, planned in conjunction with, and largely provided by, the Post Office, made possible the complex cross-channel system which was rapidly built up from D-Day.

Brig. Harris was one of the team of planners for operation "Overlord" and was subsequently appointed to the staff of General Eisenhower in charge of the telecommunications section of S.H.A.E.F. For these and other services in connection with the rehabilitation of the continental cable network for military use, he was awarded the C.B.E. and honoured by the Allied Governments with the French Legion of Honour and the United States Legion of Merit.

As a corporal with the Australian Forces he laid D.8 with the horse-drawn cable wagon, and, as a brigadier, planned communications using the latest technique of carrier telephony on coaxial cables.

He returned from the war to become Regional Director of Scotland and in 1949 was promoted to Controller of Research. Some of the important projects on which work had proceeded while Brig. Harris was in charge of Research were, the developments in submerged repeaters and the solution of allied problems concerning long-life valves and reliability in components; investigations into transistor action, characteristics and applications, and the production of high-purity germanium; the study of television and broadband transmission problems; the design of electronic circuits for automatic telephone exchanges, computors, etc.; and work on special magnetic materials. In all these and the many other lines of research and development now current at Dollis Hill he took, and continues to take a keen personal interest.

In such widely different jobs as Army Signals Commander, Regional Director and Controller of Research his knowledge of men and of engineering, and his power of control and leadership, inspired loyalty and respect and resulted in a keen and happy team.

He is an author with a seeing eye, and has written in "Signal Venture" an entertaining account of his personal experiences before, during and in between the two world wars. It brings to vivid life both scenes and persons, and stimulates the memory of all who have trodden the same path either geographically or vocationally.

His many friends in all branches of the Service will wish him, with confidence, every success in his new appointment.

J. R.

"Open Day" at Research Station, September 1954

U.D.C. 061.6

The 1954 "Open Day" at the Post Office Research Station was visited by some 450 representatives from Industry, the Universities and Government departments; and by the Press, senior Post Office staff and friends and families of the Station staff. This note briefly describes some of the more important exhibits and demonstrations which served to illustrate the notable advances made since the last "Open Day" in 1951.

A selection of exhibits and demonstrations illustrative of current work at the Post Office Engineering Research Station was shown to visitors on "Open Day," 24th September, 1954. This, the third open day since the war, gave visitors and staff a rare opportunity of gaining an overall view of new developments and prospects in communications. It is not possible in the compass of a short article to convey such a general view, but a brief account will serve to indicate the main developments. Some of the exhibits require no more than a mention, for they have recently been described in this journal. Thus the time-division-multiplex electronic P.A.B.X., with some 40 lines now being connected, was shown in operation, as were the mercury-delay-line register-translator, the laboratory speech voltmeter, the telegraph distortion analyser, the stretched-carrier lapping machine for thin quartz plates, and an annular saw with a very thin blade kept rigid by the same stretching technique. A description of the annular saw appears in this issue.

A group of exhibits was devoted to transistor developments. There were demonstrations of the techniques recently described in this journal for the production of monocrystalline transistor-grade germanium by zone refining and growing the crystal from a seed. Various equipments for testing diodes and triodes were shown and there were some examples of applications, including two line amplifiers, one for speech and the other for music; the speech amplifier has reached the stage of field trials.

It is well known that speech can be synthesised in terms of six parameters, larynx pitch and level, hiss level, and the frequencies of the three major resonances of the vocal tract. These parameters vary slowly so that there is the possibility of conveying speech intelligence in a very much smaller bandwidth than that required for normal speech transmission. The principal difficulty lies in the continuous and substantially instantaneous extraction of the three vocal-tract-resonance parameters from the applied speech. Some progress has been made, however, and an apparatus was demonstrated in which the resonances are located by continuous spectral analysis by means of a group of bandpass filters with continguous pass bands.

Submerged repeaters were the subject of a large group of exhibits, which included a deep-sea repeater similar to the one that will be used in the British section of the Transatlantic Telephone Cable. Very precise information on the characteristics of submarine cables is necessary, for mop-up equalisation along the route is impracticable, and this has necessitated the development of new measuring equipment. A gain-measuring equipment having a long-term comparison accuracy of 0·003 db. was shown. Great reliability is essential in the repeaters. Extreme care is taken in the manufacture of the components and the amplifier circuits are so designed that the failure of any one component will not seriously degrade the performance. Perhaps the most difficult problem has been in the development of long-life valves, and this has been intensively attacked. As described in this issue, high-slope pentode valves with passive-platinum-cored oxide cathodes having a very slow rate of deterioration are being made at the Research Station, and various stages of processing were demonstrated on Open Day.

The spread of the television network about the country is creating a demand for improved methods of testing and much attention is being given to pulse methods. An experimental equipment, which was demonstrated, measures the pulse response of a system in terms of a series of meter readings, indicating the ordinates at various parts of the output pulse. An improved waveform corrector of the echo type, for reducing the distortion in television links, has been designed. Advanced or delayed replicas of the received signal are so added to it as to neutralise distortions in the transmission system.

A new method of testing multichannel telephone systems for intermodulation distortion was demonstrated. The system under test is energised with white noise to simulate traffic and a few "holes" in the applied noise, produced by bandstop filters, represent quiet channels. The noise in the quiet channels, due to all causes, is measured at the receiving end. The technique, which is very simple to use, is finding applications in tests on cable systems; it is virtually indispensable on F.M. radio links, where feeder reflections and multipath propagation effects may give rise to intermodulation products of high, but in general unknown, order.

The application of microwave links to multichannel telephony is giving rise to many other measurement problems and a display of newly-developed test equipment included group-delay measuring sets for 4,000 Mc/s and 60-70 Mc/s (intermediate frequency), standing wave meters, a sweeping oscillator and a 4,000 Mc/s insertion-loss measuring set for the accurate measurement of losses up to 70 db. Some of these developments have been described recently in this journal.

Equipment for long-distance radio communication in the 4-30 Mc/s frequency band is judged by its performance in combating, in the presence of noise and interference, the fading and multipath phenomena characteristic of ionospheric propagation. Tests in service are apt to be slow and inconvenient and a means for simulating the natural phenomena under controlled conditions is very desirable. A "fading machine" for producing frequency-selective fading effects, by combining two or three differently-delayed signals of constant amplitude but varying relative phase, has been in use for many years; recently it has been modified so that the differently-delayed signals individually fade in a substantially random fashion approximating closely to that observed in nature.

A scale model technique has been developed as an aid in investigations of directional aerials such as are used in point-to-point communications in the 4-30 Mc/s band. The model, energised at about 3,000 Mc/s, is mounted on a rotating turntable. A horn receiving aerial mounted on a movable boom allows the radiated energy to be sampled at any zenithal angle and the resulting polar diagram is indicated in a cathode-ray tube display. Comparisons of different kinds of aerials can be made much more quickly and cheaply than in full-scale tests, and the effects of obstacles, such as masts and buildings, can readily be determined.

H. B. L.

The XVIIth Plenary Assembly of the C.C.I.F. Geneva, October, 1954

U.D.C. 061.3:621.395

A brief account of the engineering matters dealt with by the Study Groups of the C.C.I.F. at the XVIIth Plenary Assembly held in Geneva in October, 1954.

Introduction

THE Plenary Assembly of the C.C.I.F. met in Geneva from the 4th to the 12th October, 1954, and was attended by representatives of 36 countries.

The work of the C.C.I.F. is largely done in its Study Groups and their sub-committees. These meet at intervals as required between Plenary Assemblies (which are held once every three years), and there had been a series of Study Group meetings at Geneva in September. Most of these Study Groups are concerned with engineering matters, under the following broad headings: First (Protection), Second (Corrosion), Third, Fourth and Fifth (Transmission in its many aspects), Eighth (Signalling and Switching systems). The others (Sixth and Seventh) are concerned with traffic and operating questions and tariffs. A number of questions concern more than one Study Group and arrangements are made for co-operation and, if necessary, joint representation of the different groups. It is for the Plenary Assembly to approve the recommendations made by the Study Groups on the various questions set for study, and also the proposals made for future studies.

The Plenary Assembly considered a number of organisational matters, including such questions as the possible amalgamation of the C.C.I.F. and the C.C.I.T., the general organisation and finances of the C.C.I.F., the election of Chairmen and Vice-Chairmen of Study Groups, the extension of the term of office of the present Director of the C.C.I.F. and the arrangements to be made for revising and publishing the C.C.I.F. documents. It is proposed, however, to confine these notes primarily to the very important engineering matters dealt with, and it is thought that the best course will be to deal separately with the dominant aspects of the work of the various Study Groups. At the XVIIth Plenary Assembly, the body dealing with maintenance questions, which has so far been of sub-committee status and designated as "The Permanent Sub-Committee for Maintenance", was elevated to full Study Group status and will henceforth be known as the Ninth Study Group.

First Study Group—Protection from Interference Caused by Power Lines

This Study Group deals with problems of induction on telecommunications circuits arising from the operation of both power lines and traction systems. It was assisted in its deliberations by representatives of C.I.G.R.E. (the International Conference of Major Electric Systems), U.N.I.P.E.D.E. (the International Union of the Producers and Distributors of Electrical Energy) and U.I.C. (the International Union of Railways).

From the Post Office standpoint, the most important change agreed by the Plenary Assembly was the raising in a specific case of the limit of the induced voltage which may be permitted on a telecommunications line. Since 1948 the limit for induced voltage on all overhead and on most underground telecommunications circuits of the types usually met with in Great Britain has stood at 430V R.M.S. This is the maximum voltage which may appear on any part of the circuit due to induction from an earth fault current in the power line. It has now been agreed that for a class of power lines, referred to as "high-security lines," which are built to rigid electrical and mechanical specifications so as to have a low fault liability—and which also are fitted with fast operating circuit breakers—the voltage limit shall be 650V R.M.S. It is a requirement that in the case of an earth fault the circuit breakers shall make the power line dead within $\frac{1}{2}$ sec. in all cases and within $\frac{1}{5}$ sec. in most cases. At the moment the new limit applies only to overhead telecommunications lines.

Study is to be continued during 1955-56 of problems relating to magnetic induction, electric induction and noise. The first of these is important to the Post Office because on practically all the major high-voltage power lines in this country the neutral points of the transformers are solidly earthed and earth fault currents are often large. Electric induction is relatively unimportant because most telecommunications plant is in cable. Noise interference is not a serious problem largely because of our awareness in the past of the need for balance in circuits, particularly in the apparatus.

Second Study Group—Protection against Corrosion

This Study Group is primarily concerned with protection against corrosion and other deterioration, and its range covers the consideration of measures to be taken to protect telecommunications cables and other plant against corrosion, decay of poles and the effects of lightning, etc. The mitigation of corrosion involves the consideration of cable sheathings other than lead and of problems relating to the use of plastic and aluminium sheaths.

Particular attention was paid to methods of reducing interruptions to service by keeping cables under continuous gas pressure. By this means when a hole develops in a cable sheath ingress of water is prevented, or impeded, and the fall in gas pressure resulting from the leak enables the seat of the trouble to be located and the fault repaired, without affecting service. The actual leak may be located by using a special gas such as "Freon" which can be readily recognised with a flame detector. An alternative way to locate the leak is to use radio-active gas and a Geiger counter.

One of the new questions of outstanding interest is the study of the special steps to be taken when telecommunication cables, power cables, gas pipes, etc., are connected together for the purpose of instituting a scheme of cathodic protection against corrosion. In the past it has generally been the aim in this country to separate such items of plant from one another. Now, when applying a cathodic protection scheme, they must be considered as a whole so as to avoid safeguarding one sort of plant at the expense of another. This is tantamount to connecting the various types of plant together electrically. The working out of methods for doing this without introducing hazards of burn-out or explosion is the prime purpose of the study.

Another interesting study is the measures to be taken to counter corrosion when D.C. power with earth return is fed over a telecommunication cable for the purpose of energising repeaters.

Third Study Group—Long Line Transmission

This Study Group is primarily concerned with line transmission. The subjects dealt with covered a wide field ranging over the whole aspect of line transmission and involving problems in connection with telegraph and television transmission.

Since the end of the war a high proportion of the effort of the Third Study Group has been concentrated upon the problems and standardisation of carrier and coaxial systems (and radio relay systems) used in Western Europe. This work has continued with the standardisation of the essential characteristics of 12-circuit carrier systems which use a different frequency spectrum for each direction of transmission (12 + 12 circuit systems) on symmetrical pair cables, and the extension of 12- and 24-circuit carrier systems and cable specifications to include 36-, 48- and 60-circuit carrier systems. In response to increasing pressure from the less telephonically developed countries, the specifications for 3-circuit and 12-circuit carrier systems for use on open wire lines have been revised and extended in scope. New questions have also been placed to study with the purpose of providing detailed recommendations on methods of construction and transposition, and the specification, and allocation between the component parts, of noise limits for these systems.

For some time past the variation of the equivalent of international circuits in Europe has been causing some concern and a second series of tests to determine the state of the European network has recently been made under the direction of the Maintenance Sub-Committee. These tests indicated that for international circuits in Europe the variation of equivalent with time had a standard deviation of 1·9 db. This figure showed no improvement over a series of tests taken some two or three years previously. It was therefore decided that a special detailed investigation should take place next year to determine the causes of the variations. During the discussion the American delegate gave a very interesting statement of the methods which had been adopted in the U.S.A. to reduce the variation of circuit equivalent. This included giving talks in repeater stations to emphasise the value of taking great care in making adjustments and the provision of a simple statistical control in the repeater stations, which would attract the interest of the staff in their efforts to improve the performance of the circuits.

Recommendations were made regarding the arrangements and precautions necessary when selected super-groups are derived from a coaxial system or transferred between two systems. In this application derivation implies filtration at line frequency as distinct from filtration and reduction to the basic super-group frequency range. The methods proposed are those to be used in the United Kingdom. Another question being studied is the extension of the frequency spectrum of coaxial lines above 4 Mc/s, and the possibility of transmitting telephony and television simultaneously over the same coaxial pairs.

The published C.C.I.F. recommendations concerning transmission are to be reprinted and opportunity was taken at the meeting to review the existing recommendations for circuits of all types with a view to bringing them up to date and deleting any obsolescent recommendations. The amount of work was too great to complete during the period of the meeting and a working party was formed of representatives of five countries, one of which was the United Kingdom, to meet in February, 1955, to review the recommendations in more detail.

Arising from the Eighth Study Group agreement for signalling on a European semi-automatic network, the Third C.E. were asked to give their views as to the necessity for echo suppressors in the future high-velocity European network. The Third Study Group was able to assure the Eighth Study Group that in only a very small percentage of the calls would an echo suppressor be necessary and that it could be inserted by some simple means by the outgoing operator and, therefore, there was no necessity to plan for any automatic facility to bring an echo suppressor into circuit in the automatic system.

Meetings were also held with representatives of the International Telegraph Consultative Committee. For a long time it has been considered that the C.C.I.F. Recommendation allowed too high a power to be transmitted to an international line with amplitude-modulated picture transmission, and the Third Study Group proposed that this level should be reduced to −10 db. at a point of zero relative level. The C.C.I.T. representatives were unable to agree and after much discussion an interim agreement was made that the transmitted power should not exceed 1 mW at a point of zero relative level. Arising out of this discussion, it appeared that many of the joint recommendations of the C.C.I.F. and the C.C.I.T. concerning picture telegraphy were out of date, and it was recommended that a joint study should be made by the two C.C.I.s to revise them.

A number of problems concerning television transmission over lines was considered and a framework was proposed for a "nominal maximum circuit" for television transmission over coaxial cables of a length of 2,500 km and incorporating two video points. This circuit will be studied before the next meeting, and at the same time the C.C.I.R. are to consider an equivalent "nominal maximum circuit" for television transmission over a radio-relay link of similar length. It is hoped then to be able to combine the two proposals and produce a mixed "nominal maximum" circuit on which the future design of European television plant will be based.

An interesting discussion took place concerning test signals for television circuits. It was considered to be premature to standardise one set of signals but countries gave details of the signals they were using or were proposing to use. For testing the response of the middle and upper part of the video spectrum the U.K. and Germany proposed a signal consisting of a sine-squared pulse together with a half-line bar, whereas the French Broadcasting Authorities proposed a series of short rectangular pulses. For the lower video spectrum a 50 c/s square wave was generally agreed. Two signals were suggested for testing for non-linearity distortion: the U.K. and Germany were in favour of a signal of the "variable-lift" type and France for a signal incorporating a sine wave on "variable lift."

