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Magnetic Materials with Rectangular Hysteresis Loops

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A number of magnetic materials exhibiting rectangular hysteresis loops are now available and are being used in applications such as information storage for computors. This brief account outlines a generally accepted theory explaining the rectangular feature and shows how various manufacturing processes produce materials of this type. Several applications are then described and the character'.tics of a number of commercial materials tabulated for reference. An extensive bibliography is included.

INTRODUCTION

SOFT magnetic materials (for example, Mumetal or Stalloy) usually have hysteresis loops similar in general shape to that shown in Fig. **1**(*a*). A few kinds of material have loops which are almost rectangular, as in Fig. **1**(*b*), in

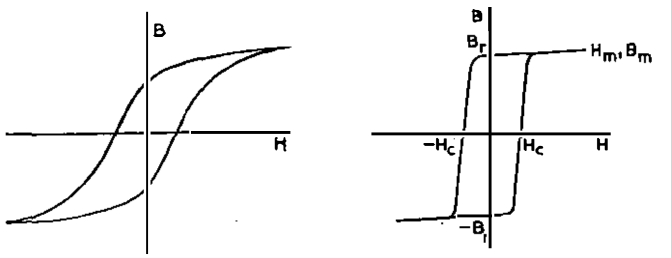

FIG. 1.—HYSTERESIS LOOPS; (*a*) ORDINARY; (*b*) RECTANGULAR.

which H_m is the maximum applied field, B_m the corresponding flux density, H_c the coercivity, and B_r the retentivity. It will be seen that the main features of this loop are:

(*a*) A high "retentivity ratio", B_r/B_m.

(*b*) A high, constant, rate-of-change of flux dB/dH along the sides, or irreversible parts, of the loop. The rate-of-change of flux is sometimes known as the differential permeability, and is denoted by μ_d.

(*c*) A low, constant, value of μ_d along the top and bottom, or reversible parts, of the loop.

(*d*) Fairly sharp corners.

Rectangular-loop materials were first produced in the laboratory many years ago. They are now available commercially, as both metals and ferrites, and are being used in a variety of applications.

Among the materials which show rectangular loops when the field is in the right direction are single crystals, and also certain polycrystalline materials, including grain-oriented nickel-iron and silicon-iron, certain nickel-iron alloys heat-treated in a magnetic field, Mumetal-type alloys of very thin gauge, when specially processed, and certain ferrites.

Some of the properties of rectangular loop materials are best understood in terms of the Domain Theory of Ferromagnetism.[1] According to this theory (which is now well supported by experiment) a demagnetised ferromagnetic body consists of regions (or "domains") each magnetised to saturation but with the directions of magnetisation of the domains (the "domain vectors") arranged so that the net external magnetic moment of the body is zero. Magnetising the specimen as a whole to saturation consists of aligning the domains with their vectors parallel to the direction of the applied field. There are three steps involved in this process, corresponding roughly to the three parts of the magnetisation curve (the initial permeability region, the steep part, and the rounded "knee").

If the field is low the boundaries between the domains move so that those domains whose vectors are most nearly parallel to the field vector grow at the expense of the others. This is a reversible process, so that if the field is removed the boundaries return to their original positions. Increasing the field causes further movement of the boundaries, but now the movements are much larger, and irreversible. Finally, when all the vectors are more or less parallel to the field vector, a further increase in the field causes the domain vectors to rotate into line with the field vector; this rotational process is reversible.

MATERIALS AND PROCESSING

Properties of Single Crystals.

It has been known for many years that single crystals of iron, nickel, and cobalt can be more easily magnetised in some directions than in others; the effect is called "magneto-crystalline anisotropy." Honda and Kaya studied it[2,3] and their results for iron are shown in Fig. 2. It will be seen that the cube-edge (or [100]) direction is the easiest for magnetisation, the face-diagonal direction [110] more difficult, and the cube-diagonal direction [111] the most difficult of all. For nickel the opposite is true; the easiest direction is parallel to the cube diagonal, and the most difficult is parallel to the cube edge. Measurements on single crystals of 3·85 per cent. silicon-iron cut in the form of a picture-frame (to avoid demagnetisation effects) showed that the directional properties were similar to those of iron.

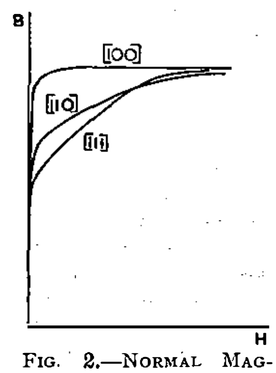

FIG. 2.—NORMAL MAGNETISATION CURVES FOR A SINGLE CRYSTAL OF IRON.

Tests have been made on many other alloys. In the nickel-iron series the direction of easiest magnetisation, as well as the amount of anisotropy, depends on the composition: in two important alloys (those with 50 per cent. and 65 per cent. nickel, respectively) the easiest direction is parallel to the cube edge.

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A

Complete hysteresis loops of single crystals are rectangular when the applied field is in the easiest direction. This may be explained in terms of the domain theory as follows. In an unmagnetised crystal the domain vectors are all parallel to one of the easiest directions of magnetisation, because this arrangement involves the least energy, so that for iron the domain vectors are all parallel to one of the cube edges. If a gradually increasing field is applied parallel to a cube edge, magnetisation first proceeds by reversible boundary displacements; those domains whose vectors are parallel to the field vector grow at the expense of the others. When the field reaches a certain value, large irreversible boundary displacements suddenly occur, and all those domains disappear whose vectors are not parallel to the field vector, so that the crystal becomes saturated. On removal of the field the vectors do not move because their direction is a natural one, and hence the retentivity is equal to the saturation flux density. Application of a gradually increasing negative field has no effect until it is equal in value to the coercivity. At that point all the domain vectors suddenly reverse and the crystal becomes saturated in the opposite direction. As before, removal of the field produces no change in the magnetisation. The hysteresis cycle is completed by re-applying a positive field; there is again no change until its value equals the coercivity, whereupon all the domain vectors, and hence the magnetisation, reverse suddenly. The hysteresis loop, therefore, consists entirely of vertical and horizontal straight lines.

If the field is not applied parallel to a cube edge an additional step is involved in the magnetisation process. After the reversible and irreversible boundary displacements occur the domain vectors will not be in line with the direction of the field, but merely with that cube edge which is most nearly parallel to it. Saturation is not complete until the domain vectors have been rotated into line, and to do this a comparatively strong field is required. The magnetisation curve now contains a long knee (see Fig. 2), and because the rotational process is reversible the retentivity is less than the saturation flux density.

In most polycrystalline materials the crystals are randomly oriented, so that the applied field is parallel to one of the easiest directions for only a small proportion of them. The magnetisation curve, therefore, has a long knee, but the point at which the latter begins is usually not well defined, because each crystal has slightly different properties.

Grain Orientation.

Single crystals cannot easily be made on a large scale and research has been directed mainly towards the production of polycrystalline sheet in which all the individual crystals are aligned. Early experimenters in this field were Smith, Garnett and Randall[4], and Goss[5]. Much work was carried out in Germany as well in connection with the development of the mechanical rectifier[6], which is described later. Nickel-iron and silicon-iron alloys in particular have been studied in some detail.

In the nickel-iron series the 50/50 alloy was found to give the best results. Most manufacturers are believed to use a technique similar to the German one, which has been described by Both[7]. The billet is first reduced in thickness by about 98 per cent. without any intermediate heat-treatment. (This severe cold-rolling is the essence of the process.) The cores are prepared and are then annealed at a temperature between 1,000°C and 1,200°C. The exact temperature for the best results may vary from batch to batch, and is determined by experiment. Sometimes an anneal in a magnetic field is given as well (see the next section). In the final state the material can be most easily magnetised, and has a rectangular loop, in three directions: the rolling direction, at right angles to the rolling direction in the rolling plane, and perpendicular to the rolling plane. It can, therefore, be used not only in the form of spiral cores, but also, though with rather less effect, as "picture-frame" and "E" and "I" laminations.

In England, grain-oriented nickel-iron has the trade-name H.C.R. alloy[8]. (The initials stand for Heavily-Cold-Rolled.) In Germany the trade name is Permenorm 5000Z, and one of the United States equivalents is Deltamax[9].

With the silicon-iron alloys the method of manufacture is somewhat different, but again severe cold-reduction plays an important part. Several techniques have been described. According to one[10], a cold reduction of 70 per cent. is followed by heating for a short time at 950°C. The crystals are then found to be aligned with a cube edge in the rolling direction and a face diagonal in the transverse direction. Thus the benefits of cold-reduced silicon-iron are obtained only if it is used in the rolling direction.

Some trade-names for grain-oriented silicon-iron are Crystalloy and Alphasil in England, and Hipersil, Trancor, and Silectron in the United States.

The exact physical mechanisms by which grain orientation is produced in silicon-iron and in nickel-iron alloys are not fully understood at present.

Magnetic Annealing.

Kelsall, Bozorth and Dillinger[11–14] studied, in the following way, a large number of alloys composed of nickel and iron, or of nickel, iron and cobalt.

After a normal anneal at 1,000°C, followed by cooling to room temperature, each specimen (in the form of a single welded turn of metal) was re-heated to about 50° above its Curie point* and maintained at that temperature for one hour. A field of 16 oersteds was then applied and the furnace allowed to cool at a maximum rate of 300°C per hour. It was found that magnetic annealing increased the maximum permeability and made the hysteresis loop more rectangular provided that the Curie point was above about 450°C, and that no phase transformation occurred near room temperature. Most of the changes in the magnetic properties of the specimen took place while it was cooling from 600°C to 400°C, even though its Curie point might be much higher than 600°.

Many of the nickel-iron-cobalt alloys proved susceptible to magnetic annealing; their coercivities covered a fairly wide range. In the nickel-iron series the alloy containing 68 per cent. of nickel was found to give the highest maximum permeability. More recently, a number of other alloys have been investigated, including 50/50 cobalt-iron, which is particularly interesting because of its very high saturation flux density[15].

Bozorth and Dillinger[14] gave an explanation of the mechanism of magnetic annealing which has been fairly widely accepted in principle, although Hoselitz[10] has recently questioned some aspects of it. Briefly, their argument runs as follows. On cooling through the Curie point, domains are formed with their vectors parallel to one of the easiest directions of magnetisation. If, however, a field is applied during the cooling, then each domain vector will first take up that easiest direction which is most nearly parallel to the field, and then, if the field is strong enough, will rotate into line with it. Magnetostrictive strains will be set up owing to the tendency of the domains to expand in their directions of magnetisation, but provided the temperature is high enough for plastic flow to occur these strains will be relieved and the domain vectors will remain oriented after the field has been removed. On demagnetisation half of the vectors will reverse. Subsequent magnetisation in the original direction does not involve magnetostrictive forces on rotational processes, and is, therefore, relatively easy.

* The temperature above which the material is not ferromagnetic.

For these reasons magnetic annealing is likely to be most effective in those materials (e.g., 68/32 nickel-iron) which have:

(*a*) A Curie point considerably higher than the temperature at which plastic flow ceases.
(*b*) Some magnetostriction.
(*c*) Low magneto-crystalline anisotropy; for, if this is high, the effect of the magnetic annealing field is reduced.

Because this type of material does not rely on grain orientation for its rectangular-loop properties, cores can be made in forms other than clocksprings or picture-frames (e.g., flat rings). It is not yet known, however, whether a high degree of domain orientation can easily be conferred on laminations of "E" form.

In England, magnetically-annealed cores of 65/35 nickel-iron alloy are marketed under the trade name Permalloy F[16].

Mechanical strain can produce effects which are similar to those of magnetic annealing. Thus magnetostrictively-positive materials when under tension, and magnetostrictively-negative materials when under compression, have rectangular loops, provided that the strain is elastic[1]. As far as is known, this effect has not yet been used in any practical application.

Ultra-thin Tape.

Littmann[17] has described the effect on the magnetic properties of various alloys as they are rolled down to thicknesses of less than 0·001 in. The most striking changes are shown by 4/79 Permalloy (an alloy of the Mumetal type). As the thickness is reduced the hysteresis loop for a field applied in the rolling direction gradually becomes more rectangular, until at 0·00025 in. the retentivity ratio is approximately the same as that of grain-oriented nickel-iron of the same thickness.

This effect has not been explained theoretically, but may be due to grain orientation caused by the method of rolling employed.

Ferrites.

Non-metallic rectangular-loop materials have been available in the United States for about two years[18,19]. A British equivalent has recently been put on the market. Residual mechanical strains are probably responsible for the development of rectangular loops in ferrites, since it is known[20] that certain types of ferrite have rectangular loops when externally compressed.

The great advantage of ferrites over metals is their very high resistivity, so that eddy-current losses are very small. Other types of loss, however, may be important at high frequencies.

Applications

Mechanical Rectifier.

In the electrochemical industry rectifiers are needed which are capable of handling very large currents at low voltages with a high efficiency. The mercury-arc rectifier is unsuitable because of its low efficiency at low voltages. During the recent war the Germans developed a mechanical rectifier which has an efficiency of 97 per cent. at 200V[6]; manufacturers in other countries, including Britain[21], have since produced similar machines. The principle of the mechanical rectifier is as follows:

In theory, alternating current can be rectified by reversing mechanical contacts at the precise moment that the current goes through zero, but in practice the reversals cannot be made without severe arcing, and consequently damage to the contacts, because the current does not remain at a sufficiently low value for a long enough time. If, however, an inductor having a rectangular-loop core is placed in each phase of the supply, the impedance of the circuit will rise to a very high value when the core begins to operate over the steep part of the loop (Fig. **1**(*b*)), because of the high differential permeability. The current is therefore held to a low value until the knee of the loop is reached. With proper design this does not occur until the contacts have had time to reverse without arcing. Once the knee is reached the differential permeability of the core drops to a low value and the effect of the inductor on the supply current is very small.

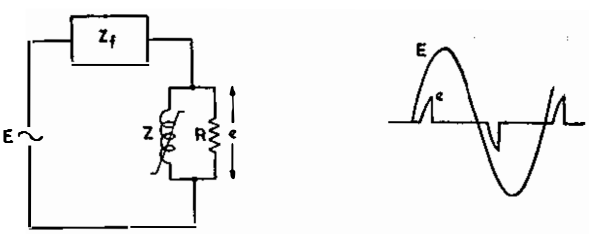
The core material should have a high saturation flux density, and its differential permeability should change suddenly from a very high value to a very low one at the knee of the loop. Strictly speaking, its retentivity ratio need not be high.

It is probable that most of the production of rectangular-loop metals is taken by manufacturers of mechanical rectifiers, for the cores are usually several feet in diameter and have large cross-sectional areas.

Pulse Generation.

We have seen that the impedance of an inductor with a rectangular-loop core changes suddenly from a high value to a low value at the knee of the hysteresis loop. This property has been used in the generation of pulses, and there are a number of possible methods[22]. The following is an outline of one that has been used when direct pulse-production from a sinusoidal source is required.

Referring to Fig. **3**(*a*), assume $Z_u \gg R \gg Z_s$, where Z_u and Z_s are respectively the unsaturated and saturated values of Z. Then, if the impedance Z_f of the series feed



(*a*) (*b*)

Fig. **3**.—Circuit of Simple Pulse Generator and Corresponding Voltage Wave-forms.

is resistive, the output voltage e across R will rise sinusoidally (Fig. **3**(*b*)) until the resulting current through the saturable inductor is sufficient to magnetise its core to the knee of the hysteresis loop. Further increase in the input voltage E causes e to fall to a low value and the process is repeated every half-cycle. The pulse shape is poor, however, and the efficiency is low because power is consumed in the feed.