The present recommendations for the maintenance of high-frequency plant and for the groups and super-groups routed over this plant were originally produced by the U.K. in 1946. With the rapid growth of the European network some revision was considered necessary and although a framework to form the basis of the new recommendations, proposed by the Permanent Maintenance Sub-Committee, was reviewed it was not possible to obtain complete agreement. The study will be continued. A useful series of definitions for such terms as "group link," "super-group link," etc., were agreed.

At the joint meetings with the Fifth Study Group and with representatives of the C.C.I.R. perhaps the most important question dealt with was that of noise on wide-band systems. The C.C.I.F. already have limits for noise on a "nominal maximum circuit" for a coaxial cable system and propose to extend this to a symmetrical pair system of the same length of 2,500 km. The C.C.I.R. are studying the problem for a wholly radio-relay system. It is hoped to combine all these proposals in the future and in the meantime the C.C.I.F. laboratory are to carry out articulation tests to determine impairment due to noise arising from the three types of system.

Fourth Study Group—Local Transmission

The Fourth Study Group works in close co-operation with the Third Study Group, and deals with transmission between the subscriber and the local exchange, and in particular with the rating of telephone instruments and with methods of specifying transmission performance generally. It is responsible for the experimental work carried out by the C.C.I.F. laboratory.

It will be recalled that at a meeting in London in December, 1938[1] it was recommended that international agreement should be sought on some method of assessing telephone transmission including the effects of the subscriber's reactions; and it was agreed that the best criterion then known was obtained from observations of repetition rate by such methods as those reported by the A.T. & T. Co. of U.S.A. At the XIVth Plenary Assembly[2] the C.C.I.F. defined "Articulation Reference Equivalents" (AEN) and recommended that provisionally, the tendency in future should be to use them for planning transmission networks. In 1949 equipment for measuring Articulation Reference Equivalents was made available to the C.C.I.F. Laboratory[3] and meetings were held in London, Scheveningen and Paris,[4] at which results of tests on different types of local telephone circuit provided by the A.T. & T. Co. and on telephone sets supplied by five other Administrations were considered, and a further programme of tests by the C.C.I.F. Laboratory was agreed. At the XVIth Plenary Assembly (1951)[5] the results of this programme and of tests of telephone sets of four more Administrations were considered and it was agreed that AEN values should be introduced as soon as practicable for assessing, experimentally, national networks of some European countries, so that the C.C.I.F. might proceed to substitute AEN values for the Volume Reference Equivalents hitherto used in its directives.

In the interval between the XVIth and XVIIth Plenary Assemblies, meetings were held (including representatives of Third C.E.) at Stockholm (June, 1953) and Geneva (October, 1953) and many different types of telephone sets were tested at the C.C.I.F. Laboratory by the technique that had been evolved for AEN tests. It became apparent that with so large a variety of different types of telephone sets, AEN assessments can fail to be realistic as between the most extremely different types. The C.C.I.F. Laboratory had arranged for various of the telephones to be connected, in pairs, to demonstrate this fact to members of the Fourth C.E. meeting at Geneva in 1954.

To investigate discrepancies between laboratory results, and the reasons why some ratings are unrealistic, a programme of tests of selected telephones, to be carried out at Geneva, Stockholm and London, had been arranged in October, 1953, but it had not been completed before September, 1954. Nevertheless some experimental evidence was available to the meeting of the Fourth C.E. to explain a considerable part of the discrepancies.

The 1954 meeting of the Fourth C.E. considered the data which had been furnished by some Administrations of the assessments of their telephone networks, rated in AEN values, and agreed that, in view of the discrepancies which had been demonstrated, the specification in terms of volume reference equivalents should not yet be abandoned, but it proposed an additional clause for AEN ratings which should not be exceeded for 90 per cent. of international calls. After discussion at the Plenary Assembly the additional clause is retained as provisional, to be reconsidered in one year's time. The meeting of the Fourth C.E. also discussed, in the light of the experience with many telephones, alterations to the testing technique with a view to minimising possible discrepancies, but it was ruled that questions relating to assessment of ratings by subjective tests are no longer admissible.

Fifth Study Group—Interconnection of Line and Radio Systems

This Group deals primarily with the interconnection of line and radio systems, and its work is closely linked with that of the Third Study Group.

Joint meetings of the Third and Fifth C.E.s of the C.C.I.F. were held with representatives of the C.C.I.R. present, to consider those questions on radio-relay systems which were of joint interest to the C.C.I.F. and the C.C.I.R. These questions included, on the one hand, those set by the C.C.I.F. and which relate, for example, to the permissible levels of noise and crosstalk on radio links, methods of multiplexing, etc. and, on the other hand, questions set by the C.C.I.R. and on which the opinion of the C.C.I.F. was sought. The latter questions included the channel levels and overall frequency bands to be used in frequency-division multiplex radio-relay systems in order that ready interconnection between radio and line systems might be achieved; and the form of the hypothetical reference circuit to be used as a basis for the design of radio-relay systems transmitting one or more super-groups. These questions had been considered by a meeting of Study Group IX of the C.C.I.R. held in Geneva immediately prior to the C.C.I.F. meeting. Agreement was reached between the C.C.I.F. and the C.C.I.R. on preferred values for the channel levels and the overall frequency bands of the frequency-division multiplex signals for radio-relay systems with up to 24, 60, 120, 240 and 600 channels; the general form of the hypothetical reference circuit was also agreed.

Sixth and Seventh Study Groups—Operating and Tariffs

These Groups deal, respectively, with operating and tariff questions. As these notes are limited to a description of the salient engineering aspects of the work of the XVIIth Plenary Assembly, it is not proposed to enter into any detail as regards the work of these two groups, though it will be appreciated that they have a heavy and interesting programme. Included among the many matters considered by these groups were such questions as agreement on the international priorities to be given to various types of telephone call, the use by public utilities of international telephone circuits, and the difficult problems of the charges which should be applicable to international television transmissions and to international press telephone calls.

Eighth Study Group—Signalling and Switching

The Eighth Study Group is concerned with signalling and switching problems and during the last few years its most important work has been in connection with the choice of a signalling system for use on international semi-automatic circuits. The technical interests of the Eighth Study Group and the operating interests of the Sixth Study Group have been co-ordinated via the Sub-Committee for Rapid Operating Methods; and a special committee called the Field Trials Committee was set up to conduct trials of the two systems which had been proposed, a 1-frequency (1 V.F.) system and a 2-frequency (2 V.F.) system.

The Field Trials Commission issued its final report on the field trials of signalling and switching equipment for international semi-automatic operation in May, 1954. This report indicated that it was possible to establish all classes of international calls on a semi-automatic basis with both service and economic advantages as compared

[1] *P.O.E.E.J.*, Vol. 32, p. 52.
[2] Montreux, 1946, English text, p. 273.
[3] *P.O.E.E.J.*, Vol. 43, p. 1.
[4] *P.O.E.E.J.*, Vol. 42, p. 170.
[5] *P.O.E.E.J.*, Vol. 45, p. 35.

with manual operation, but that the trials had given no definite indication of the superiority of one signalling system over the other. It was therefore decided to prepare a list of factors to be taken into account in choosing a signalling system and ask Administrations to give their qualitative opinions of the importance of these factors.

The joint meeting of the Sixth and Eighth Study Groups and the Permanent Maintenance Sub-Committee was held from 1st September-15th September to consider the replies of Administrations to these enquiries, in conjunction with the final report of the C.E.A., with a view to making a recommendation to the XVIIth Plenary Assembly as to the signalling system to be used for international semi-automatic telephone operation. The meeting was unanimous in expressing the opinion that semi-automatic operation was both practical and advantageous. It was also unanimous in recommending the facilities that should be available at the incoming centre and the organisation of the semi-automatic network to provide terminal and transit service with a measure of automatic alternative routing at outgoing and transit centres. The opinions expressed with regard to re-routing from the outgoing centres, indication at the outgoing operator's position of the route followed by a call under alternative routing conditions, and the choice of signalling system, were, however, divided. The meeting therefore recommended to the XVIIth Plenary Assembly of the C.C.I.F. that for semi-automatic telephone operation, Administrations and Private Operating Companies should, for terminal service, and by mutual agreement, use exclusively one or other of the two signalling systems which had been subjected to field trials; and that where agreement could not be reached to use the same signalling system for both directions of operation, the system adopted on each direction of operation should be that preferred by the outgoing centre. It was also recommended that, for transit traffic, the 2 V.F. system would be used except where a special agreement was reached between three or more countries to use the 1 V.F. system for transit working between them.

At the Plenary Assembly, this recommendation, after only minor textual changes, was unanimously approved, thus providing a most satisfactory solution to a long and difficult study, and tribute was paid to the fine spirit of understanding which had led to this excellent solution of a problem for which it had appeared so difficult to reach general agreement on a decision; this problem (the choice of an international signalling system) had been the subject of work without precedent in the history of the C.C.I.F. and the work was carried out with a remarkable team spirit.

The way is now clear for rapid progress in the introduction of international semi-automatic operation. The essential advantages of this method of operation were outlined in another recommendation to the Plenary Assembly, which was unanimously approved, and which drew attention particularly to:—

(*a*) The large economies in personnel which are secured by the introduction of semi-automatic working not only at the incoming centre but also at the outgoing centre.

(*b*) The very small number of faults due to the international semi-automatic equipment.

(*c*) The improvement in the "efficiency" (ratio of chargeable time to total occupation time) of semi-automatic circuits compared with the efficiency of manual circuits operated in rapid service.

(*d*) The improvement in the quality of service afforded subscribers—improvement due to the reduction in the time of setting up a call.

(*e*) The fact that all types of call can be set up without difficulty over semi-automatic circuits.

To enable the semi-automatic service to be introduced as soon as possible, it was agreed that the operating instructions, specifications, and general maintenance instructions which had been prepared for the field trials should be revised and standardised as early as possible. To this end the Plenary Assembly agreed that a delegation of powers be accorded to the Rapid Operating Commission to deal with the first and third of these items, and to a Working Party, to be appointed by the Eighth Commission, to deal with the specifications.

During the course of its own meeting the Eighth C.E. made a further examination of the replies which had been drafted during its meeting in October, 1953, as regards those questions which it had been asked to study. It also examined those questions which were not replied to during the meeting in October, 1953, as well as the position as regards which questions should be proposed for study to the XVIIth Plenary Assembly, either for the study to be continued or to be commenced. In addition, in accordance with the recommendation of the joint meeting of the Sixth and Eighth Study Groups and the Permanent Maintenance Sub-Committee, the Eighth Study Group made recommendations with regard to the composition of, and terms of reference for, a Working Party to be accorded a delegation of powers to revise and issue the specifications for the recommended international signalling systems.

Replies were given to seven questions (including two referred to the Eighth Study Group by the Third Study Group) and it was proposed to continue the study of six questions as well as to undertake the study of six new questions.

Among the questions answered, the following may be of particular interest. On the subject of interference between national signalling systems connected together via an international circuit, it was recommended that new national signalling-on-speech-path systems employing one or more frequencies in the 2,000-3,400 c/s band should be planned in such a way that:—

(*a*) no fraction of a national signal exceeding 35 mS duration may be able to pass into another country, and

(*b*) the connection between an international circuit and a national circuit shall be split at the international exchange 30 mS before a signal is sent from this exchange over the national signalling system.

One method of meeting the first of these recommendations is to adopt a splitting time of less than 35 mS for national systems, but it is recognised that where such a short splitting time is not justified for the national system itself it would be possible to introduce an arrangement at international terminal centres to limit the duration of national signals liable to pass over an international circuit to a country where a danger of interference would arise.

On the question of the amount of crosstalk attenuation to be permitted within an international exchange, it was recommended that:—

(*a*) the crosstalk measured between any two 2-wire connections through an international exchange should not be less than 70 decibels or 8 nepers, and

(*b*) provisionally, a figure of 50 decibels could be accepted for the signal/crosstalk ratio between the "go" and "return" paths of a 4-wire connection passing through an international exchange.

With respect to the possible overloading of common amplifiers on wide-band transmission systems by 500/20 c/s signalling current it was recommended that steps be taken to reduce the output of the 500/20 c/s generators to 1 mW for 500 c/s *uninterrupted* ringing current, and to limit the duration of the sending of this current to two seconds.

Among the subjects whose study will be continued are those relating to the nature of noise experienced on circuits and its effect on signal receivers, the duration and frequency of short breaks in a transmission path and their effect on signalling, and the reliability of contacts in speech paths in international exchanges.

One particularly interesting new question is concerned with the technical aspects of recording call charges having in mind the development of international subscriber-to-subscriber dialling.

CONCLUSION

The general impression left by the Assembly meetings is encouraging in nearly all the fields covered by the C.C.I.F. Since the last Plenary Assembly at Florence in 1951,[5] the emphasis has mainly been on planning, and the Plenary Assembly just concluded, represented in some ways a turning point. In certain important respects, the way in which developments are likely to take place seems now clear, and there will be considerable emphasis in the next three years on bringing to fruition plans which have been under consideration for some time. As has been indicated, many further matters are in course of study, and there seems little doubt that, with the excellent spirit of co-operation which has characterised the work of the C.C.I.F., further important international agreements over a wide field of telecommunication matters can be anticipated, which cannot but lead to improved international services, and it is to be hoped, to ever-increasing understanding and co-operation among mankind. D. A. B.

Institution of Post Office Electrical Engineers

Annual Awards for Associate Section Papers—Session 1953/54

The Judging Committee has selected the following from the papers submitted by the Local Centre Committees, and prizes of £4 4s. 0d. and Institution certificates have been awarded to the following in respect of the papers named:—

G. L. Sanderson, Technical Officer, London Centre—"Television Outside Broadcasts."

M. P. Steel, Technician I, Lincoln Centre—"Wayleaves—an Outline of the Duties of a Wayleave Officer."

D. Curtis and J. F. Auckland, Technical Officers, Lincoln Centre—"P.A.B.X. No. 1."

W. W. Yeats, Technical Officer, Hastings Centre—"The Communications of Co-operation in Modern Industry."

E. O. M. Grimshaw, Technical Officer, Middlesbrough Centre—"Cables and Corrosion."

In addition, the following papers which were considered worthy of submission to the Judging Committee for the main awards have been awarded a prize of one guinea each:—

K. Hamilton, Technical Officer, Middlesbrough Centre—"Introduction to Carrier Current Telephony."

C. S. Wicken, Technical Officer, London Centre—"An Experimental Subscribers' Observation Circuit."

B. Gould, Technical Officer, Dollis Hill Centre—"Pentodes and Tetrodes."

The Council is indebted to Messrs. C. A. Beer, A. K. Robinson and Lt.-Col. J. Baines, O.B.E., for kindly undertaking the adjudication of the papers submitted for consideration.

H. E. WILCOCKSON,
Secretary.

London Centre

The programme of meetings arranged for the second half of the 1954-55 session is as follows:—

*Ordinary Meetings**

11th January, 1955.—"Common Control and Electronic Devices in Auto Exchanges." T. H. Flowers, M.B.E., B.Sc.(Eng.), M.I.E.E.

8th February, 1955.—"Depreciation and Service Life of Telecommunications Equipment." N. V. Knight, B.Sc.(Eng.), M.I.E.E.

8th March, 1955.—"Some Non-Linear Magnetic Devices and their Application to Telecommunications." J. W. McPherson, B.Sc.(Eng.), A.M.I.E.E.

6th April, 1955.—"Regional Problems in the Provision and Maintenance of V.H.F., U.H.F. and S.H.F. Radio Links." F. Moxon, A.M.I.E.E.

†4th May, 1955.—"On Making a Thinking Machine." A. W. M. Coombs, Ph.D., B.Sc.(Eng.).

Informal Meetings‡

26th January, 1955.—"London Trunk and Toll Exchanges—Their Functions and Future." R. C. Devereux, A.M.I.E.E.

23rd February, 1955.—"Is our Telephone Equipment too Complex?" F. Scowen, B.Sc.(Eng.), A.Inst.P., A.M.I.E.E.

23rd March, 1955.—"The Communications of Staff Co-operation—Lessons from Industry." W. W. Yeats (Associate Section).

20th April, 1955.—"Acceptance Testing of Auto Exchange Equipment." L. G. Tite, A.M.I.E.E.

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

† This meeting will be preceded by the Annual General Meeting of the Institution, commencing at 5 p.m.

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

Additions to the Library

2231 *Television Engineers' Pocket Book.* Ed. E. Molloy and J. P. Hawker (Brit. 1954).
A compendium of useful reference data, practical hints on installing, fault-tracing and aligning, full notes on test equipment, etc., for television engineers, dealers and service men.

2232 *A Statistical Primer.* F. N. David (Brit. 1953).
Designed to present the elements of statistical theory to the research worker who has no advanced knowledge of mathematics.