Better results are obtained if the feed is a high-Q inductor of reactance X_o. The leading edge of the pulse then becomes much "sharper" and the top "flatter." The conditions for a good pulse shape are,

$$Z_u \gg R \gg X_o \gg Z_s.$$

Assuming a factor of 10 in the inequalities, this means that $Z_u = 1000 Z_s$ which is not always easy to achieve; eddy currents decrease the value of Z_u, while for a small core Z_s may be greatly increased by the resistance of the winding and the reactance due to air flux.

Magnetic Amplifiers.

The theory and applications of magnetic amplifiers have been fully described in numerous papers[23]. It is usually said that the core material should preferably have the following properties:—

(*a*) High maximum permeability.
(*b*) A linear normal magnetisation curve between the origin and the knee.
(*c*) A normal magnetisation curve with a sharp knee.

(*d*) Low hysteresis and eddy-current losses.

(*e*) High saturation flux density.

Requirement (*e*) is important only if a large power output is required. (*a*), with (*b*), means that the initial permeability must be high.

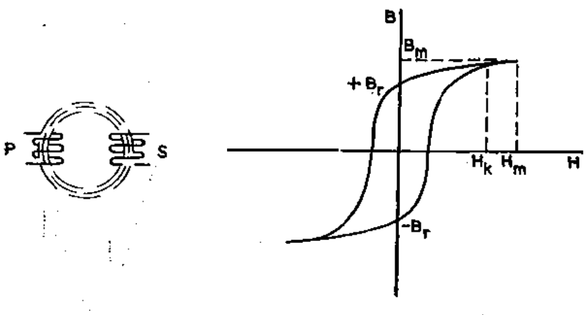
H.C.R., Permalloy F, Deltamax and Permenorm 5000Z satisfy (*a*), (*c*) and (*e*) fairly well, and are particularly useful when high power output is required because they have higher saturation flux densities than Mumetal or Permalloy C. They do not satisfy (*b*) and (*d*) so well as Mumetal or Permalloy C, and for low-output applications the latter are usually preferred.

The above discussion relates to amplifiers of conventional design, but a fast-response amplifier has been invented by Ramey[24] in which it is desirable (though not essential) to use rectangular-loop material for the core. This type of amplifier can be used as a computing element.[25] Its disadvantage as an amplifier is its low power gain.

Information Storage.

This application has become very popular during the last three or four years, especially in the United States.

Fig. **4**(*a*) represents a saturable inductor having primary and secondary windings P and S, and Fig. **4**(*b*) the saturation hysteresis loop of the core corresponding to the field produced by a current in P.



(*a*) (*b*)

FIG. **4**.—A SATURABLE INDUCTOR WITH TWO WINDINGS, AND THE HYSTERESIS LOOP OF THE INDUCTOR CORE.

If a current producing a field of value $+H_k$ or more is applied to P and is then removed, the final flux state of the core will be $+B_r$, or "positive retentivity." Similarly, if the current is in the opposite direction, the final flux state will be $-B_r$, or "negative retentivity." Since the final condition of the core is always either $+B_r$ or $-B_r$ the inductor has two stable states, provided that the current equals or exceeds a value corresponding to H_k.

These states may be used to represent binary digits in a computor, whatever the shape of the hysteresis loop, but it will be shown that inductors with rectangular-loop cores are particularly suitable.

Apart from the saturation loop, other major loops exist which correspond to values of maximum field lower than H_k. An inductor may therefore have a large number of other stable states, corresponding to the various values of core remanence, and these states can be used to represent digits in a scale higher than the binary; this practice is not common, however.

Assume that the inductor of Fig. **4**(*a*) represents the digits "1" and "0" when the flux state of the core is respectively $+B_r$ and $-B_r$. Then information may be stored by applying to the core a magnetising pulse H_m of appropriate sign, where $H_m \geqslant H_k$. To read out the information a field of $-H_m$ is applied. If the stored digit is a "1" the resulting total flux change is $(B_m + B_r)$, but if it is a "0" then the flux change is only $(B_m - B_r)$. The voltage induced in S is therefore greater for a stored "1" than for a stored "0" (neglecting any consideration of the rate-of-change of the flux), but the discrimination—i.e., the ratio of these voltages—is not high enough to be useful without the aid of special circuits. If the hysteresis loop is substantially rectangular, however, the "0" output is very small and the discrimination is adequate.

One of the most important properties of a core when used for information storage is its time of response to a step-field pulse. Dorey[26] has derived an expression for the response time of rectangular-loop metal cores from classical eddy-current theory. The time T required to change the flux state of a core from $-B_r$ to $+B_m$ is given by,

$$T = \frac{\pi}{10^9} \cdot \frac{B_m\, d^2}{\rho\,(H_m - H_c)} \text{ seconds,}$$

where, B_m is the maximum flux density (gauss),
d is the thickness of the lamination (cm.),
ρ is the resistivity (ohm-cm.),
H_m is the maximum applied field (oersted), and
H_c is the coercivity (oersted).

The formula is found to give reasonable agreement with practice provided that the product of H_m and d is at least 100 oersted-microns (0·001 in. $\simeq$ 25 microns). The ratio of measured to theoretical response time gradually increases as this value is reduced: for example, the theoretical value of T for a certain specimen of 0·001-in. H.C.R. and an applied field of 0·8 oersted was 22 microseconds, but the measured value was 120 microseconds. Such discrepancies arise because the classical theory assumes the material to be magnetically homogeneous, whereas it is in fact inhomogeneous because of its domain-and-wall structure[27]. The response time of a ferrite core, however, is usually only about one or two microseconds even with a field as low as 2 oersteds. To achieve a similar result with H.C.R., strip not more than about **6** microns thick would probably be required. The better performance of ferrites is due to their much lower eddy-current losses.

Static Delay-Line, or Shift-Register.

When information is read out of a core the flux state always returns to $-B_r$, and hence all "ones" are destroyed, but information may be transferred from one inductor to another by using the output voltage of the first to magnetise the core of the second in such a direction that the new flux state of the second core is the same as the original state of the first. This discovery was due to the Harvard University Computation Laboratory, and they used the principle to make static delay-lines. The first step[28] was to produce a trigger-pair circuit (Fig. **5**) in which, if each core is pulsed

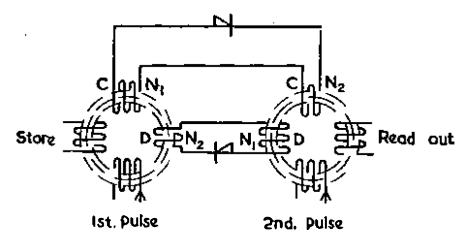


FIG. **5**.—A TRIGGER-PAIR CIRCUIT.

alternately, the stored information may be read out indefinitely. In this circuit the numbers of turns N_1, N_2 on coils C and D are such that N_1 is greater than N_2; otherwise, due to leakage inductance and the resistance of the link circuits CC, DD, a stored "1" would gradually decrease to "0" as it is switched between cores by alternate pulses.

The circuit operation may be followed by assuming that a "1" is stored in the left-hand core, and a "0" in the right-hand one; and that a pulse applied to the first core in the direction of the arrow tends to reverse its flux. The reversal of flux produces voltages across coils C and D of the first core which tend to drive the flux of the second core to the "1" state. Considering the link circuit CC, the voltage developed in C (N_1) is larger than the back e.m.f. produced in C (N_2) because N_1 is greater than N_2; thus the effects of resistance and leakage inductance are nullified and the flux in the right-hand core can be completely reversed. In the link-circuit DD the net voltage tends to send a current against the direction of the rectifier which, if the latter were not there, would tend to prevent the change of flux in the right-hand core. Similarly, when the information is transferred from the right-hand to the left-hand core the upper rectifier is operative.

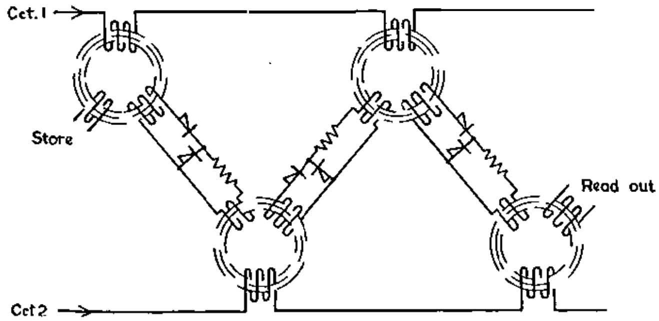


FIG. 6.—A DELAY-LINE CIRCUIT USING TWO CORES PER DIGIT.

Fig. 6 shows a delay-line circuit using two cores per digit[29,30]. The output winding of each inductor is connected to the input of the next, and information is stepped along the line by alternately pulsing circuits 1 and 2. Two inductors per digit are necessary, since information cannot be taken from an inductor at the same time that new information is supplied to it. The series rectifier prevents information from travelling beyond the next inductor; the parallel rectifier prevents backward flow of information.

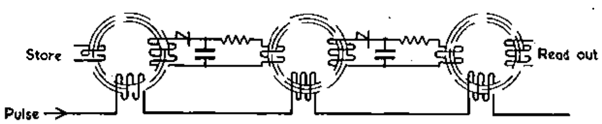


FIG. 7.—A DELAY-LINE CIRCUIT USING ONE CORE PER DIGIT.

A circuit (Fig. 7) that needs only one core per digit has recently been described[31]. The information is read out into a capacitor, which then discharges into the next inductor and magnetises its core. It has been reported that this circuit has some disadvantages not possessed by the two-core-per-digit line.

Some applications of the magnetic shift-register are:—

(*a*) As a delay-line in a computor. If it is desired to have all the information continuously available the output is connected to the input. Any particular digit can be made available with less delay by using an auxiliary advancing pulse to form a trigger pair with the inductor containing the required digit.

(*b*) As a link between units operating at different speeds. Information can be stored for an indefinite time and read out when required. The frequency of the line can be varied over a wide range, so that information can be stored and read out at different rates.

(*c*) As a converter of information from the serial to the parallel form, and vice versa, by taking outputs from alternate inductors in the line.

(*d*) As a frequency divider, by connecting the output to the input. If there is only a single "1" stored in a 10-digit line and the pulsing rate is 10,000 per second, then an output taken at any point in the ring will appear as a train of pulses at 1,000 per second.

The design of the two-core-per-digit line has been discussed by Dorey and by Sands[26,32]. The cores are usually clockspring in form, and the diameter is kept small in order to economise in driving current. The value of the driving field is usually about 5 oersteds, and the number of cores that can be operated in series depends partly on the voltage developed across the driving winding, which in turn depends, among other things, on the cross-sectional area of the core. The number of turns on the output winding of each core is usually twice the number on the input winding, and the time required to transfer a digit from one core to the next is then about four times the response time of the unloaded core. The resistance of the linking circuit must not exceed a certain value.

Matrix Store.

In a serial storage device (such as a static magnetic delay-line), time is used as one of the selecting dimensions; the access speed is therefore relatively low. If, instead, the digits are stored in a two- or three-dimensional array, and selection is made on a co-ordinate basis, it is possible to reduce the access time considerably. Forrester[33] proposed a coincident-current matrix composed of inductors with rectangular-loop cores, and various developments of this idea have been described.[19,34,35]

The principle of the matrix is shown in Fig. 8, which illustrates a two-dimensional array of nine inductors.

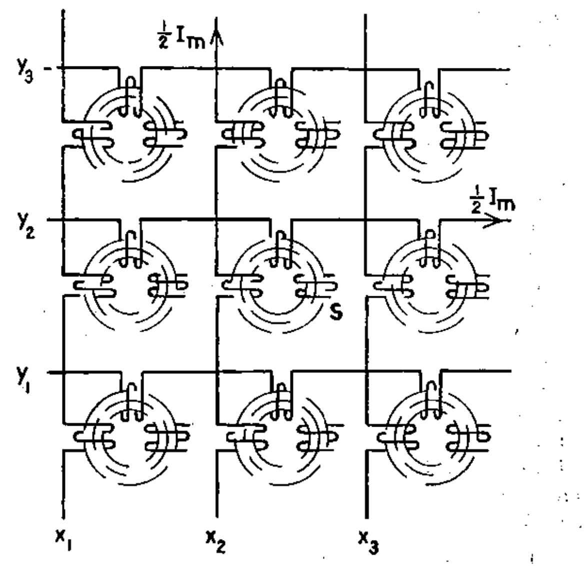


FIG. 8.—A TWO-DIMENSIONAL COINCIDENT-CURRENT MAGNETIC MATRIX STORE.

As with the static delay-line an inductor represents "1" or "0" depending on whether its core has positive or negative retentivity.

Assume that all the inductors in the matrix are set at "0". Then to store "1" in inductor (x_2, y_2) currents of $\frac{1}{2}I_m$ are applied to the lines x_2 and y_2, where $\frac{1}{2}I_m$ is the current that produces a field of $\frac{1}{2}H_m$ (Fig. 9). The field applied to cores (x_1, y_2), (x_3, y_2), (x_2, y_3) and (x_2, y_1) is therefore $\frac{1}{2}H_m$, but core (x_2, y_2) is acted on by a total field of H_m. Thus, if the hysteresis loop for core (x_2, y_2) is represented by Fig. 9, it will "switch" to $+B_m$, while the other cores will remain virtually undisturbed, the field $\frac{1}{2}H_m$ being not strong enough to change their flux states very much. A "0" is stored by applying currents in the opposite directions.

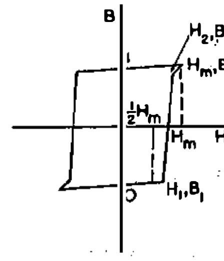


FIG. 9.—SIMPLIFIED HYSTERESIS LOOP FOR THE CORE OF A MATRIX-STORE INDUCTOR.

Reading-out is accomplished by a similar coincident-current process, except that the read-out currents are always negative. The secondary, S, is connected in series with all the

TABLE 1

Material	Density g/cc	Resistivity ohm-cm	Curie Temp. °C.	μ_0 gauss/oersted	μ_{max} gauss/oersted	D.C. Hysteresis Loop Data					
						Thickness in.	H_m oersted	B_m gauss	B_r gauss	B_r/B_m	H_c oersted
H.C.R. Alloy ..	8·25	40×10^{-6}	500	1,000	60,000		3	15,600	14,800	0·95	0·2 approx.
Permalloy F ..	8·4	26×10^{-6}	550	400-2,000	250,000	0·002	0·2	13,500	13,100	0·97	0·05
Permenorm 5000Z	8·25	45×10^{-6}	450 approx.	850	95,000	0·002	3	14,800	14,400	0·97	0·09
Deltamax ..	8·25	51×10^{-6}	500	400-1,700	130,000	0·002	2·5	15,000	14,500	0·97	0·1
Deltamax (mag. annealed)					220,000		12	15,100	14,800	0·98	0·06
Ferramic Type S1		2×10^{7}	300	40	515			1,780	1,590	0·90	1·5
Ferramic Type S2				49	1,300			2,000	1,800	0·90	0·7
Ferramic Type S3				45	1,100			2,000	1,920	0·96	0·65
Ferroxcube* Grade D1			300				5	2,250	2,150	0·96	1·25

* Provisional Data.

others, and the information may be re-stored by making the output signal actuate the writing circuit. The total access time of the matrix is usually about two or three times the response time of a single core.

If the number of inductors in a two-dimensional matrix is n^2, then the problem of selecting a single inductor is reduced to one of providing two switches each with n outputs, one switch to drive the rows, and the other to drive the columns. The number of valves to be provided ($4n$) would still be large, but if each switch consists of n inductors having rectangular-loop cores, every inductor driving a row or column of the matrix, then the number of valves needed can be reduced, by suitable interconnection of the inductors[35], to $4 \log_2 n$ (i.e., $2 \log_2 n$ "flip-flops").