2233 *Millimicrosecond Techniques.* I. A. D. Lewis and F. H. Wells (Brit. 1954).
Mainly devoted to a consideration of basic circuit elements and pieces of equipment of universal application; with two chapters on specific applications, mostly in the field of nuclear physics instrumentation.

2234 *Heat Engines.* A. C. Walshaw (Brit. 1954).
Intended to serve as an introductory text-book for students preparing for first examinations in heat engines and applied thermodynamics.

2235 *Rocket Propulsion.* E. Burgess (Brit. 1954).
Designed to provide a link between the non-technical and popular works, and highly technical papers and books.

2236 *Rockets, Missiles, and Space Travel.* W. Ley (Brit. 1952).
An encyclopaedic survey of every aspect of rocket propulsion.

2237 *The Essentials of Physics.* D. R. J. Wood (Brit. 1954).
Presents in a summarized form all the essentials which are necessary for the Advanced and Scholarship levels of the G.C.E., for Inter. B.Sc., and for Open Scholarships.

2238 *Applied Electricity.* E. Hughes (Brit. 1950).
Covers the syllabus of the O.N.C. in Electrical Engineering, the "Applied Electricity" of Part 1 of B.Sc.(Eng.), C. & G. Intermediate "Electrical Engineering Practice," and the "Principles of Electricity" I.E.E. Joint Section "A."

Notes and Comments

Commendation by H.M. the Queen

The Board notes with pleasure that H.M. the Queen has commended Mr. J. Carter, Technician IIA, Oxford Telephone Area, for rescuing a man from attack by a bull.

Commendations by the Postmaster-General

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

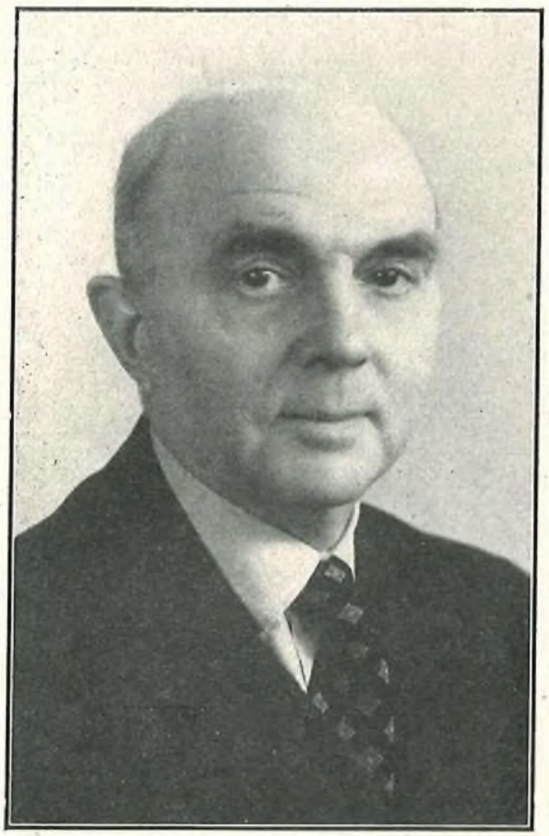
Mr. G. R. Steer, Technician IIA, London Telecommunications Region, to whom the Royal Humane Society has awarded its Testimonial on Parchment for the part he played in the rescue of a family of seven after their boat had overturned in the River Thames on 7th June 1954.

Mr. W. J. Kettle, Technician IIA, Liverpool Telephone Area, to whom the Liverpool Shipwreck and Humane Society has awarded its Parchment for his bravery in attempting to rescue a child from drowning in the River Mersey at Warrington on 31st July 1954.

G. J. S. Little, C.B.E., G.M., B.Sc., M.I.E.E.

Mr. G. J. S. Little took up his duties as Controller of Research on 18th October, 1954, having been Assistant Engineer-in-Chief since January 1947.

Mr. Little studied for his degree in Mechanical Engineering before the first world war, but did not actually take his degree until after the war: he then spent some time with a structural engineering firm. He entered the



Engineering Department by the Open Competitive Examination as an old-style Probationary Assistant Engineer in 1922 and joined the Line Transmission Section of the Research Branch, in those days situated in Marshalsea Road. In 1930 he was transferred to the Lines Branch, and two years later was promoted to Executive Engineer in that branch. Over this period the basic principles of carrier telephony were, of course, being steadily worked upon but the great advances could not come until negative feedback and static modulators had been developed. In the next period, terminating in September 1938, during which he was promoted to Assistant Staff Engineer, Mr. Little helped to lay the foundations of wide-band working as we now know it, and these are clearly described in a series of articles on Carrier Telephony which he contributed to Vol. 29 of this Journal. In 1934, he visited the United States to report on the developments of carrier and coaxial techniques there. An important landmark in line transmission was the international agreement of the frequency allocations for twelve-circuit carrier and coaxial systems, recommended by a sub-commission of the C.C.I.F. in 1938 under Mr. Little's presidency, which have, broadly speaking, become standard all over the world. It is interesting to note that this committee also posed a number of questions on television transmission, some of which we are still trying to answer.

In September 1938, Mr. Little severed his connection with the Engineer-in-Chief's Office for a while, to become Superintending Engineer N.W. District, and he was therefore the first Chief Regional Engineer of the newly-formed North West Region in 1939. It was while he occupied this position that he was awarded the George Medal for meritorious work and conduct in connection with the saving of Central Exchange Manchester from fire, following air attack on the night of December 23rd and 24th, 1940.

In 1945, Mr. Little returned to the Engineer-in-Chief's Office as Staff Engineer of the Radio Maintenance Branch and in the following year he visited South Africa and Australia with officers from the Engineering and Telecommunications Departments to study methods of Trunk Working.

On 9th January, 1947, Mr. Little was promoted to Assistant Engineer-in-Chief and in this capacity he was responsible for trunk lines, local transmission and external construction. He was President of the 3rd C.E. of the C.C.I.F. from late 1947 until this year, during which period very important matters have been discussed dealing with international and semi-automatic working, the transmission of television and wide-band telephony, and the interworking of carrier and radio systems. We are sorry that on his promotion he has had to relinquish the presidency and his intimate connections with the C.C.I.F.

It is obvious that as Controller of Research Mr. Little will bring to this coveted post a wealth of practical and technical knowledge and that, in addition, his kindness and unfailing good humour will ensure his popularity with all ranks. We wish him every success.

H. W.

Journal Binding

The current issue completes Volume 47 and readers are reminded of the binding facilities available as described on p. 252.

D. A. Barron, M.Sc., M.I.E.E.

The appointment of Mr. D. A. Barron as Assistant Engineer-in-Chief following Mr. G. J. S. Little, who has become Controller of Research, will be welcomed by his many friends and colleagues. He brings to his new position a very wide and varied experience, not only nationally but internationally.

After graduating with honours at Bristol University, Mr. Barron entered the Post Office as a Probationary Assistant Engineer in 1927, and gained his early experience

in the Technical Section of the old South Western Engineering District at Bristol, where he was engaged for some years on local line development, and also in the Plymouth Section, where he was particularly concerned with the transfer of Plymouth Exchange to automatic working. In 1936 he was promoted to Sectional Engineer in charge of Works Execution at Liverpool, where he earned special commendation for his work in connection with the planning for the transfer of the Liverpool Area to director working. He remained there until he was transferred to the Telephone Branch of the Engineer-in-Chief's Office in April 1940, where, in January 1941, he was promoted Assistant Staff Engineer in charge of circuit design, apparatus and relay design and standardisation, and the Circuit Laboratory.

It was undoubtedly his wide knowledge, not only of telephone apparatus and circuits but also of subscriber's line plant distribution which caused him to be chosen in 1945, to lead a team of Traffic and Engineering officers to prepare plans and specifications for the transfer of the whole of the Calcutta area to automatic working. For this purpose he was seconded to the Telephone Manufacturers of India Limited, as Chief Consultant to the Indian Post and Telegraphs Department.

On his return to the Post Office in 1947, he was placed in charge of a working party to survey circuit switching methods and associated plant and to examine the problem of subscriber-to-subscriber dialling. During this period he took a small party to America to examine parallel practices in that country. His paper "Subscriber Trunk Dialling in the United Kingdom" has been widely read at a number of centres of the Institution and was awarded the Senior Silver Medal of the 1952/53 session. In November 1949, he was promoted Staff Engineer of the Telephone Branch.

Mr. Barron has attended a number of meetings of the C.C.I.F. in a representative capacity, and in recent years he has been Chairman of a Field Trials Commission to conduct trials of two signalling systems suggested for international semi-automatic working. At the recent Plenary Assembly of the C.C.I.F. he was elected Chairman of the 8th Study Group—Signalling and Switching, and this is the only chairmanship of a main Study Group now held by the United Kingdom.

In his new post Mr. Barron will take charge of the Telephone, Subscribers' Apparatus, Equipment, Training, and Power Branches and, in addition, he will be Chairman of the Headquarter Boards for promotions to Assistant Staff Engineer and Regional Engineer and to Senior Executive Engineer. He brings to his new duties an abundant ability for clear thinking and lucid expression and a very wide understanding of human nature. All who have come into contact with him will undoubtedly wish him well for the future.

C. E. M.

The Inventor of the Valve

Coinciding with the recent Jubilee of the invention of the Thermionic Valve, an occasion which was marked by celebrations at the Institution of Electrical Engineers and University College, London, the Television Society published a short biography of Sir Ambrose Fleming, whose original patent has given rise to the science of electronics and radiocommunication.

It has been written by his former student and assistant, Professor J. T. MacGregor-Morris, with a Foreword by Prof. E. W. Marchant and an Appendix of personal recollections by Mr. Arthur Blok, O.B.E. The text, of 134 pp., is illustrated with reproductions of original notes and letters, many of which are published for the first time.

The edition is limited to 1,000 copies, and copies are obtainable from the Television Society's office, at 164 Shaftesbury Avenue, W.C.2, price 10s., post paid.

Book Review

"Crystal Rectifiers and Transistors." Consulting Editor M. G. Say, Ph.D., M.Sc., M.I.E.E. Compiled by E. Molloy. George Newnes, Ltd. 168 pp. 127 ill. 18 tables. 21s.

The book describes the production and purification of germanium for use in semiconductor devices, and gives an elementary account of the properties of germanium and silicon diodes, point-contact transistors and junction transistors. A short section is devoted to the elementary physics of semiconductors. Nearly half the book, however, is taken up with operating data on commercially available semiconductor devices, some of which are already obsolete. In view of the rapid progress in this field, the author has been unwise to devote so much space to commercial data. The book has a section dealing with oscillographic display of the characteristics of transistors, and a section dealing with photo devices, including a simple account of the theory of their operation. The final chapter deals with applications, but surprisingly makes no mention of the hearing aid, perhaps the most promising immediate application of the junction transistor. On the other hand the Doherty amplifier, of little more than academic interest, is dealt with in some detail.

Frequent repetition and the absence of a bibliography tend to detract from the value of the book.

H. G. B.

Regional Notes

London Telecommunications Region

OPENING OF LONDON TRUNK, KINGSWAY

The second mechanised trunk unit, designated "London Trunk, Kingsway," which it is hoped to describe in some detail in a later issue, was opened to public traffic on 30th October, 1954, at 9 a.m. This addition to the trunk system constitutes a through switching centre for trunk calls between provincial centres and, to a lesser extent, a London terminal switching point for trunk traffic to and from those centres. The first unit,[1] opened in Faraday Building S.E. Block on 27th February, 1954, functions for outgoing traffic from London.

The exchange equipment which was manufactured and installed by Siemens Bros. & Co., Ltd., comprises 312 racks of motor uniselectors and 209 racks of incoming, outgoing and bothway relay sets for signalling as follows:—

Outgoing trunk circuits—A.C.1 with regenerators, A.C.3, A/A, D.C.1, D.C.2, C.B.

Incoming trunk circuits—A.C.1, D.C.1, D.C.2.

Bothway trunk circuits—A.C.1, D.C.2.

As in London Trunk, Faraday, automatic routiners are installed for outgoing trunk and junction circuit testing as well as for equipment tests. The trunk circuit test cycle relies on an answering signal from the distant trunk exchange for a complete test of a circuit. All routiners, of which there are 25, are associated with automatic fault recorders, the recorder associated with the outgoing trunks and junctions being located in the test room.

MOTOR UNISELECTOR RACKS IN KINGSWAY TRUNK EXCHANGE.

The size and layout of this exchange required the installation of four I.D.F.s with initial capacities varying up to 108 verticals. The close association of the exchange with the Kingsway repeater station has necessitated the installation of an M.D.F. of 28 verticals: this frame is wholly equipped with connection strips and is additional to a standard M.D.F. of 78 verticals. The test room is equipped with a suite of 21 test racks for trunk circuit testing and six test racks for junction testing, three fault record racks, a Verbal Delay Announcement Control rack and three four-position fault reporting and recording tables. The exchange capacity is 5,000 trunks and approximately 5,000 junctions, and the extent of the switching installation has involved the contractor in the manufacture and running of approximately 337 miles of switchboard cable and the erection of three miles of cable racking. Considerable saving in switchboard cable was effected in the cabling of selectors and relay sets between I.D.F.s instead of across I.D.F.s in the more usual manner. Further economy resulted from the uniform location of routiner access racks at the ends of rack suites.

The power plant is of special design to meet a total load of 4,000A, with three 55V, 1,000A rectifier units (ultimate four) automatically switched in or out of the float system as the load varies. Two 5,000Ah batteries function on the divided-battery float principle. Associated with the rectifiers is a three-unit filter having a total weight of approximately 10 tons. Two more rectifiers may be operated at 55V, 500A for floating or 72V, 250A for charging.

The bus bars from the two batteries to the battery switching and distribution panel contain 18 tons of copper and those from the rectifier equipment and in the exchange distribution comprise 20 tons of aluminium. The bus bar size involved the use of several bars per pole (maximum 7), and to reduce inductance to a minimum positive and negative bars are interleaved; this has made necessary sheet metal trunking external to the battery room to afford protection against mechanical damage. Jointing of bus bar lengths necessitated high-pressure assembly using high tensile strength bolts, the bracket assemblies being built up with Permali details.

The main 415V A.C. 3-phase supply is available over two alternative feeders and four 300kVA standby diesel generator sets are now being provided.

Assistance traffic is switched to Faraday Building North Block, Room 2M, while delay booking is controlled in the South Block, Room 6S. Verbal delay announcements are connected to late-choice outlets of motor uniselectors. The opening date traffic is carried by 1,504 outgoing and bothway trunks and 1,042 incoming trunks.

An extremely involved and important feature of this exchange opening was the very large number of trunk circuits switched into the Kingsway system. There were 1,226 outgoing and bothway trunks and 876 incoming trunks switched at Kingsway, while 429 and 380 trunks, respectively, involved switching at various distant ends. The control of all switching was vested in the London Trunk test room, for which agreement had been established with all Regions concerned. A preparatory conference of Regional representatives was held in the L.T.R. to acquaint all concerned with the procedure to be followed and the full significance of the pre-opening and opening operations: in consequence, very extensive testing and switching operations were executed with full co-operation from the Provincial centres and the transfer operation was completed without difficulty.

The circuit work involved the provision, rearrangement and re-lining of some 3,650 trunk circuits and 85 carrier groups; and the provision of 2,833 junction circuits, 120,000 jumpers involving 500 miles of jumper wire, 600,000 soldered connections, 20,000 jumpering schedules and 32,000 record and information cards.

In order that the required ready-for-service date could be achieved, much of the manufacture of the plant had been pressed forward as development data were agreed with the Engineering Department. The study of accommodation and engineering problems extended over more than three years prior to the commencement of installation on 1st July 1952, when access to site was restricted and rendered operations of this character difficult. For this reason, the manufacturers' installation plan provided for the complete erection of cable racks and all the running of cable in advance of the arrival of apparatus racks, with considerable advantage, in this particular case; it was possible to proceed speedily with a large block of work at a time when accommodation was not fully available for the acceptance of apparatus.

The success of this project was largely the result of close and cordial operation between Siemens Bros. & Co., Ltd., and the Post Office organisation at all levels, and in all departments, throughout the entire planning, engineering and installation work.