The hysteresis loop of a matrix core must satisfy the condition $H_2 < 2H_1$[34]. Hence the effective driving field $< H_c$. We have seen that the response times of metals in low fields are surprisingly large, and hence metals are, on the whole, unsuitable for use in matrix stores. Ferrite cores are used instead; they can be obtained with a diameter of less than 0·1 in. Specially-treated Mumetal-type alloys of thin gauge do not show this low-field effect as strongly as other types of material, however, and they have been used to make cores for matrix stores where the speed is fairly low.

Published Data for Commercial Materials

The data for a number of British and foreign materials are given in Table 1. Some discrepancies will be noted in the data for materials which are nominally similar. In comparing retentivity ratios for different cores or materials, it is important to bear in mind the corresponding value of H_m, for the retentivity ratio usually decreases as H_m is increased, until the core is saturated. All the data have been taken from manufacturers' literature.

Conclusion

Rectangular-loop magnetic materials have many storage and switching applications in both the electronics and power fields, some of which have not yet been fully exploited. The materials are particularly useful in storage applications where it is important that the information be retained if the power supply should fail. If the number of digits to be stored is not large the magnetic shift-register may provide the best solution. The maximum speed of operation is probably limited, by eddy currents, to about 100,000 digits per second if cores of metal tape are used, but with ferrite cores higher speeds can probably be obtained. The coincident-current matrix can store a larger number of digits, and ferrites have been successfully used where response times of the order of one microsecond are required.

Metal cores can be supplied by two British manufacturers, one of whom has a range of small cores suitable for use in delay-lines. Another British manufacturer has recently put a range of ferrite cores on the market.

Future research into materials will probably have a two-fold object: a metal with a higher saturation flux density and resistivity, and a ferrite with a lower coercivity and a shorter response time, than current materials have.

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Field Trial of Pressurised Cable System

J. F. KEEP†

U.D.C. 621.315.211.4:621.317.333.4

A field trial of gas-pressurised telephone cables has now been in progress since 1950 and encouraging results have been obtained. The author describes this trial and discusses the arrangements made for sealing and pressurising the selected cables; the contactors fitted to the cables, which give an electrical indication of gas leakage; the alarm and control apparatus; and the pressure testing equipment used for routine tests on cable pressure and contactor operation. The method of fault location is then explained, and the results to date briefly mentioned.

Introduction

A WELL-KNOWN method for the protection of lead-covered cables against low insulation faults is to keep them under a constant gas pressure. A cable to be protected in this way is filled with sufficient compressed gas—either air or nitrogen—to raise its pressure to a steady value which usually ranges from 10-15 lb./sq. in. Consequently a leakage of gas from the cable will reveal itself by a fall in pressure, and a considerable warning period is obtained during which suitable action can be taken to guard against the ingress of water at the leakage point. Indication that a leakage is occurring is given by some form of pneumatic switch which operates when the normal gas pressure has fallen by 3-4 lb./sq. in. These switches (or contactors) are distributed at intervals along the length of the cable, and the contacts of each are generally wired to a common test pair. The prompt measurement of the resistance of this pair, after an alarm has been received, will indicate the position of the first contactor to operate in the vicinity of the leakage.

The apparent attractions of this system of protection led the Post Office to conduct a field trial on a 29-mile length of main underground cable as long ago as 1930, but for various reasons the results were not sufficiently encouraging to warrant general adoption of the system at that time.

In 1950, however, it was decided to conduct another trial on a larger scale with the object of developing a system which could readily be applied to cables in the main underground and junction networks. The primary object of the trial was to be able to locate the length containing the perforation rather than to determine the precise position of the damage. The reason for this approach to the problem arises from the fact that the majority of the Post Office cables are laid in ducts, and hence, unless the position of a leakage can be located with an error of, say, less than a yard, the breaking down of the ductline to effect an *in situ* repair is impracticable.

Basis of the Field Trial

In this trial the cables are maintained at a steady pressure of 10 lb./sq. in. and a positive signal is given over a test pair when the pressure falls to 6 lb./sq. in. Contactors which operate under these conditions are installed in joints as suggested by J. M. Walton[1] and are situated at approximately 0·25 mile intervals. An automatic bridge and recording apparatus are installed at the controlling exchange and the test pairs of each of the several cables under pressure are connected to the banks of a linefinder which provides access to the common test equipment.

The trial extends to seven sections of M.U. and C.J. cables which either pass through or originate at Leatherhead Exchange in the L.T.R., a total of 62 route miles being involved. Details of the cables included in the scheme are given in Table 1.

The cables are made gas-tight by sealing all exchange terminations and interceptions, by-pass valves being fitted across each full interception point to give the facility of interconnection between individual gas sections. As each

TABLE 1

Cable	*Type*	*Age*	*Pressurised*	*Amount*
Kingston-Leatherhead (M.U.)	216 pr/20 PCQT	12 years	1950	12 miles (entire length)
Cobham-Leatherhead (C.J.)	54 pr/20 PCQL	9 years	1953	5 miles (entire length)
Esher-Leatherhead (C.J.)	150 pr/20 PCQL & 74 pr/40 PCQL	18 years	1953	6 miles (entire length)
London-Chichester (M.U.)	254 pr/20 PCQT	18 years	1953	12 miles (Liberty Exchange-Leatherhead Exchange)
	254 pr/20 PCQT	Not completed		9 miles (Leatherhead Exchange-Capel Exchange)
	254 pr/20 PCQT			9 miles (Capel Exchange-Horsham Exchange)
London-Guildford M.U.	542 pr/20 PCQT	13 years	1954	5 miles (Epsom Exchange-Leatherhead Exchange)
		Not completed		4 miles (Leatherhead Exchange-Dorking Exchange)

loading coil was found to be a complete gas block, by-pass valves are also fitted at each one. Lead tubes are soldered into each stub-joint and connected together by a by-pass valve clamped on to the loading-coil casing. This provides a ready means of allowing the gas to by-pass the loading-coil case. In addition it permits a loading-coil section to be isolated, a valuable facility when a cable length has to be renewed since it allows this to be done with a minimum loss of gas. The maximum length of cable, between seals, through which the gas has free access is limited to 12 miles, and the minimum length thought to be worth while pressurising is 4 miles. The general layout of the scheme is shown in Fig. 1.

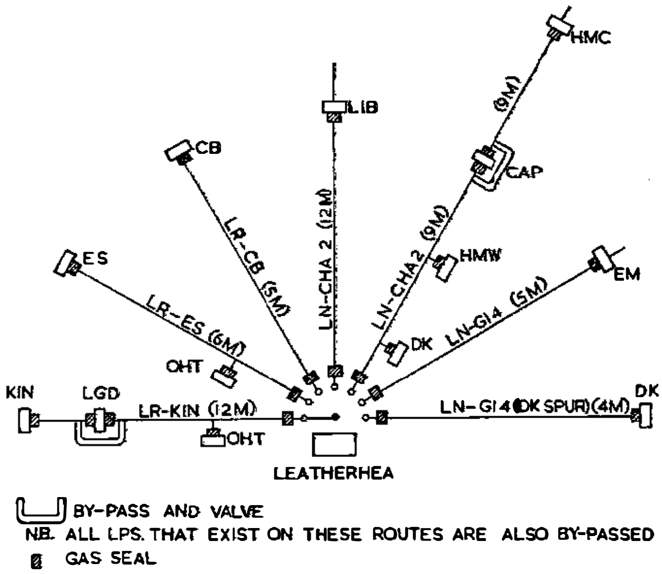

FIG. 1.—LAYOUT FOR PRESENT FIELD TRIAL.

The Kingston-Leatherhead cable is fitted with wax-filled seals which were made before installation and jointed in at each interception point. The remaining cables are sealed, where required, by the injection of a cold-setting resin. Both types of seal are shown in Fig. 2 and in each type the cables are simply prepared by the removal of a small portion of cable sheath and all the layer wrappings.

The wax used contains a high percentage of a synthetic

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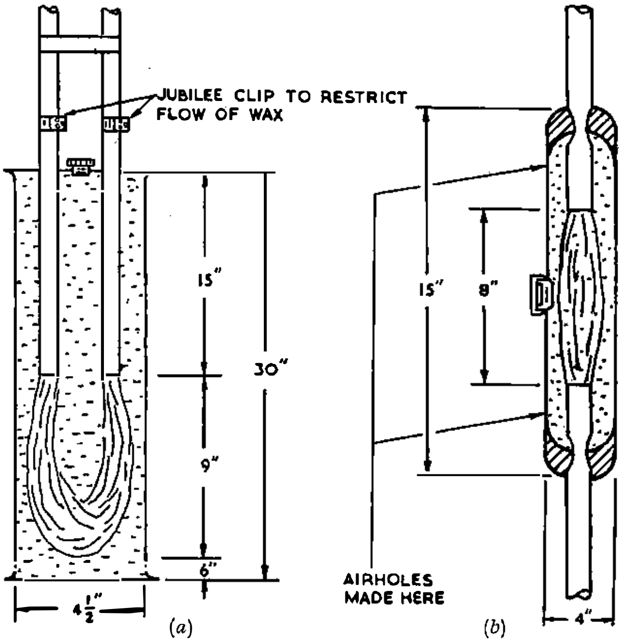

FIG. 2.—TWO TYPES OF GAS SEAL: (a) WAX-FILLED, (b) COLD-SETTING RESIN.

resin with a hydrocarbon base. It is injected into the casing at a temperature of about 300°F and at a pressure which is just sufficient to keep it moving into the seal. A slight pressure is also maintained during cooling to compensate for the shrinkage of the main body of the wax.

The cold-setting resin is a medium-viscosity solution to which a low-viscosity hardener is mixed immediately before use. The curing time is approximately 24 hours, after which the seal takes the form of a hard mass in which the wires are firmly embedded.

PRESSURISATION

Nitrogen and air have both been used on this field trial, but nitrogen was used exclusively on the Kingston–Leatherhead cable until the trial was extended in 1953. It was then decided—mainly for convenience—to change to the use of air. This is obtained from small compressors installed at various places as required. A $\frac{1}{3}$-h.p. mains-driven compressor installed in Leatherhead Exchange cable chamber is sufficient to keep the two short cables "topped-up," although an additional supply of gas at Kingston and Liberty Exchanges is required to recharge the two longest sections. In addition, a portable 24V D.C. compressor which will work from a normal manhole lighting set is used by the maintenance party.

The compressors, which deliver approximately 90 cu. ft. per hour at a pressure of 60 lb./sq. in., charge small receivers acting as reservoirs. A small separator and filter device combined with a reducing valve is fitted to the receivers which removes much of the moisture and any oil mist present before the air, now reduced to about 14 lb./ sq. in., passes into a final desiccating chamber. In the installation at Leatherhead an activated alumina adsorber is used to give a final stage of drying. This incorporates a heater element which is used for the reactivation of the alumina. Calcium-chloride filled cylinders are used by the maintenance party.

CONTACTORS

The contactors are 2 in. long and 0·9 in. in diameter. They are designed to lie horizontally within a joint and operate when the pressure falls from the normal pressure of 10 lb./sq. in. to 6 lb./sq. in. Two main types are in use at the present time:

(a) The differential type, in which the bellows are maintained in a more or less unstressed condition whilst the contactor is kept under a pressure of 10 lb./sq. in.

(b) The compression type, in which the bellows are kept compressed by the normal cable pressure of 10 lb./ sq. in.

The differential contactor (Fig. 3) operates in the following manner. The gas in the cable has access to the inside of

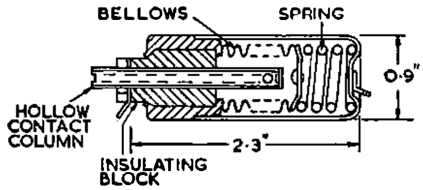

FIG. 3.—THE DIFFERENTIAL CONTACTOR.

the bellows via the hollow contact column. This opposes the action of a calibrated spring sealed between the bellows and the case. Consequently under normal cable pressure of 10 lb./sq. in. the bellows are held in an approximately unstressed condition. When the cable pressure falls the spring compresses the bellows and this completes an alarm circuit via a contact fixed to the underside of the bellows, the top of the adjustable contact column and the case.

In the compression type of contactor (Fig. 4) the inside

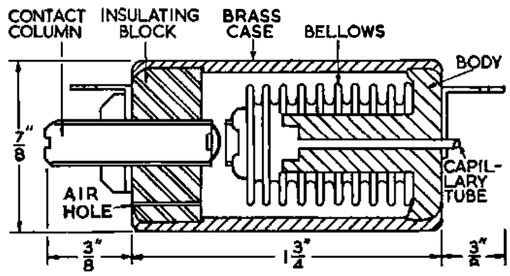

FIG. 4.—THE COMPRESSION-TYPE CONTACTOR.

of the bellows is sealed at atmospheric pressure, and thus when the contactor is placed under pressure the bellows are compressed. Several of this type of contactor are used in the Kingston–Leatherhead cable.

The aim has been to produce a contactor which will operate within the limit of $\pm 0{\cdot}1$ lb./sq. in. of the nominal figure of 6·0 lb./sq. in. Of the alternative types tried so far the differential contactor appears to be the most satisfactory, and 75 per cent. of this type met the specification mentioned whilst the remaining 25 per cent. were within $\pm 0{\cdot}2$ lb./sq. in. The compression contactors were less satisfactory and this is attributed to the bellows being kept in a compressed state.

Prototypes of a new form of contactor are also being installed using an evacuated bellows unit of a different type which is designed to be maintained in a compressed state. The bellows now operate a micro-toggle switch which, once operated, requires a pressure of about 8 lb./sq. in. to reset it.

ALARM AND CONTROL APPARATUS

The gas pressure system of maintenance lends itself readily to an automatic system of electrical location. One quad is taken from each of the cables for use as a test circuit and the contactors are wired in parallel across one of the pairs. The quad is then rearranged to provide the external arms of a bridge circuit. The average difference in line resistance between contactors with this arrangement is 11 ohms and the use of the bridge principle ensures that the measured location of an operated contacto[illegible] of any possible resistance of [illegible] ...or is independent [illegible] tion of the [illegible] the contacts. A brief descrip- [illegible] ...ipment and facilities is as follows:—

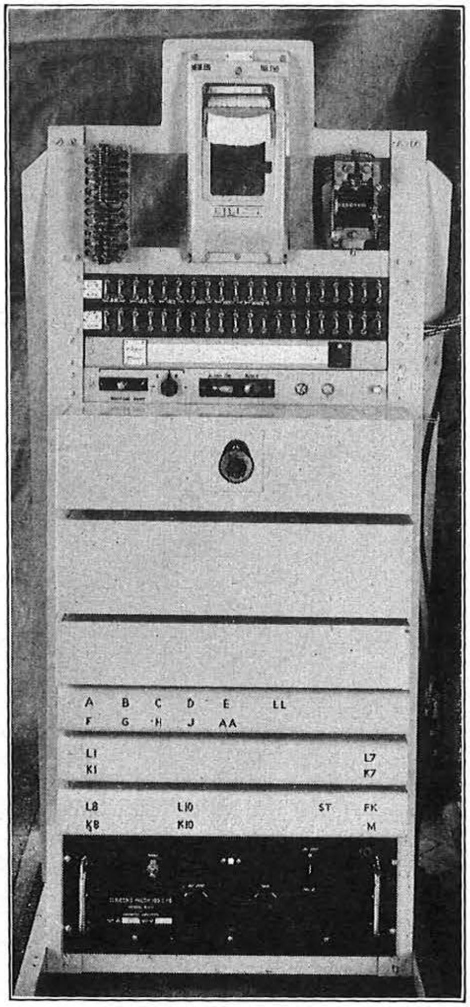

FIG. 5.—THE EQUIPMENT AT LEATHERHEAD EXCHANGE.