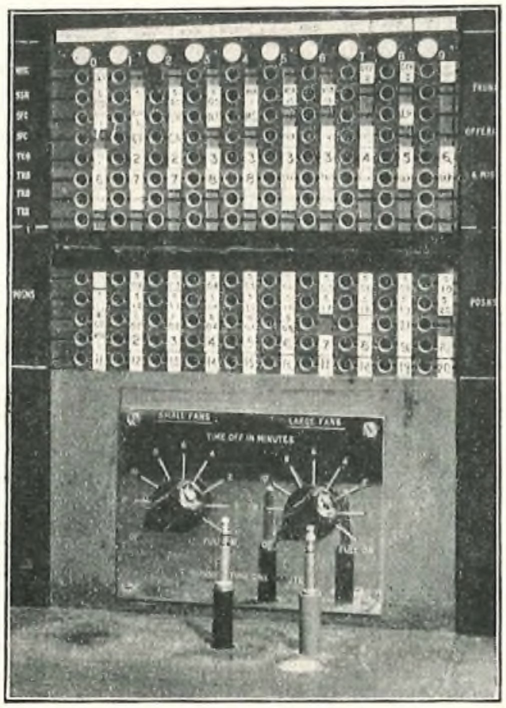
F. B. C., F. V. P.

[1] *P.O.E.E.J.*, Vol. 47, p. 53.

Scotland

CENTRALISED EXHAUST FAN CONTROL

It has been necessary to fit four large exhaust fans at Edinburgh Joint Trunk Exchange to assist ventilation, due to the very congested nature of the switchroom. Normally these fans are run intermittently, the periods on and off depending very much on the temperature, humidity, number of staff on duty, etc., at the time. Originally manual switching at the various points behind the switchboard was undertaken by an operator at prescribed intervals, but a centralised control



EXHAUST FAN CONTROL ON SUPERVISOR'S DESK.

circuit has now been fitted to the supervisor's desk embodying a variable automatic timing feature. It consists essentially of a uniselector and three relays fed from a 30-second time pulse, and arranges for the fans to run for approximately 1 minute at a time, the interval of switch-off between subsequent 1-minute runs being selected by the supervisor on a 12-position Yaxley switch on her desk.

After a little experience, the supervisor is thus able to set the switch to suit the air conditions existing in the switchroom and the fans will continue to switch on and off at that setting. A closer balance has been obtained by separating the fans into two groups each independently controlled. These arrangements have been in use throughout the summer and have worked very satisfactorily. J. J. L.

REPLACEMENT OF APPARATUS AT DUNDEE PARK EXCHANGE

An unusual exchange transfer of some 2,300 subscribers and 260 junctions took place on Wednesday, 3rd November, 1954, at Dundee Park satellite exchange.

The pre-2000 equipment at this exchange was replaced by 2000-type, in the same apparatus room, and a new power plant provided. The power plant was changed in advance to release space in the apparatus room taken up by the old power board, motor-generator and ringer panel. It was, however, necessary to retain the old ringer panel and machines in a temporary position in the apparatus room to supply the old equipment until after the change-over.

Owing to lack of space in the apparatus room it was necessary to install four uniselector racks in temporary positions until after the transfer. Also, owing to floor space difficulties, it was necessary to defer the installation of the traffic recorder and associated access racks and the outgoing junction automatic routiner and access racks. Relay sets for the 9 and 0 levels were accommodated temporarily on an old-type rack until space was released for the new rack.

The old satellite exchange used the discriminating selector repeater but the new exchange employs the group selector method of working.

The extension of the new exchange, to be put in hand after the recovery of the old apparatus, will enable some 300 subscribers to be transferred from the temporary Balgay C.B.S.2 relief exchange installed in the same building.

A unique feature of Park exchange is that it is the first one to be equipped with the new SE 50 switch. A special trial of this switch is being made at Park exchange and at Caterham, Surrey, the 2,000-type switch and the SE 50 having been fitted in alternate positions in the grading.

Although the circuit of this switch is very similar to the 2000-type, and the switches are interchangeable, its construction and operation are very different. The construction is on the unit principle enabling complete units to be removed and adjustments made on the bench, e.g., the vertical and rotary magnet assemblies. The new switch employs a release magnet and releases in the same manner as the pre-2000 switch but both the vertical and rotary release actions are under the control of separate springs.

Dundee also claims uniqueness in two other exchanges in addition to Park. At Dundee Central and Broughty Ferry visitors may see some peculiar looking equipment working alongside pre-2000 and 2000-type equipment. This is the old "North Electric" equipment with banks behind the mechanism of the switches whose wipers travel in the rotary direction before the vertical. This equipment was installed in 1924 and is still giving good service. A. F. H.

Wales and Border Counties

NEW POLICE TELEPHONE AND SIGNAL SYSTEM

Cardiff has many claims to be regarded as the foremost city in Wales; and on 22nd July, 1954, it could with reasonable pride be regarded in one respect as the leading city in the United Kingdom because on that particular day an entirely new police telephone and signal system was brought into service for the use of the Cardiff City Police. Standard type P.B.X.s are used with the new system, and this is a considerable improve-

By courtesy of "Western Mail," Cardiff.

POLICE PILLAR (POST PA No. 2).

ment on the old method of installing a special switchboard (PA 150) with its associated amplifier and line signalling equipment. Sections, Switch P.B.X. SA 7560 were provided at Cardiff, and the interesting features of the new system include the following:—

Normal standard P.B.X. facilities are available; and in addition a line jack, a line lamp, a ring and reset key, and a ring lamp are associated with each pillar. The jacks, lamps and keys are in strips of 10 and are accommodated in the extension line multiple.

Party-line working has been dispensed with and separate cable pairs are used for each pillar. The lines terminate on two types of strip-mounted sets, the one type (PA 455) being suitable for lines with line loop resistances less than 300 ohms, and the other type (PA 454) for lines exceeding this resistance limit. These strip-mounted sets together with the common equipment (PA 453) are usually mounted on Racks, Apparatus No. 15, but as the available floor space at Cardiff was rather limited a 10 ft. 6 in. Racks, Apparatus AD 5208A was used. The common equipment includes a standby ringing vibrator circuit and two circuits for interrupting the ringing current at approximately 0·75 seconds on and 0·75 seconds off for flashing the street call-point lamps.

Lamps have been placed, at positions corresponding to the pillars, on a large-scale street map of Cardiff used by the police. These lamps flash when a pillar is being rung by the switchboard operator, and give a steady glow when the pillar is in use by the police or public.

At the pillar (Posts PA No. 2) or police kiosk, an ordinary H.M.T. is provided for the use of both police and public. The pillar has three compartments and is surmounted by an amber signal light. The top compartment contains the telephone and a 60W lamp for illuminating the Perspex signs round the top of the post and in the door. The bottom two compartments are normally accessible only to the police and include a writing shelf and storage space for first-aid outfit and policeman's cape. The bottom compartment also houses the lamp signalling unit (Unit Signalling PA No. 2), the mains cut-out, a radio interference suppressor, and a Protector and Fuse No. 1.

The pillars were found to be awkward to handle in busy streets and a "Minilift" hoist proved to be of immense value.

At the opening date 19 pillars were brought into service. A further 26 pillars will be installed by the end of March, 1955, and the remaining 45 during 1955/56.

There is little doubt that the new system is a considerable improvement on the old one and gives improved line utilisation and transmission performance.

E. L. J.

Associate Section Notes

Dollis Hill Centre

Having now been in existence for two years as a separate centre, the Dollis Hill Centre has developed into what we believe to be one of the most efficiently controlled centres of the Associate Section.

This has been possible due to its relatively large membership —some 350 members—being confined to a compact physical area where all members enjoy full facilities.

At the time of writing 17 popular periodicals are circulated amongst members, frequent visits arranged and monthly lectures given.

A large part of this rapid progression must be attributed to the zeal of the past chairman, Mr. B. Gould, whose energy and resourcefulness played a great part in the development of the Centre.

Officers for the 1954/55 session are: *Chairman:* Mr. G. W. Smith; *Secretary:* Mr. A. A. Payne; *Treasurer:* Mr. F. Thomas; *Liaison Officer:* Mr. S. Welch; *Radio Secretary:* Mr. R. T. Whitlock; *Talks Secretary:* Mr. H. J. Hawkins; *Visits Secretary:* Mr. C. A. Jackson; *Asst. Visits Secretary:* Mr. G. J. Wallis; *Librarian:* Mr. R. A. Daymond; *Asst. Librarian:* Mr. R. P. Clarke.

A. A. P.

London Centre

The 1954-55 session commenced on the 21st September with a lecture entitled, "The Solution to Some Technical Problems which have occurred in the development of Telecommunications." The lecturer was Colonel C. E. Calveley, O.B.E., President of the Associate Section. The lecture was built up around many well-arranged demonstrations and it was evident that a great deal of thought and work had gone into its preparation.

On 21st October, Mr. R. W. Palmer of the Engineer-in-Chief's Office gave a lecture on "Auto Maintenance in other Countries." In the course of this general review references were made to the practices adopted in Australia, Eire, Germany, Norway, Sweden, Spain and the U.S.A. The lecture was accompanied by some very interesting slides. The questions asked after the lecture were many and varied, proving that the evening had been well spent. Amongst the visitors at this meeting the London Centre were pleased to welcome Mr. W. J. A. Hughes, who was a member of the British Productivity Team which Mr. R. W. Palmer led in the U.S.A.

The title of the lecture for the meeting held on 18th November was "Conceptions of Space and Space Travel." The lecturer, Mr. Lankshear, gave a general review of the various technical problems to be considered and gave an idea as to their solution. Rockets and their design were briefly considered and the importance of fuel was explained. A description of a journey to the moon concluded the lecture. Models of rockets and an illuminated space chart helped to clarify many points. After the lecture a film strip was shown which indicated the past work on this subject and also the progress that is being made on it here and abroad. The attendance at this lecture and the many questions asked of the lecturer proved that a great amount of serious interest is being taken in this subject.

The News Letter published by the London Centre has been altered to a "Quarterly Journal." The London Centre Committee hope that their members will take advantage of its space to pass on their written thoughts and ideas. E. W. B.

Birmingham Centre

The opening meeting of the 1954/55 session was held on 13th September, when Mr. W. A. W. Merrick presented a paper on "Television and Coaxial Control." A small but very interested audience thoroughly enjoyed the meeting and were later shown the equipment concerned in the Repeater Station at Telephone House. On Saturday, 25th September, a party visited Hams Hall "B" Power Station and spent the morning being shown all the equipment there.

The October meeting consisted of a paper entitled "Sewage Purification" which was given by Mr. C. E. Winsor, the Superintendent of the Coleshill and Minworth Works of the Birmingham Tame and Rea District Drainage Board. A most interesting and informative evening was followed by a visit to the Board's Coleshill Works on Saturday, 23rd October, when members were able to see all the processes concerned.

An interesting and varied programme has been arranged for the session and the remaining items are as follows:—

24th January.—"The Work of the Post Office Factories Department," by T. H. Southerton, Factory Manager, Fordrough Lane Factory.

26th January.—Visit to Fordrough Lane Factory.

8th February.—"The Moon—How Information is Obtained," by E. J. Burdon, LL.B., of Birmingham Astronomy Group.

24th February.—Visit to Birmingham Astronomy Group Observatory Telescope.

9th March.—"Electronics in Telephone Exchanges," by T. H. Flowers, M.B.E., B.Sc., M.I.E.E., Dollis Hill Research Station.

19th March.—Visit to Elmdon Airport.

4th April.—"Redevelopment of the City of Birmingham," by Neville Borg, A.M.I.C.E., City Surveyor's Department.

16th April.—Visit to Saltley Gas Works.

26th April.—Annual General Meeting.

A slight fall in membership has occurred this session, but the Centre is still quite strong, the present figure being 285. The Officers and Committee continue to find the attendance at meetings rather disappointing, and all members are urged to attend the very interesting talks which have been arranged for their benefit and enjoyment.

The room now being used for meetings is much larger than the present Conference Room in Telephone House and has met with the general approval of those members who have attended the first two meetings. This room has been booked for the majority of meetings this session in view of the fact that more members can be accommodated, and it is hoped that on future occasions the room will be well filled.

K. G. S. A.

Brighton Centre

Activities for the 1954/55 session commenced on Wednesday, 15th September, when a party of 32 members visited the Esso Petroleum Company's Oil Refinery at Fawley, near Southampton. The visit was a very interesting one, and the party were guests of the Company for lunch and tea.

The winter programme commenced on Wednesday, 6th October, with a lecture by Mr. L. R. F. Harris of the Dollis Hill Research Station, entitled "Electronic Exchanges." Mr. Harris dealt most admirably with a very technical and topical subject, and the lecture was greatly enjoyed by an audience of over 60.

The rest of the winter programme is as follows:—

5th January.—Film Show.

2nd February.—Lecture entitled "Atomic Energy and its Meaning," by Mr. H. V. Thorpe of the Senior Section, Brighton.

2nd March.—Lecture entitled "Telecommunications in Rural Areas," by Mr. L. B. Brazier of the Associate Section, Brighton.

6th April.—Annual General Meeting.

We are also pleased to be able to report that our membership is still increasing. K. E. G.

Carlisle Centre

The Annual General Meeting of the Carlisle Centre was held on Tuesday, 13th April, 1954 in the King's Head Hotel, Carlisle.

The following officials were elected:—

President: Mr. L. A. Triffitt, B.Sc., A.M.I.E.E.; *Chairman:* Mr. H. R. N. Inniff; *Vice-Chairman:* Mr. A. Shirt; *Secretary:* Mr. W. A. Harper; *Deputy Secretary and Librarian:* Mr. R. D. Cleaver; *Committee:* Messrs. J. M. Gibson, P. Hurson, J. T. Harrison, C. B. McCarthy, S. Shane, A. Wilson and W. V. S. Todhunter; *Hon. Auditors:* Messrs. P. Hurson and G. T. Priestley.

The programme for the remainder of the Session is as follows:—

11th January.—To be announced later.

8th February.—"Transatlantic Telephone Cable," by J. F. Bampton, B.Sc., A.M.I.E.E., and P. T. F. Kelly, B.Sc.(Hons.), A.M.I.E.E.

8th March.—"Some Aspects of Underground Cable Construction," by Mr. A. Kilgour.

12th April.—Annual General Meeting. W. A. H.

Chiltern Centre

At the time of writing, our programme has been almost completed for 1954, one meeting remaining, when Mr. Hartwell visits us to talk about "Telephones and their Development," on 25th November. Our Annual General Meeting follows early in December, and it is hoped by then to have the 1955 session arrangements completed.

Past meetings this session included many really interesting papers:—"Iron and Steel" (Mr. J. Evans), "Producing your Local Paper" (Mr. G. Higgs) and "Repeater Station Power Plant" (Mr. R. C. Kyme). An outstanding event was our visit in May to Siemens' Cable Factory when 16 members spent a most enjoyable day seeing various types of cable being made. The warm welcome and hospitality extended to us by Siemens was much appreciated. H. J. T.

Darlington Centre

An enjoyable conclusion to the 1953/54 session was a visit to the Cable Ship *Recorder* on Saturday, 14th August, when an enthusiastic party of 20 members travelled at their own expense to Newcastle where the trim, business-like vessel was tied up at the quay-side. The party were conducted over the ship by Fourth Officer Clark and Testing Officer Mawson and were fascinated by the description of the intricate operations involved in cable repairs and the evident efficiency of the arrangements. In an atmosphere of mutual enjoyment many questions were asked and answered.

The members read with pleasure that *Recorder* was well on her way again after the misfortune on her maiden voyage and they wish her every success in her future career.

The 1954/55 session opened on 14th October with a talk on "Gas—Manufacture and Utilization" prefaced by two most interesting sound films. The speaker was Mr. C. Hindle, Engineer and Manager, Darlington Gas Works. He gave a very able description of the industry and its uses in the present era, following which there was over an hour's very enjoyable discussion. Arrangements were made for a party to be shown over the Gas Works on Saturday, 20th November, to see a new manufacturing plant in operation.

Further meetings were:—

25th November.—"Cable Faults," by Mr. H. C. Naylor, A.M.I.E.E.

14th December.—"Some Aspects of Modern Telegraphy," by Mr. L. S. Airey (Centre Member).

A cordial invitation is extended to Middlesbrough Centre members to come along to any of our meetings. C. N. H.

Dundee Centre

The season is well in its stride and so far we have had some most instructive evenings together. On the 13th September, Mr. S. J. Smith, T.M., Scot.West, read a paper on the "Storm in the North East, 1953" which was very interesting. On the 27th September a party was conducted over an Intermediate Repeater Station by two T.O.s, Messrs. G. Douglas and J. Matthew, who explained in full the modern power plant and New Equipment Practice. The 11th October brought us a Film Show arranged by the Esso Petroleum Co. These films were of a very high standard and greatly appreciated. This was followed on the 25th October with a visit to a local observatory where we were introduced to some of the planets, Mars, Jupiter, etc.

Monday the 8th November was the occasion for a talk on office machinery and a visit from the C.R.E., Mr. Hines, when he presented one of our members, Mr. G. Douglas, with a Certificate gained in last year's Essay Competition.