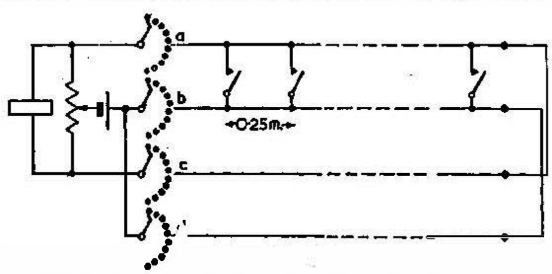

FIG. 6.—BRIDGE CONNECTIONS OF TEST QUAD AND CONTACTORS.

The apparatus, shown in Fig. 5, as installed at Leatherhead, consists of a linefinder circuit, display panel and bridge control equipment. Location is effected in two stages and two separate self-balancing bridges are used. Referring to Fig. 6, when a contactor operates in one of the cables the particular test quad is selected by the linefinder and extended to a bridge circuit. This bridge, which is self-compensating for resistance/temperature variations on the cable, self-balances by the operation of a motor-driven potentiometer and, from previous calibration, the position of the potentiometer at balance indicates the location of the operated contactor.

As soon as the first bridge is balanced the quad is changed over to a second self-balancing bridge to which a recording voltmeter is connected automatically when balance is obtained. The second bridge indicates on the recording voltmeter, in swings of equal amplitude to the right and left of a zero line, the changes in balance caused by sequential operation of contactors—and consequent line resistance changes—as pressure in the cable falls progressively. The direction of swing shows whether the contactor concerned is further from or nearer to the exchange in relation to the position of the first contactor to operate. The trace obtained by this means, giving the order in which successive contactors operate and the time interval between operations, is used to locate the fault in a manner described later.

Once the equipment is connected to a particular cable a continuous record is maintained until the equipment is reset manually. Thus, there is no automatic selection of any further cable which develops a fault but the fault condition is indicated by a display and alarm.

The two basic bridge circuits are shown in Fig. 7. The

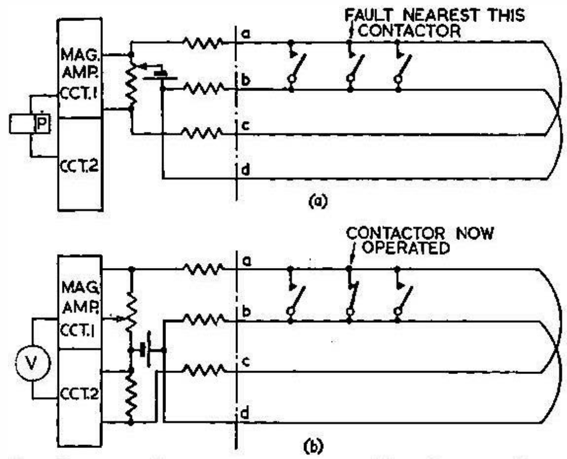

FIG. 7.—OUTLINE CONNECTIONS OF THE TWO BRIDGE CIRCUITS: (*a*) MURRAY LOOP, TO LOCATE FIRST CONTACTOR TO OPERATE; (*b*) FOR LOCATION OF CONTACTORS OPERATING SUBSEQUENTLY.

mechanism of the recording voltmeter is started by the operation of the linefinder circuit. To avoid the use of a sensitive moving-coil type of relay to control the bridge motors, a magnetic amplifier has been incorporated in the circuit. This serves two purposes. Firstly it provides a simple method of obtaining a high degree of D.C. amplification, which permits the use of a robust control relay, and secondly it amplifies the very small current changes caused by successive contactors operating.

The potentiometers are driven by two small split-field motors which have a final shaft drive of about five revolutions per minute. The drive motors are electrically stalled just before balance occurs. The existing arrangement of the circuit produces an accuracy of reading within $\pm 0{\cdot}2$ per cent. of the total loop resistance. This is sufficient in the present circumstances as the maximum loop resistance is 1,056 ohms with a contactor separation of about 11 ohms.

PRESSURE TESTING EQUIPMENT

As mentioned previously, pressure testing valves are soldered to the sleeve of each joint containing a contactor. There are two reasons for doing this: (*a*) to provide a ready means of checking the cable pressure without having to

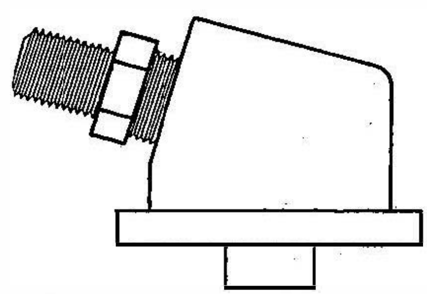

FIG. 8.—SCHRADER VALVE ASSEMBLY.

perforate the sleeve, and (*b*) to provide a ready means of making routine tests of each contactor. The valve assembly (Fig. 8) consists of a Schrader tank valve fixed into a robust gunmetal casting.

The normal 7-in. dial, 0-10 lb./sq. in., Bourdon tube pressure gauge lined with 0·1 lb. markings has been found suitable for most of the work done so far. For the more accurate measurements which are required where a very small leakage is involved, a mercury manometer is used. This, however, is a cumbersome instrument to use on the roadside or in a manhole, and alternative forms of equipment suitable for measuring small changes in pressure are under consideration.

For pressure testing at joints between Schrader valves an attachment is used (Fig. 9) which can be strapped to the joint. This allows the pressure to be observed without loss of gas, by the operation of a plunger contained in the attachment.

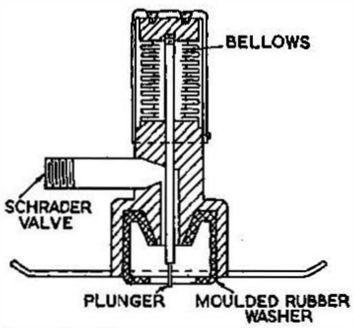

FIG. 9.—PUNCTURING TOOL FOR TESTS AT JOINTS NOT FITTED WITH SCHRADER VALVES.

The precise position of the point of leakage may be determined by a leakage indicator using difluorodichloromethane (also known as Arcton or Freon), a gas which is widely used as a refrigerant. Two forms of detector are available for use with this gas. In its simplest form the detector consists of a small methylated spirit or Methanol blowlamp, the flame of which impinges on a copper ring. The operation of the detector is based on the fact that any gas containing a halogen, i.e., fluorine, chlorine, bromine or iodine, will decompose when passed over a glowing piece of copper and will then burn with a characteristic green flame. This type of detector is reasonably sensitive and has been used with some success to detect leakages at joints and loading coils. The method used so far has been to fill the suspected portion of cable with an Arcton-air mixture and pass the inlet tube of the lamp over the cable or coil until a colour change in the lamp flame has been observed. Simulated leakages along the duct have been detected by this means.

A more positive form of electronic detector is based on the principle that when a gas containing any of the elements listed in the previous paragraph is passed over a heated platinum electrode the rate at which positive ions are discharged is greatly increased. This type of detector has not been used so far in this field trial, but it has advantages in convenience and sensitivity over the flame type of detector and would have an especial value for the detection of leaks along the duct.

A disadvantage in the use of Arcton is that while it is non-toxic at ordinary temperatures the use of a blow-lamp will decompose the gas in strong concentration, forming hydrochloric and hydrofluoric acids as by-products. Consequently it is necessary to scavenge the cable of excess gas. There are other methods of leak detection using radio-active gases, which have certain advantages.

METHOD OF FAULT LOCATION

First indications of the presence of a leakage are given by the equipment at the exchange, which records the time and order in which the contactors nearest to the leakage operate. Generally no further action is taken until at least three contactors have operated—by which time it is possible to estimate the position of the leakage. To know when field investigations should be put in hand is mainly a matter of experience, and for a very slow leakage it is often found convenient to recharge the cable with gas and leave the field investigations until later.