The remainder of the session's programme holds many attractions, and it is hoped that more of our membership will take advantage of them. R. L. T.

Edinburgh Centre

On 12th October, Mr. G. Campbell was welcomed back to the Centre when he gave his paper "Trunk Mechanization" to a small but appreciative audience, the up-to-date information put over that evening keeping every one in the picture as regards the latest developments in this field. The November meeting was on entirely different lines, a Centre member, Mr. J. Mann, giving a most interesting talk on silversmithing at home. The excellent examples shown that evening made many members wish they had such a hobby at their finger-tips.

Three new additions to the session's programme have now been announced, "Further Steps in Photography" being on the agenda for January, "Mechanical Aids" for February, and what promises to be of great topical interest to all, a talk on "Atomic Power" in March.

New members are still required to make the Centre a real go-ahead organisation of benefit to all. The potential in Edinburgh is such that it should be possible to double the membership. Non-members are especially welcome at the Centre's meetings, and the Secretary would like to hear more suggestions and ideas from the members. J. R. H.

Staff Changes

Promotions

Name	Region	Date
Engr.-in-Chief to D.D.G.		
Radley, Sir Gordon	E.-in-C.O. to Post Office Headquarters	18.10.54
Contr. of Research to Engr.-in-Chief		
Harris, Brig. L. H.	E.-in-C.O.	18.10.54
Asst. Engr.-in-Chief to Contr. of Research		
Little, G. J. S.,	E.-in-C.O.	18.10.54
Staff Engr. to Asst. Engr.-in-Chief		
Barron, D. A.	E.-in-C.O.	18.10.54
Area Engr. to T.M.		
Loosemore, E. S.	Mid. Reg. to N.E. Reg.	25.10.54
Exec. Engr. to Snr. Exec. Engr.		
Clark, R. J.	Mid. Reg.	5.8.54
Broadhurst, F.	N.W. Reg. to Scot.	24.8.54
Wilcher, F. B.	S.W. Reg.	30.8.54
Lash, A. R.	E.T.E.	27.4.54
Gill, M.	L.T. Reg. to N.W. Reg.	23.8.54
Gilbey, P. D.	N.E. Reg. to E.-in-C.O.	20.9.54
Eley, A. C.	Mid. Reg.	10.9.54
Ellenden, A. H.	H.C. Reg. to E.-in-C.O.	1.10.54
Gordon, S. C.	E.-in-C.O.	11.10.54
Bailey, C. W.	Scot. to N.I. Reg.	15.11.54
Asst. Engr. to Exec. Engr.		
Paxton, C.	Mid. Reg. to E.-in-C.O.	6.9.54
Cave, A. W.	L.T. Reg. to E.-in-C.O.	13.9.54
Hayward, A. R.	S.W. Reg. to E.-in-C.O.	27.9.54
McLeod, J.	N.E. Reg. to N.W. Reg.	3.8.54
Alcock, H.	N.W. Reg.	17.7.54
Crabb, G. T.	N.W. Reg.	20.9.54
Davies, W.	N.W. Reg.	19.8.54
Hodgson, J. P.	N.W. Reg.	27.8.54
Allan, J. M.	Scot. to E.-in-C.O.	30.8.54
Burke, T. F.	N.W. Reg.	1.9.54
Purvis, C.	H.C. Reg. to E.-in-C.O.	6.9.54
Meller, V. C.	W. & B.C. to E.-in-C.O.	1.9.54
Knight, N.	Mid. Reg. to E.-in-C.O.	7.9.54
Young, A. C.	H.C. Reg.	27.9.54
Maynard, R. R. J.	S.W. Reg.	4.10.54
Westlake, C. E.	S.W. Reg. to W. & B.C.	11.10.54
Prickett, S. L.	L.T. Reg. to Scot.	28.9.54
Lauderdale, F. S.	N.E. Reg.	28.10.54
Miller, H.	N.E. Reg.	28.10.54
Chapman, A.	N.E. Reg.	28.10.54
Rowlands, E. J.	N.W. Reg.	10.11.54
Owen, E. A.	Mid. Reg. to Scot.	20.9.54
Asst. Engr. (Open Competition)		
Hutt, B. J.	E.-in-C.O.	22 11.54
Ball, P. W.	E.T.E.	22.11.54
Morse. G. E.	E.-in-C.O.	22.11.54
Dell, F. R. E.	E.-in-C.O.	22.11.54
Easterbrook, P. J.	E.-in-C.O.	22.11.54
Weddell, E.	H.C. Reg.	22.11.54
Spicer, F. V.	L.T. Reg.	22.11.54
Morling, K. F.	E.-in-C.O.	22.11.54
Kennard, D. E.	E.-in-C.O.	22.11.54
Hutcherson, P.	E.-in-C.O. to L.P. Reg.	22.11.54
Doble, J. E.	E.-in-C.O.	22.11.54
Hobbs, D. E.	N.W. Reg.	22.11.54
Nicholls, D. G.	Mid. Reg.	22.11.54
Logue, H.	E.-in-C.O.	22.11.54
Bist, A. G.	E.-in-C.O.	22.11.54
Nye, P. J.	E.-in-C.O.	22.11.54
Inspector to Asst. Engr.		
Weeks, C. R. J.	S.W. Reg.	23.6.54
Thompson, E. K. S.	S.W. Reg.	26.9.54
Smith, A. W.	N.W. Reg.	20.9.54
Bangay, R.	L.T. Reg.	30.5.54
Mills, J. F.	L.T. Reg.	30.5.54
Worrall, R.	L.T. Reg.	1.7.54
Hobley, H. F. G.	L.T. Reg.	21.8.54
Appleton, W. A.	L.T. Reg.	19.7.54
Nisbet, I. O.	Scot.	13.8.54
Rawlinson, W.	N.E. Reg.	1.11.54
Stewart, R.	Scot.	1.10.54
Lauwers, A.	L. T. Reg.	20.9.54
Tech. Offr. to Asst. Engr.		
Griffiths, F. J.	N.W. Reg.	19.8.54
Booth, H.	N.W. Reg.	25.8.54
Medford, R. C.	N.W. Reg.	25.8.54
Emery, T. M.	N.I. Reg. to E.-in-C.O.	18.9.54
Townson, P. G.	S.W. Reg. to E.-in-C.O.	18.9.54
Eaton, R. J.	S.W. Reg. to E.-in-C.O.	18.9.54
Horne, G. H.	W. & B.C. to E.-in-C.O.	18.9.54
Peacock, S.	N.W. Reg.	20.9.54
Farmer, C.C.	S.W. Reg. to E.-in-C.O.	25.9.54
Redfern, F. C.	W. & B.C. to E.-in-C.O.	25.9.54
Doe, E. S.	S.W. Reg. to E.-in-C.O.	25.9.54
Price, D.	H.C. Reg. to E.-in-C.O.	25.9.54
Yeats, W. W.	H.C. Reg. to E.-in-C.O.	25.9.54
Baker, F. H.	H.C. Reg. to E.-in-C.O.	25.9.54
Sma'e, P. H.	S.W. Reg. to E.-in-C.O.	25.9.54
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Birdsall, W. R.	L.T. Reg. to E.-in-C.O.	16.10.54
Selby, E. J.	L.T. Reg. to E.-in-C.O.	16.10.54
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Chapman, R. K.	H.C. Reg.	26.7.54
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Hillage, R.	W. & B.C.	25.10.54
Taylor, R. A.	W. & B.C.	5.10.54

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Name	Region	Date
Tech. Offr. to Inspr.		
Cameron, P.	Scot.	2.10.54
Cockburn, W. A.	S.W. Reg.	5.7.54
Tech. I to Inspr.		
Roberts, J.	N.W. Reg.	27.8.54
Munday, F. G.	L.T. Reg.	1.7.54
Weller, S.	L.T. Reg.	22.5.54
Ray, F. W. D.	L.T. Reg.	30.5.54
Speed, R. J.	L.T. Reg.	1.8.54
Waller, W. A.	L.T. Reg.	1.7.54
Young, W. C.	L.T. Reg.	1.8.54
Jelley, R. H.	Mid. Reg.	19.7.54
Lukeman, S. R.	Mid. Reg.	9.9.54
Hastings, T. L. C.	Scot.	6.7.54
Dickson, J.	Scot.	16.8.54
Steel, M. P.	N.E. Reg.	8.8.54
Farnden, E.	N.E. Reg.	22.6.54
Stephenson, T. S.	N.E. Reg.	20.9.54
Richardson, H.	N.E. Reg.	3.5.54
Wolvey, A. F.	H.C. Reg.	21.7.54
Hemmings, G. C.	H.C. Reg.	9.6.54
Stephens, H. E.	H.C. Reg.	1.9.54
Plasom, G. A.	H.C. Reg.	21.2.54
Hunt, F. G.	Mid. Reg.	14.10.54
Finney, J. R.	H.C. Reg.	23.10.54
Tech. I to Inspr.—continued.		
Jones, B.	L.T. Reg.	8.11.54
Rawkins, F. D.	L.T. Reg.	6.10.54
Townsend, R. F.	L.T. Reg.	27.9.54
Blackwell, J. R.	L.T. Reg.	25.9.54
Evered, L. W.	L.T. Reg.	19.7.54
Bennett, A.	L.T. Reg.	23.10.54
Mogg, G. E.	W. & B.C.	5.10.54
Bradshaw, W. H.	W. & B.C.	16.10.54
Beresford, E.	W. & B.C.	5.10.54
Trew, W. H.	W. & B.C.	5.10.54
Robinson, L. J.	W. & B.C.	5.10.54
Asst. Engr. to Exptl. Offr.		
Ashton, F A.	E.-in-C.O.	1.10.54
Asst. Exptl. Offr. to Exptl. Offr.		
Auchterlonie, J.	E.-in-C.O.	8.7.54
Wild, N. H.	E.-in-C.O.	8.7.54
Wilderspin, K. R.	E.-in-C.O.	8.7.54
M.T.O. III to R.M.T.O.		
Worthington, J. S.	E.-in-C.O. to N.W. Reg.	4.10.54
A.R.M.T.O. to M.T.O. III		
Dorman, A. E.	N.I. Reg. to E.-in-C.O.	3.11.54

Retirements and Resignations

Name	Region	Date
Area Engr.		
Woodhouse, T.	N.W. Reg.	31.10.54
Exec. Engr.		
Lumsden, R. S.	Scot.	24.9.54
Asst. Engr.		
Main, B.	W. & B.C.	6.10.54
Hawes, W. J.	L.T. Reg.	19.11.54
Evans, D. O. M.	N.E. Reg.	14.11.54
Deamon, T. E.	Mid. Reg.	6.11.54
Hindes, A. G.	L.T. Reg.	1.10.54
Lawrence, C. R.	N.E. Reg.	13.10.54
Jones, A.	N.W. Reg.	13.11.54
Collins, G. A.	H.C. Reg.	5.10.54
Thorne, E.	H.C. Reg.	6.10.54
Cameron, H. A.	Scot.	21.9.54
Nash, S. A.	L.T. Reg.	7.7.54
Bisset, W. T.	Scot.	12.8.54
Weatherley, L. C.	E.-in-C.O. (*Resigned*)	30.10.54
Quinnell, C.	H.C. Reg.	30.11.54
Jones, E. O.	W. & B.C.	26.9.54
Asst. Engr.—continued.		
Pate, H. R.	E.-in-C.O. (*Resigned*)	29.10.54
Barratt, R.	Scot.	23.10.54
Inspr.		
Thomas, H.	Mid. Reg.	29.10.54
Tipper, W. T.	L.T. Reg.	5.10.54
Hunnkngs, W. A.	L.T. Reg.	7.11.54
McGowan, R. A.	N.W. Reg.	31.10.54
Sullivan, J. L.	L.T. Reg.	31.7.54
Pease, F. O.	L.T. Reg.	24.9.54
Shaw, A. E.	L.T. Reg.	31.7.54
Pidgeon, W. T.	L.T. Reg.	20.10.54
Cook, E. R. W.	L.T. Reg.	10.11.54
Russell, C. J.	E.-in-C.O.	13.11.54
Musselwhite, A. G.	L.T. Reg.	8.10.54
Asst. Exptl. Offr.		
Ratcliffe Jones, T. R.	E.-in-C.O. (*Resigned*)	17.9.54
New, R. H.	E.-in-C.O. (*Resigned*)	26.7.54
A.R.M.T.O.		
Stokes, F. W.	London	18.10.54

Transfers

Name	Region	Date
Area Engr.		
Mayo, S. J.	N.E. Reg. to L.T. Reg.	20.9.54
Exec. Engr.		
Horne, F. A.	E. Africa to N.I. Reg.	15.9.54
Marriott, P. E.	E.-in-C.O. to Nigeria	9.9.54
Lewis, T. A.	E.-in-C.O. to G.C.H.Q.	6.9.54
Saunders, C. T.	N.E. Reg. to Cyrenaica	31.8.54
Price, S. E.	E.-in-C.O. to Scot.	27.9.54
Wraight, F. A. A.	E.-in-C.O. to H.C. Reg.	15.11.54
Asst. Engr.		
Wright, J. E.	N.E. Reg. to Min. of Supply	5.9.54
Asst. Engr.—continued.		
Rendle, F. R.	Scot. to E.-in-C.O.	29.8.54
Mihell, R. H.	E.-in-C.O. to H.C. Reg.	3.10.54
Feather, F. F.	L.T. Reg. to E.-in-C.O.	26.9.54
Iles, A. R.	E.-in-C.O. to War Office	11.10.54
Prout, A. G.	Fiji to E.-in-C.O.	16.10.54
Slough, H. R.	E.-in-C.O. to H.C. Reg.	31.10.54
Stretton, J. A.	Eritrea to E.-in-C.O.	8.11.54
Hodkinson, G. L.	Scot. to N.W. Reg.	3.10.54
Bird, D. W.	L.T. Reg. to E.-in-C.O.	19.11.54
Tech. Asst. II		
Smither, F. H. P.	E.-in-C.O. to Admiralty	1.11.54

Deaths

Name	Region	Date
Exec. Engr.		
Morris, G.	N.W. Reg.	6.10.54
Trimmer, W. J.	S.W. Reg.	3.11.54
Asst. Engr.		
Brims, D. H.	L.T. Reg.	11.9.54
Asst. Engr.—continued.		
Lamerton, A. H.	L.T. Reg.	12.10.54
Inspr.		
Laycock, H.	N.E.Reg.	1.11.54
Parry, R. A.	H.C. Reg.	17.11.54

Book Reviews

"The Repair of the Small Electric Motor." Karl Wilkinson, M.A.E.T. E. & F. N. Spon, Ltd. 180 pp. 98 ill. 20s.

In his preface the author says: "Theory and major repairs have been deliberately ignored—these, together with the actual re-winding, are matters for the specialist, and have no place in this book, which treats a rather complex subject as simply as possible."

There are chapters on the Single-Phase Motor, The Automatic Switch, Rotor and Stator Winding Faults, Re-assembly, 3-Phase Motors, Repulsion and Repulsion Induction Motors, D.C. Motors, Small Electric Tools, Identification of Connections. The author has adhered strictly to his preface. Little or no theoretical knowledge is assumed on the part of the reader, nor does the author attempt to impart any. The book is essentially for the fitter who has many different makes and types of small motor to repair. It is very readable and the diagrams, although small, are neatly executed.

There is one small point which a large number of readers will undoubtedly dislike and that is the author's use, even in chapter and page headings, of 1-ϕ and three-ϕ for single-phase and 3-phase respectively. A. E. P.

"Elementary Electrical Engineering." A. E. Clayton, D.Sc., M.I.E.E. and H. J. Shelley, C.B., O.B.E., B.Sc., A.M.I.E.E. Longmans Green & Co. 490 pp. 340 ill. 14s.

This popular textbook, widely used in technical schools and other institutions, now appears in its fourth edition and evidently continues to enjoy well-merited success. The subject matter covers the syllabus for the Ordinary National Certificate and includes the elementary treatment of direct-current and alternating-current circuits, direct-current machines, the transformer, measuring instruments, secondary batteries, distribution, illumination, circuit analysis and tuned circuits. Nearly 200 questions (with answers) arranged under chapter headings are included at the back of the book.

Opportunity has been taken in this edition to introduce the rationalised M.K.S. system into the sections dealing with magnetic theory and electromagnetism, but sufficient matter relating to the C.G.S. system has been retained to assist those not completely familiar with M.K.S. units.

The book is bound, printed and illustrated in a very pleasing manner and with nearly 500 pages included represents exceptional value in these days. G. E. S.

"Electrical Engineering Problems with Solutions." F. A. Benson, M.Eng., Ph.D., A.M.I.E.E., M.I.R.E. E. F. & N. Spon, Ltd. 232 pp. 25s.

Few will disagree that the best way for a student to test the theoretical knowledge acquired from textbooks is to apply it, if possible, to the solution of problems. Thus, many textbooks on electrical engineering include a range of problems, with answers, and occasionally space is found for the inclusion of a few worked examples affording further assistance. In the volume under review the next logical step has been taken by including only problems and their solution. Thus, in Part 1 are set out 44 problem papers each containing six questions, with answers; and in Part 2 the 264 questions are worked in detail. This arrangement is very suitable as it encourages a student to attempt each question, check his answer and then compare his own with the correct solution.

The standard is approximately that of a first-year post-intermediate University student and such a student would find the book of considerable value. The price is a little high, however, for a book of this type and it is to be hoped that it will be possible to produce a cheaper edition in due course.

G. E. S.

SHORTER NOTICES

Wireless World Diary, 1955. Iliffe & Sons, Ltd. 79 pages of reference material, plus Diary pages of a week to an opening. Leather, 5s. 10s. Rexine, 4s. 1d.

The reference section includes data for receiving aerials for the forthcoming commercial television transmissions and the proposed v.h.f. sound broadcasts, useful formulae, graphical design data, base connections for nearly 600 current valves and considerable general radio information.

"Electrical Accidents and their Causes—1952." H.M.S.O. 70 pp. 4 plates. 3s.

Published for the Factory Department of the Ministry of Labour and National Service, this booklet analyses the electrical accidents of all types brought to notice during 1952.

An Appendix lists certificates issued by H.M. Chief Inspector of Factories in respect of electrical apparatus for use in certain specified atmospheres.

The Board of Editors is not responsible for the statements made or the opinions expressed in any of the articles in this Journal, unless such statement is made specifically by the Board.

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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."

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Post Office Electrical Engineers' Journal

Volume 47, April 1954—January 1955

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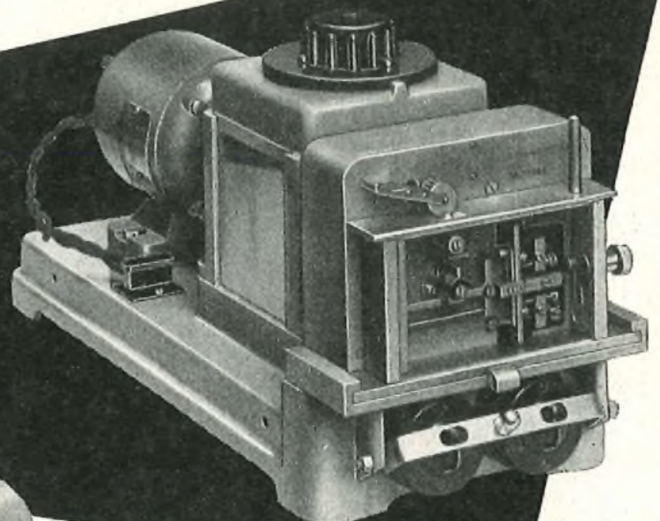

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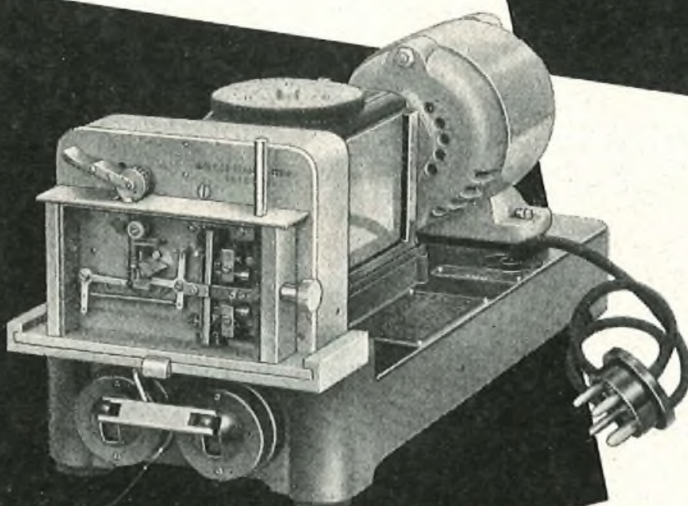

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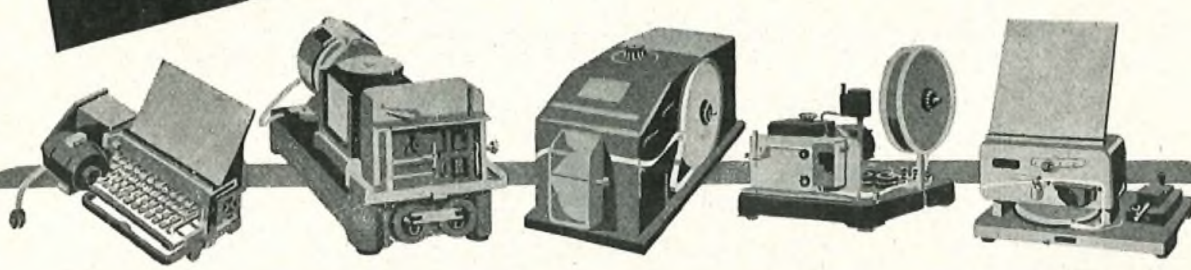

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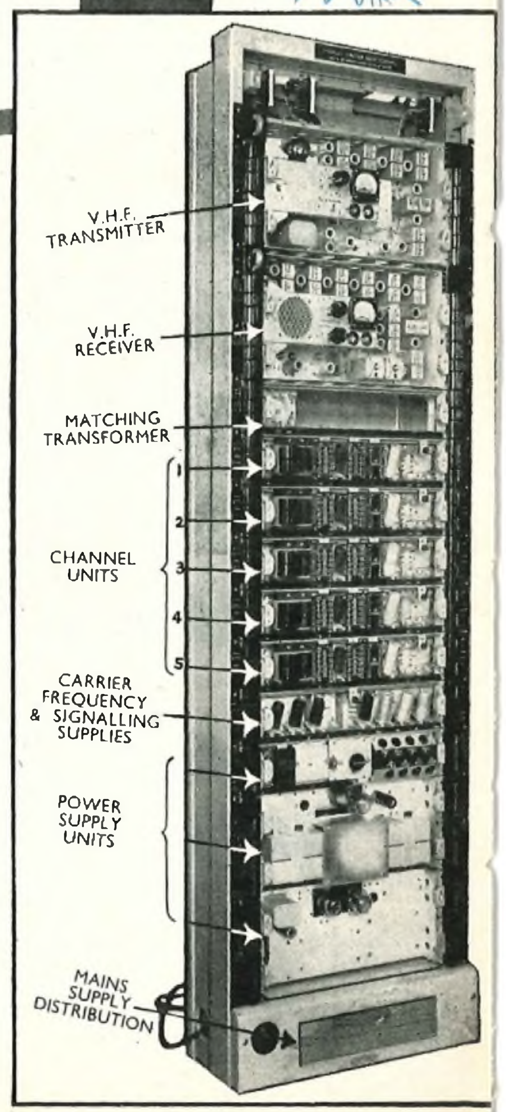

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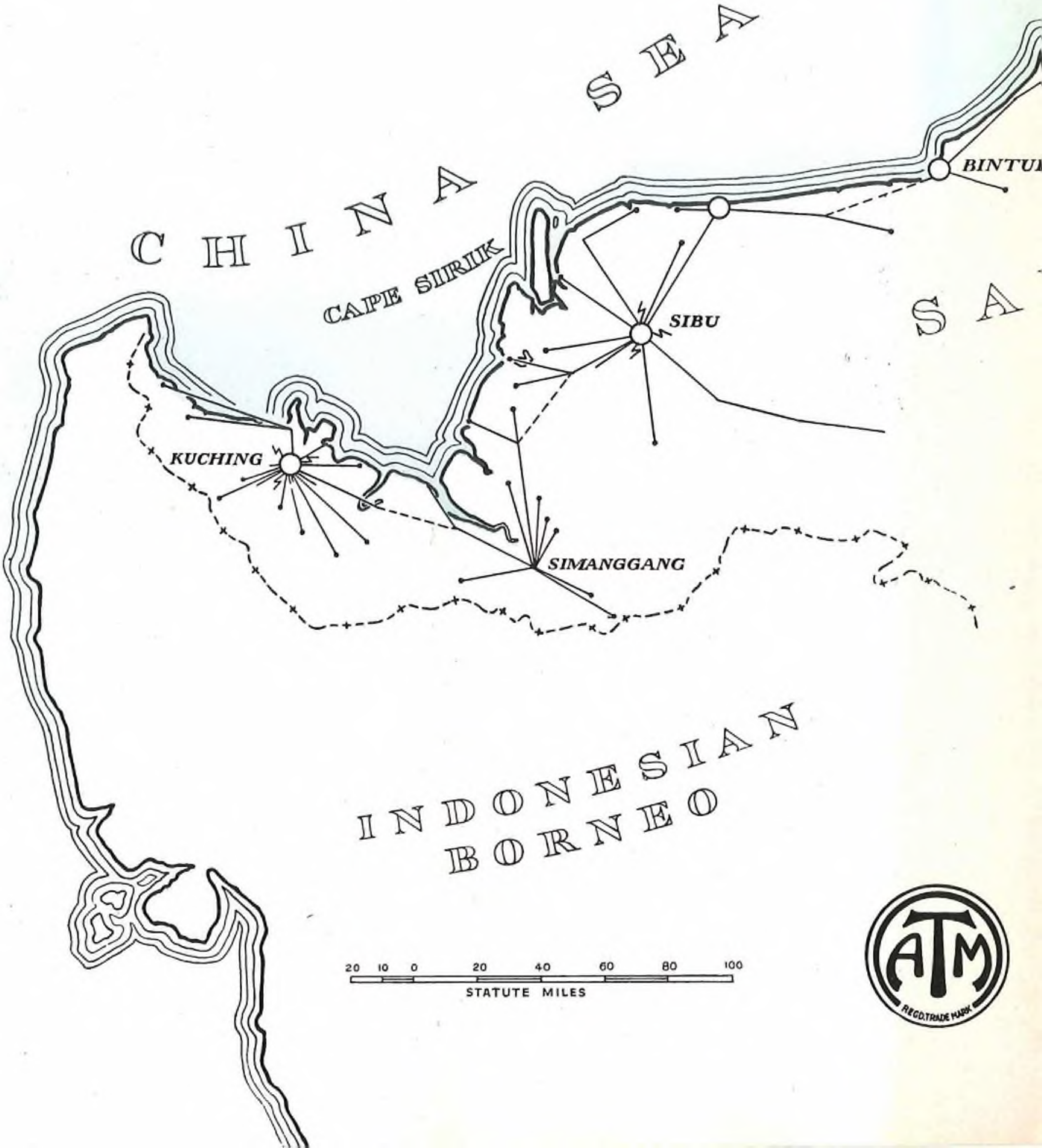

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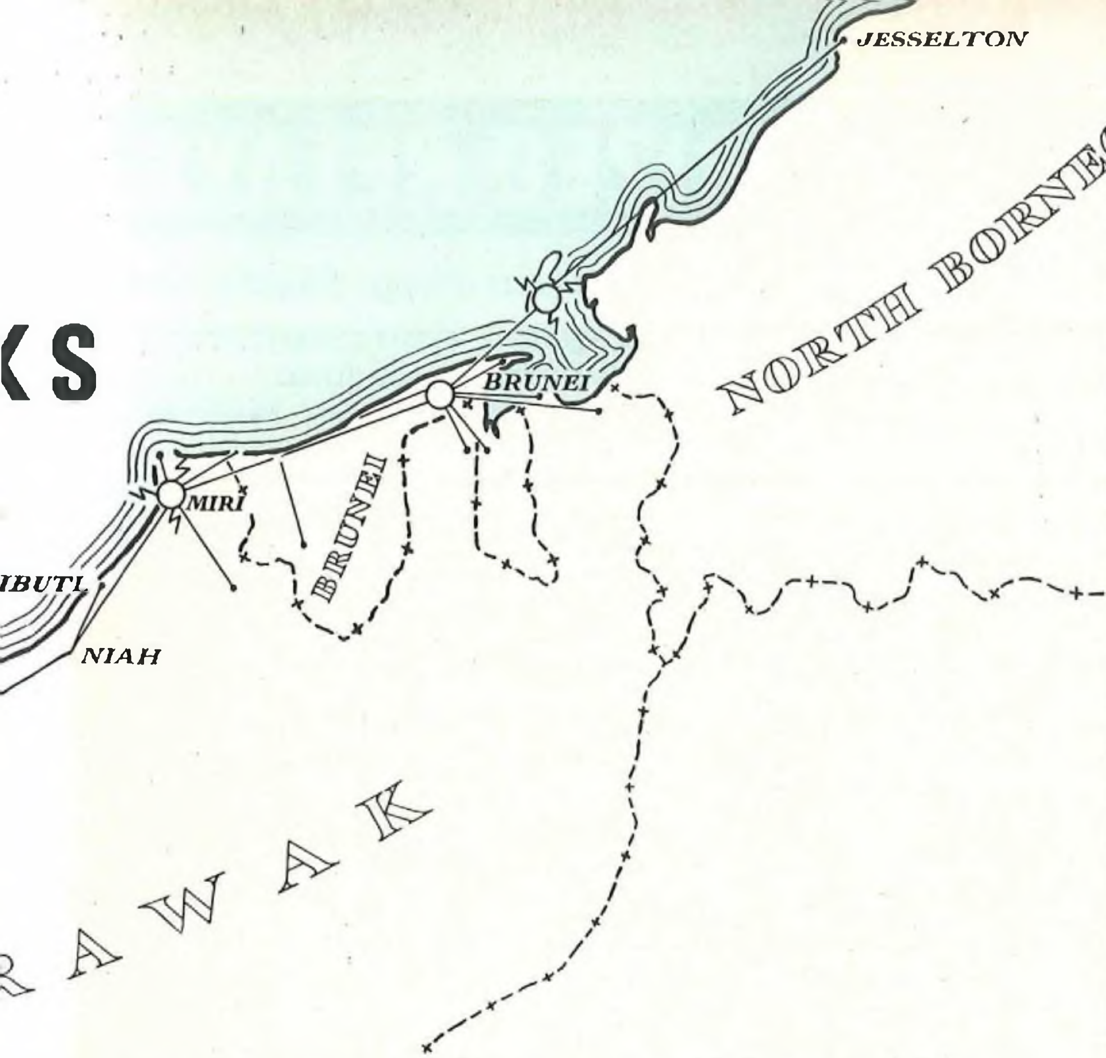

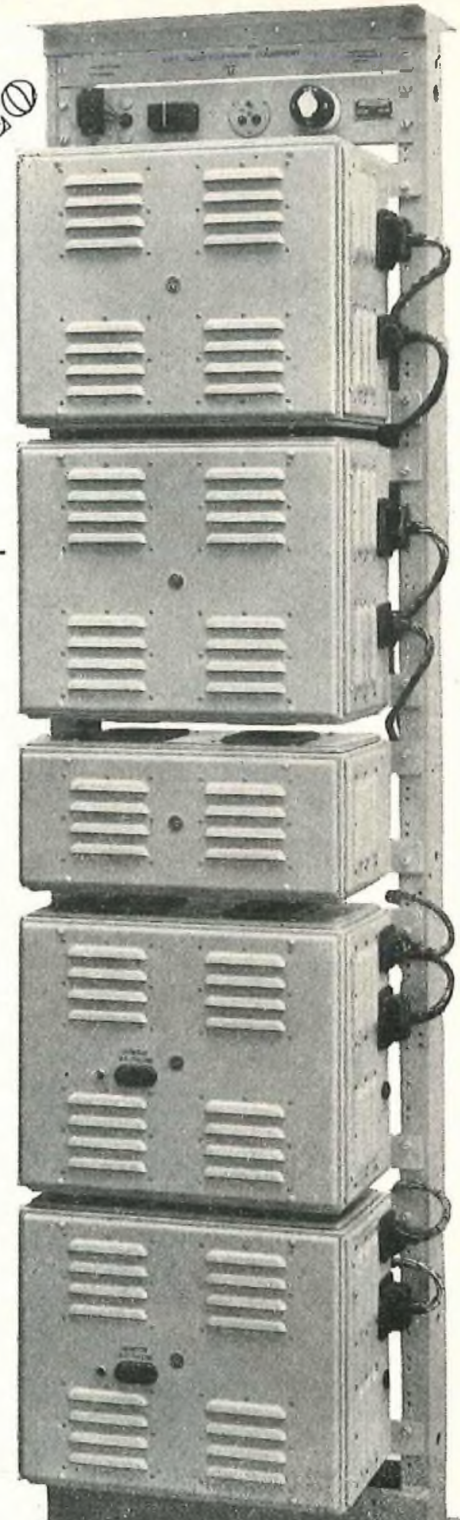
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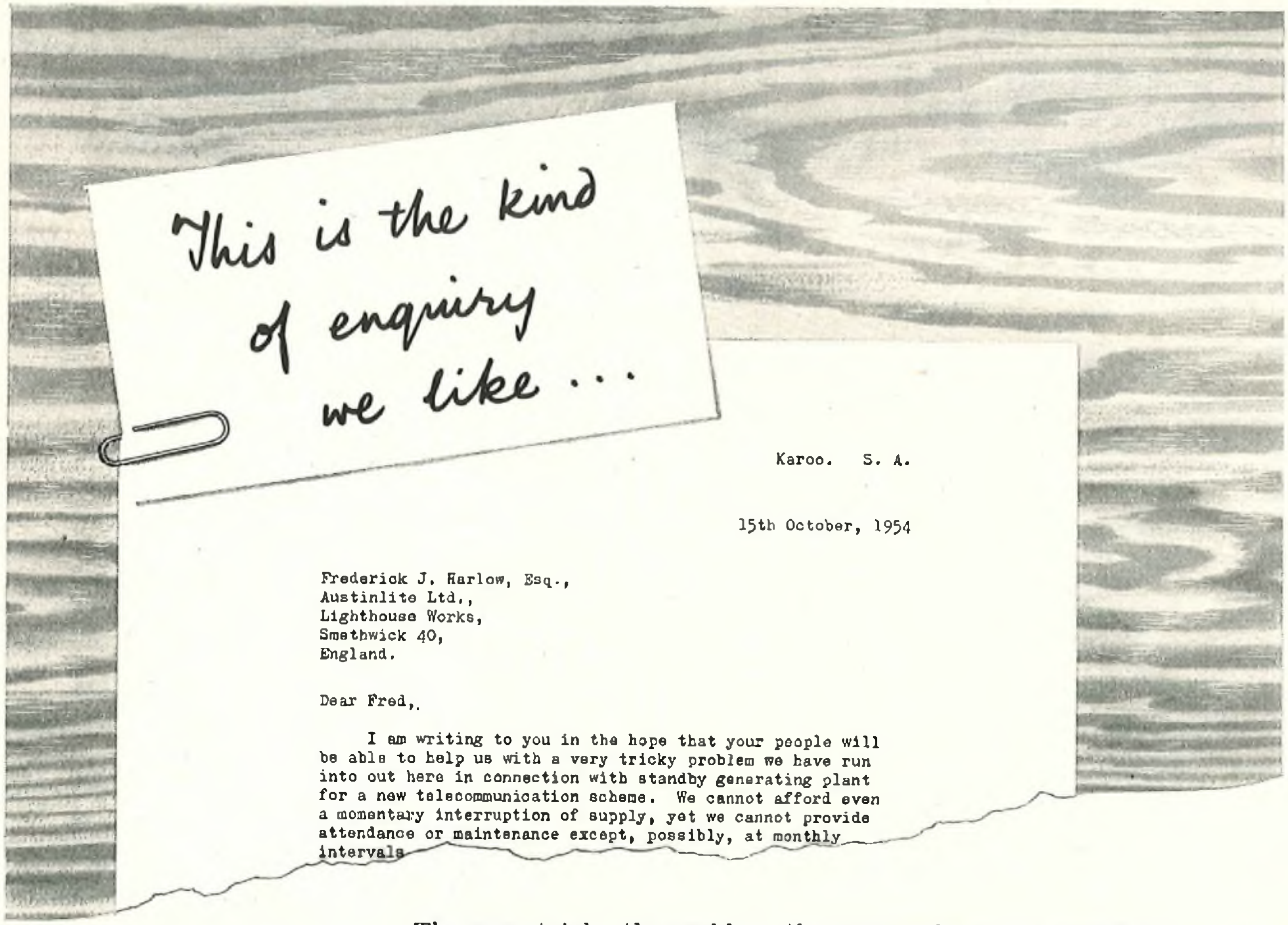

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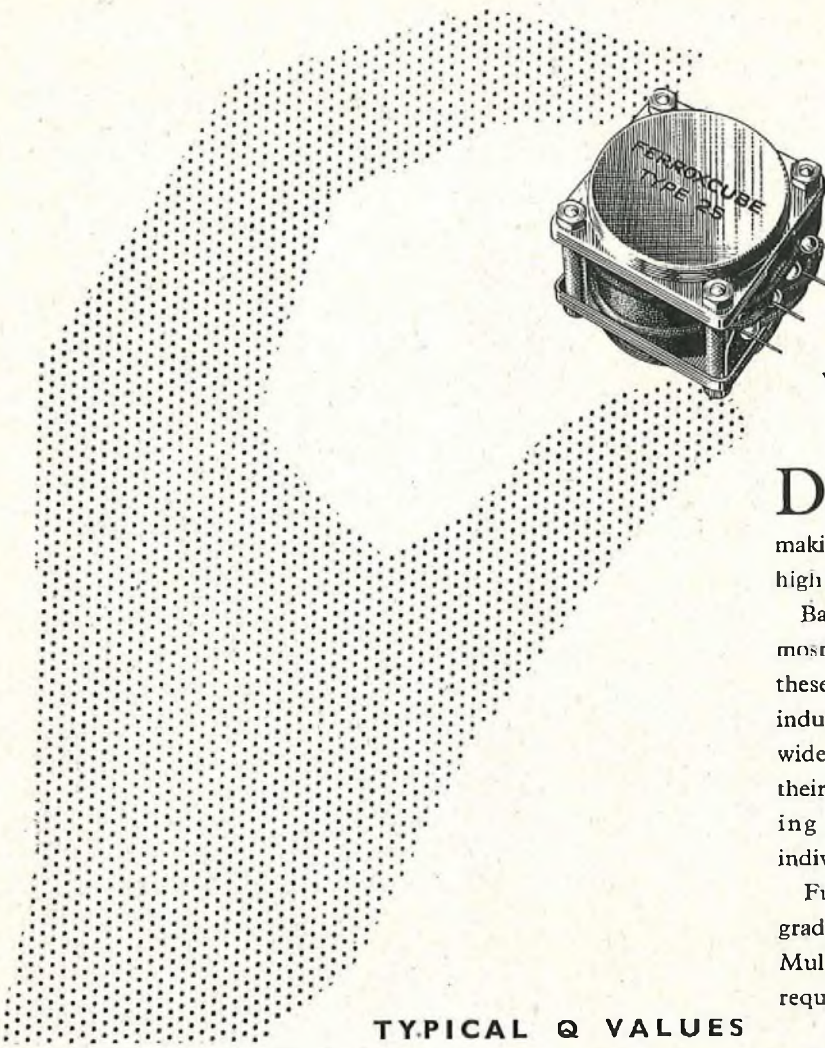

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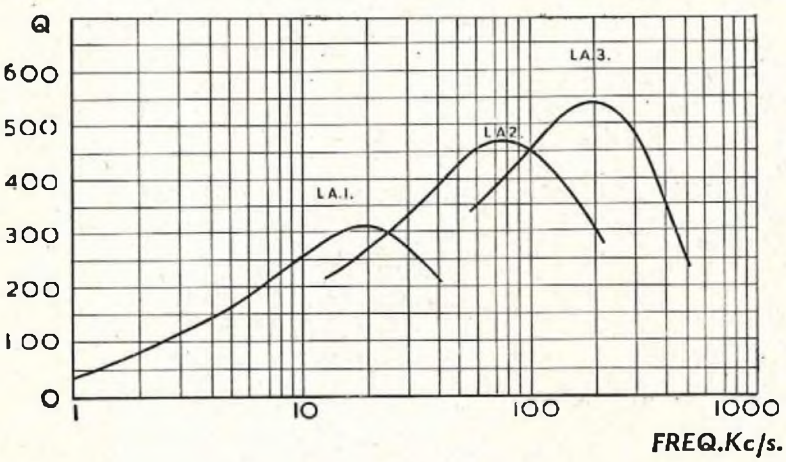

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MULLARD LIMITED · COMPONENT DIVISION · CENTURY HOUSE · SHAFTESBURY AVENUE · LONDON · W.C.2
(MM450)

F

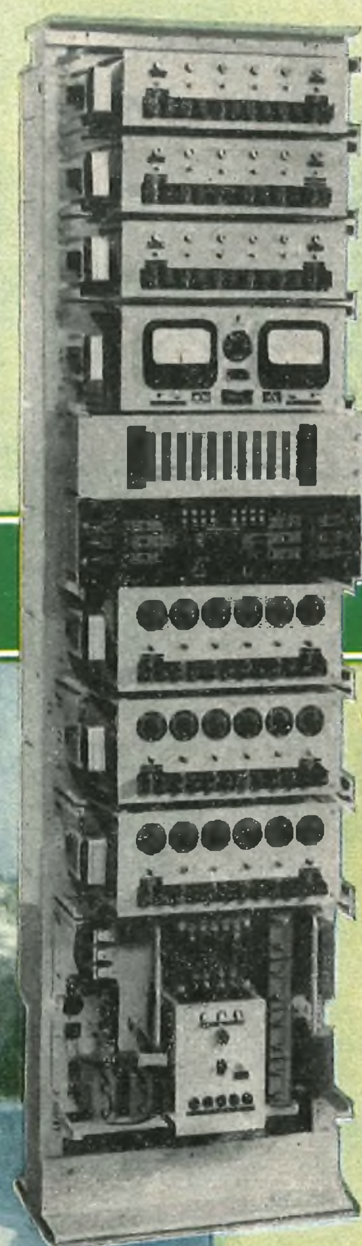
degrees of latitude or temperature

cannot impair the efficient operation of the new ERICSSON V.F. TELEGRAPH EQUIPMENT.

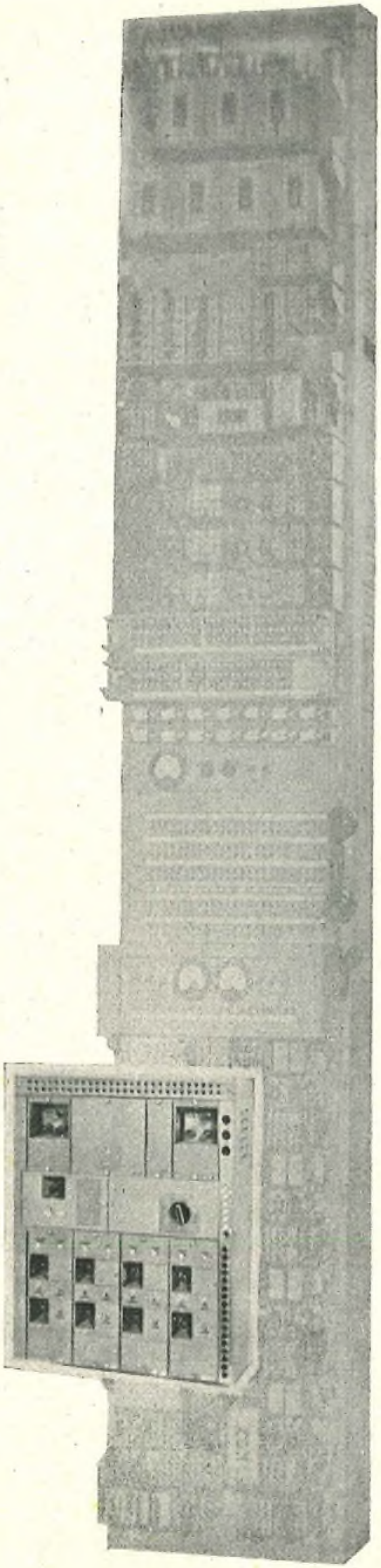
Neither sub-zero temperatures nor the heat and humidity of the tropics have any adverse effect on the high quality materials and finishes used in the manufacture of this apparatus.

The complete equipment combines all the essential features of telegraph working in a compact design which allows easy extensibility of the number of channels, when not fully equipped initially. Maintenance is reduced to a minimum.

Its installation in any part of the world is a sound and economical proposition.



ERICSSON



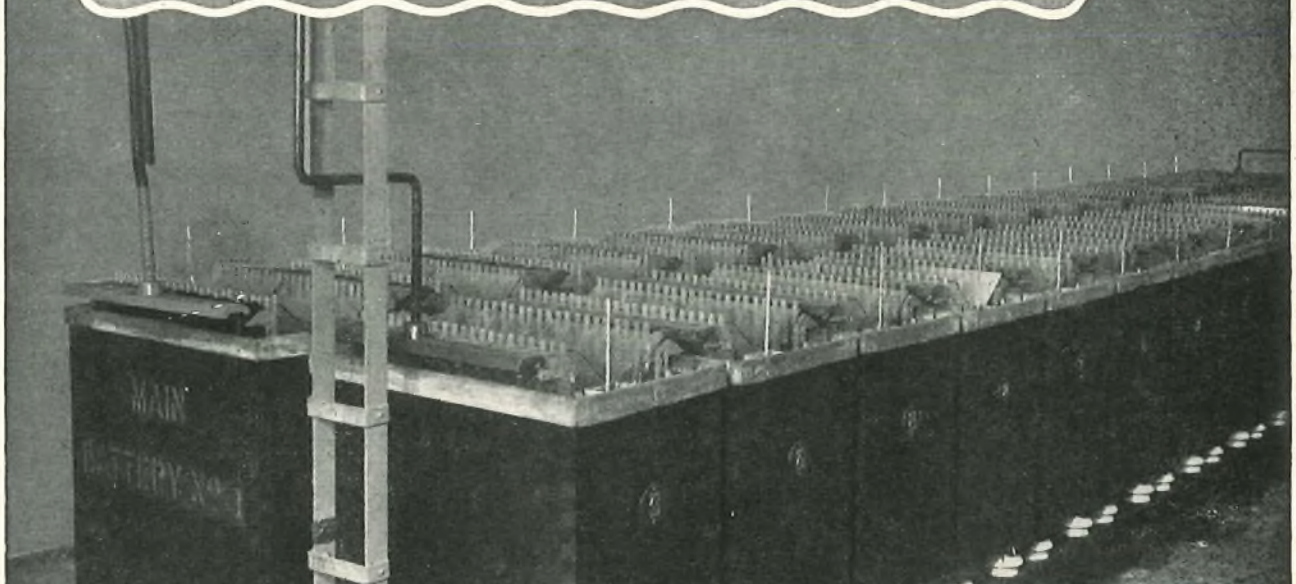
SKILLMAN

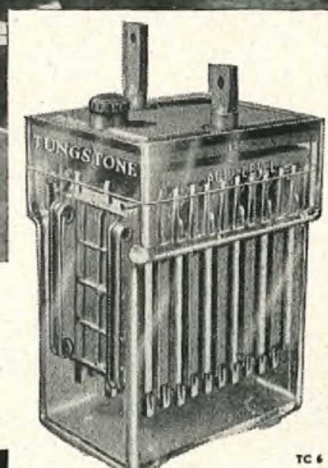
a new 1+4 or 5 CHANNEL system

for

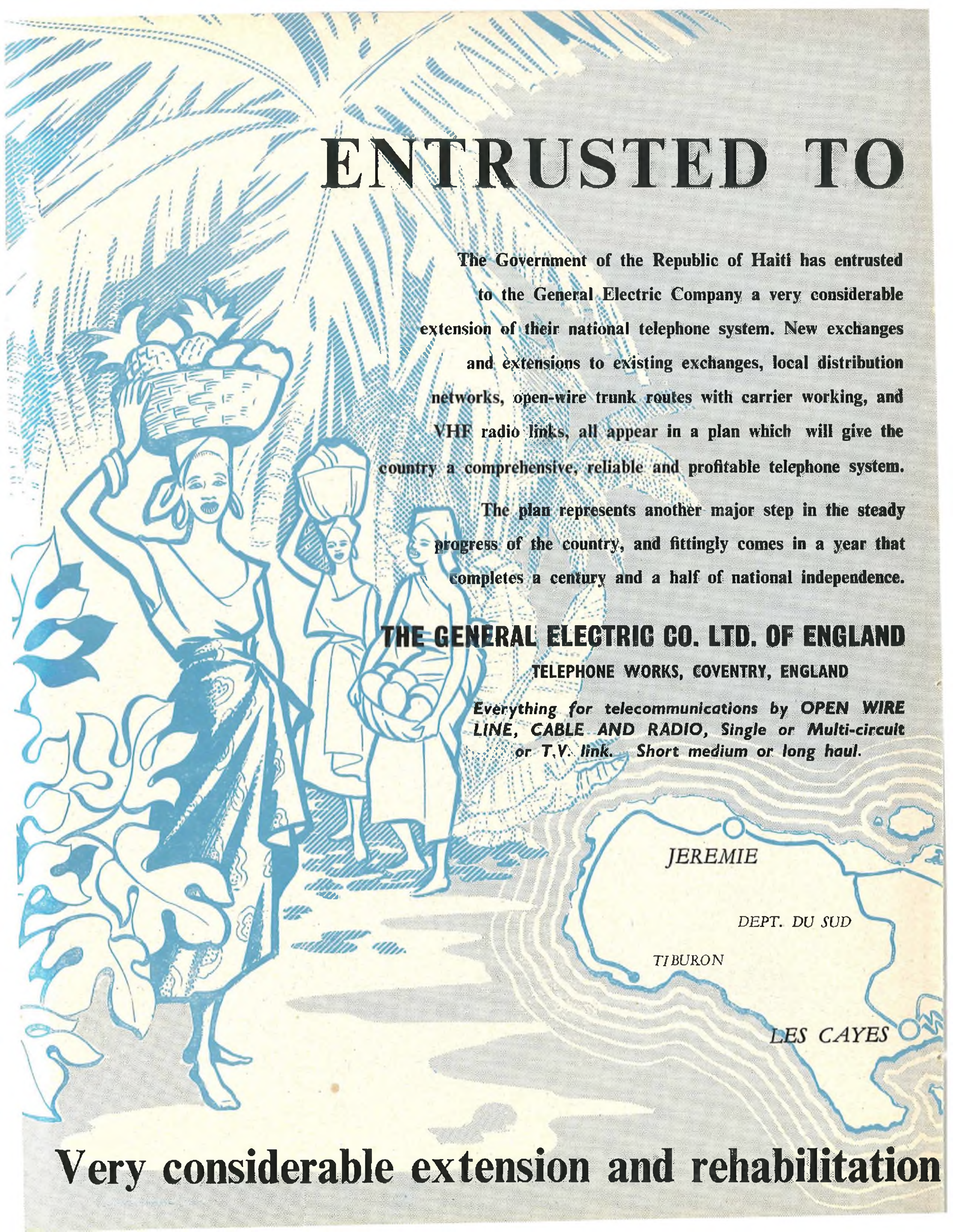
Open Wires
Single Cables
Double Cables
Radio Links

- ★ One QUARTER THE SIZE as shown by the small unit at the front
- ★ but IDENTICAL PERFORMANCE to the old standard system shown behind
- ★ at a PRICE hitherto unattainable
- ★ REPLACES the conventional 3 Channel System in all respects
- ★ and will work on routes already using standard 3 Channel.

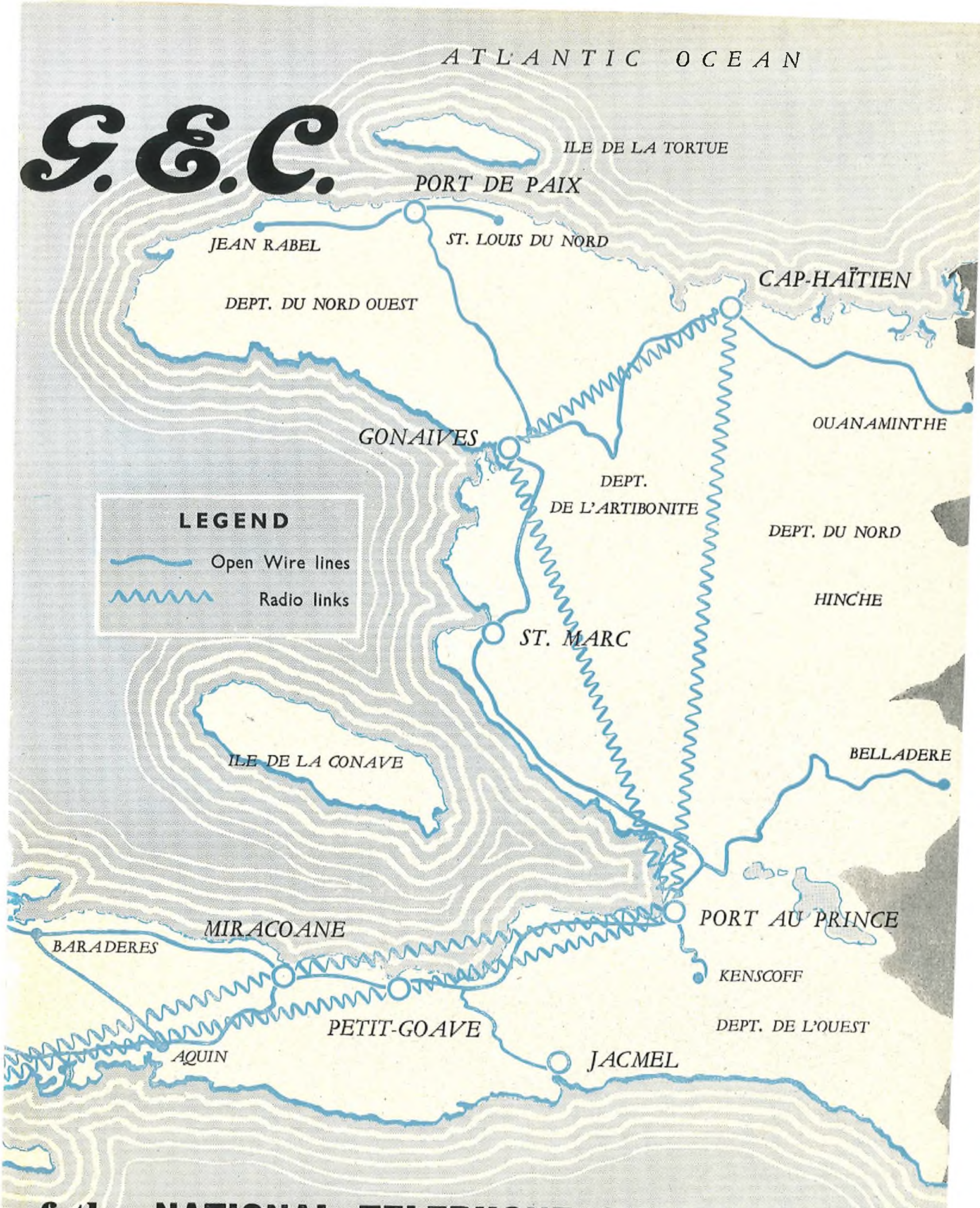




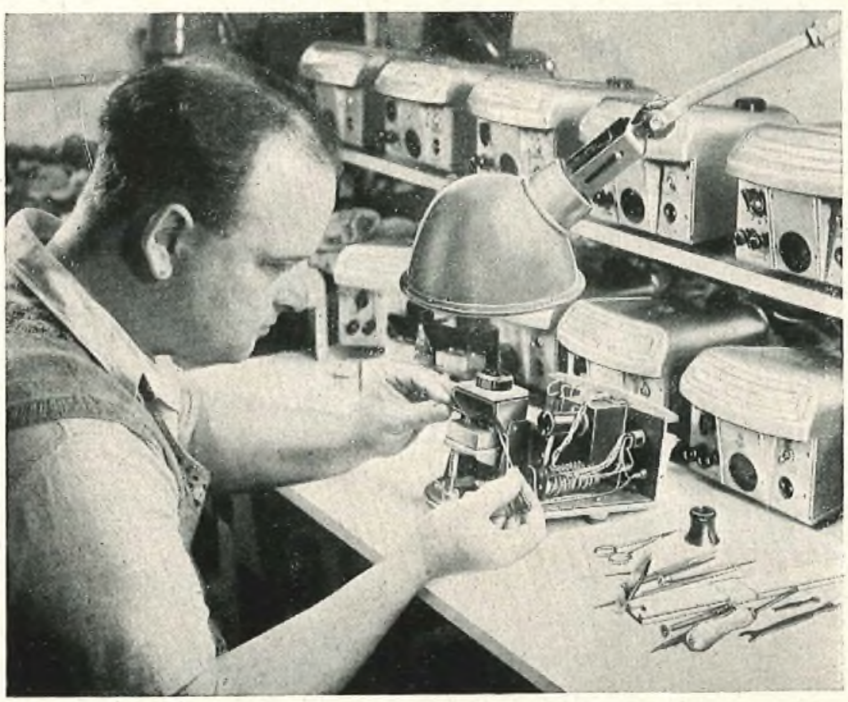
TC 6


ENTRUSTED TO
The Government of the Republic of Haiti has entrusted to the General Electric Company a very considerable extension of their national telephone system. New exchanges and extensions to existing exchanges, local distribution networks, open-wire trunk routes with carrier working, and VHF radio links, all appear in a plan which will give the country a comprehensive, reliable and profitable telephone system.
The plan represents another major step in the steady progress of the country, and fittingly comes in a year that completes a century and a half of national independence.
THE GENERAL ELECTRIC CO. LTD. OF ENGLAND
TELEPHONE WORKS, COVENTRY, ENGLAND
Everything for telecommunications by OPEN WIRE LINE, CABLE AND RADIO, Single or Multi-circuit or T.V. link. Short medium or long haul.
JEREMIE
DEPT. DU SUD
TIBURON
LES CAYES
Very considerable extension and rehabilitation

G.E.C.



of the NATIONAL TELEPHONE SYSTEM OF HAITI



and Control

One of the largest telecommunication engineering organisations in the British Commonwealth **Standard Telephones and Cables Limited** is engaged in the research, development, manufacture and installation of all types of communication and control systems.

Concerned with every aspect of telecommunications engineering, the Company is in an unrivalled position to undertake, within its own organisation, the co-ordinated systems-planning of complete communication projects involving interdependent systems of various types.

Standard products include:-

Systems:—

Telecommunications Line Transmission
Radio Broadcasting, Communication and Navigation
Railway Communication and Control
Telephone and Telegraph
Supervisory and Remote Indication and Control
Sound Reproduction
Municipal and Industrial Fire Alarms
Street and Airfield Lighting Control
Signalling (Office and Factory)
Communication Cable
Power Cable

Equipment:—

SenTerCet Selenium rectifier equipment
Power Factor Correction
Heat Treatment
Broadcast Studio equipment
Transmission Testing apparatus
Cable Testing equipment
Loading Coils

Components:—

Quartz Crystals
Transistors
Capacitors and Interference Suppressors
Germanium Rectifiers and Photo-electric Cells
Thermionic Valves
Magnetic Materials
Thermistors
Relays
SenTerCel Selenium Rectifiers
Rubber, Plastic and Textile insulated cables and wires

and Cables Limited

ENGINEERS)

London, W.C.2, England

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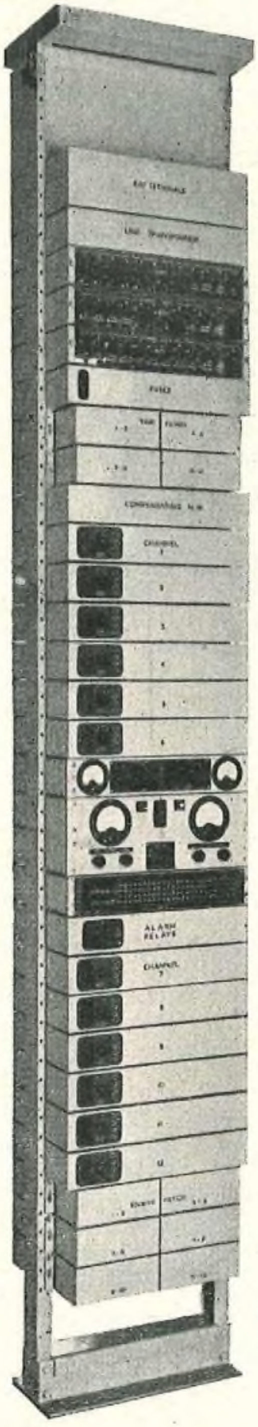
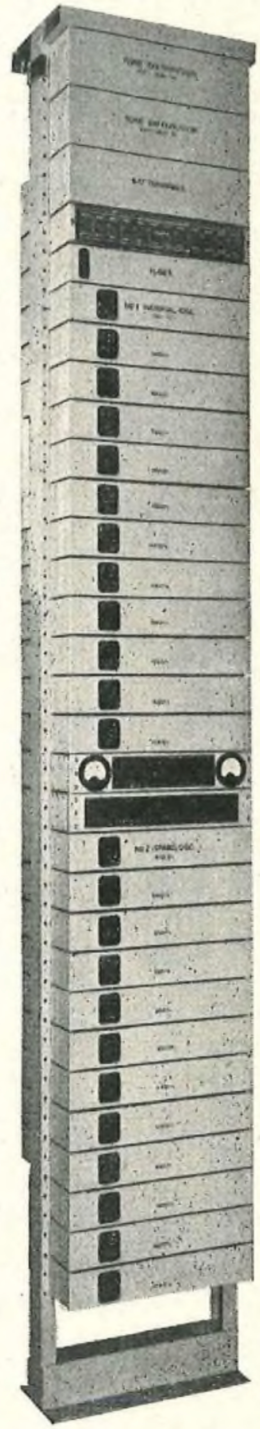
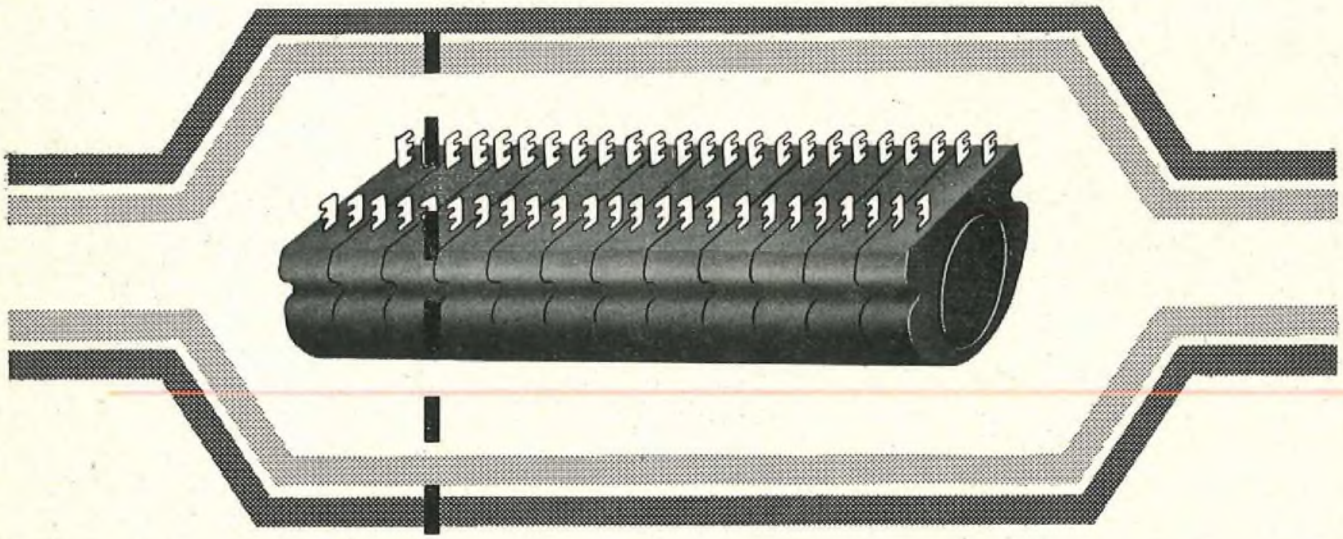


CHANNEL BAY



OSCILLATOR BAY

Loading coils **inside** the cable splice

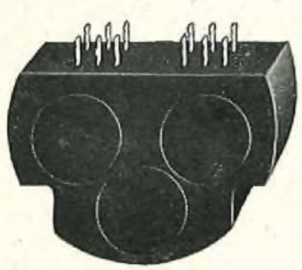


The advantages of the splice loading technique are particularly marked in the loading of small cables of up to 74 pairs. The coils can be included in a jointing sleeve or unit of only slightly larger diameter than would normally be used.

The loading coils in the Mullard L.160 Series are designed specifically for this technique. They are cast in resin, which provides complete protection from climatic conditions and allows a telephone administration to store them ready for building into loading units as and when required. Both single and triple assemblies are available for different sizes of cable.

Ferroxcube pot cores give these coils certain electrical advantages over conventional types, particularly in the loading of higher frequency circuits such as those encountered in programme and carrier applications.

You are invited to write for leaflets describing the Mullard L.160 Series coils and simple units for pole and splice loading.



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SPECIALISED ELECTRONIC EQUIPMENT

MULLARD LTD · EQUIPMENT DIVISION

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