Use of Equipment at Exchange.

The identity of the first contactor to operate is given by reference to a calibration chart, one of which exists for each cable maintained under pressure. This chart indicates beside the dial reading which is obtained from the equipment, the address of the contactor and its distance from the exchange. The order and time interval are obtained from the recording voltmeter, and a portion of a typical chart is shown in Fig. 10, on which a swing of the pen to the right

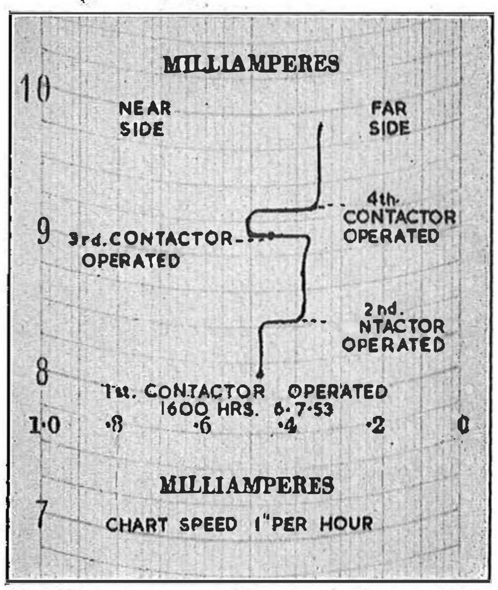

FIG. 10.—PART OF TYPICAL RECORDING-VOLTMETER CHART.

indicates the operation of a contactor which is farther away from the first to operate, and vice versa.

A simple proportional method, based on the intervals of time that elapse between the operation of the first three contactors and the distances between them, is used to calculate the position of the leakage with respect to the first contactor to operate. Two slightly differing formulae are used for this purpose, depending on the cable under consideration. The expression

$$x = \frac{1}{2}\left(\frac{t_M L^2 - t_L M^2}{t_M L + t_L M}\right)$$

is used when a leakage occurs in any of the three P.C.Q.T. cables connected to the equipment, the sequence of operation being indicated in Fig. 11. (t_L and t_M refer to the time

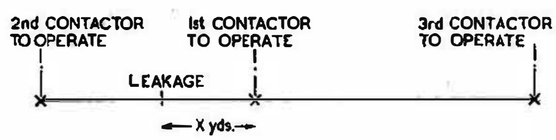

FIG. 11.—SEQUENCE OF CONTACTOR OPERATION USED TO CALCULATE POSITION OF LEAKAGE.

intervals in hours between the operation of the first and second and first and third contactors, respectively.)

The expression is modified slightly when applied to the P.C.Q.L. cable because of its different flow characteristic. This method has now been tested several times and it appears that a fairly accurate estimate of the position of a fast leak can be obtained before pressure tests are made on site.

Field Investigations.

On the advice of the exchange staff, a single pressure measurement is made on several valves in the vicinity of the leakage and following this a graph is drawn of the pressure gradient. Often, and especially where a leakage from a joint is suspected, a single measurement such as this is sufficient to give a location—and in practice it has been noticed that by far the greater number of leakages occur at joints.

When greater accuracy is required, allowance must be made for the decrease in cable pressure during the testing period. Consequently, several sets of timed readings are made at each valve point and a series of curves drawn showing how the pressure is changing at each point. It is then possible to derive a close approximation of the pressures existing in the cable at any moment, so enabling an "instantaneous" pressure gradient to be drawn (see Fig. 12).

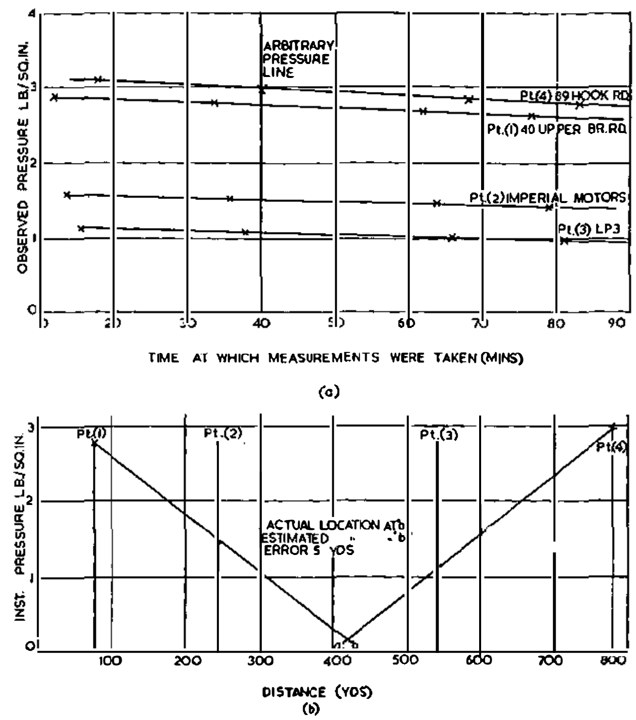

FIG 12.—LOCATION OF LEAKAGE BY DETERMINATION OF INSTANTANEOUS PRESSURE GRADIENT.

CONCLUSION

Since the first cable was put under pressure in 1950, 18 major leakages have been cleared without interruption to service. Of these, an approximate location of the position of six of the leakages was made by means of the automatic locator. On 10 further leakages the position of the first contactor to operate was indicated, but for various reasons the leakages were cleared without the apparatus being allowed to complete its full recording sequence. The remaining two leakages were observed and cleared as a result of routine pressure tests made on the cables. On one occasion when the Kingston–Leatherhead cable was pierced by a pick-axe the leakage was detected before the four circuits affected by mechanical damage were reported faulty.

On these facts alone it is thought that the field trial has been justified. It has also provided a useful training ground and starting point for the wider application of the gas pressure system of maintenance should it be decided to adopt it in the Post Office.

Among some other investigations made during the course of the field trial were the determination of the degree of water penetration which could occur from a leakage under a considerable head of water, the development of a method of routine testing contactors *in situ*, and the measurement of the pneumatic resistance of various types of cable.

ACKNOWLEDGMENTS

The author wishes to acknowledge the assistance given by various members of the External Plant and Protection Branch and of the South-West Area of the London Telecommunications Region, both during the field trial and in the preparation of this article.

Book Review

"Active Networks." V. C. Rideout. Constable & Co., London. xvi + 485 pp. 362 ill. 42s.

The combination of active components, still principally the thermionic valve, and passive linear networks forms the basis of much telecommunication equipment. The author suggests that its study should, or does, follow that of its parts and has written the book for that purpose—with considerable success.

The first chapter deals with fundamental concepts, definitions and the classification of networks; emphasis is put on the more basic relationships of four-terminal networks. The active devices are considered as circuit elements in the next chapter, receiving valves conventionally, transistors in an elementary way, and magnetic amplifiers adequately. A chapter on low-pass amplifiers, introducing maximal flatness, simple compensation and gain-bandwidth products, is very well presented. The next chapter introduces the transient response of amplifiers by way of waveforms, Fourier series and operational calculus. The elements of band-pass amplifiers follow. The sixth chapter, one of the best in the book, deduces or describes the advantages of negative feedback and discusses the important question of stability. Some miscellaneous amplifiers, including those using klystrons and travelling-wave valves, are described, very briefly, in the next. Power amplifiers then receive their due attention. But 27 pages prove insufficient for adequate descriptions of the many oscillators considered. The chapter on amplitude modulation and modulators is well balanced and is followed by two, equally satisfactory, on frequency, phase and pulse modulation and on detectors. Wave-shaping circuits—clippers, differentiators, integrators, sawtooth generators, relaxation oscillators and trigger circuits—which have entered so many fields of telecommunications, are briefly described. The final chapter emphasises the importance of noise, particularly in the various forms in which it appears in active devices, before giving a brief outline of information theory. Each chapter concludes with about ten problems, mostly with a practical flavour, and a dozen or so references, mostly American.

Although there are a few mistakes here and there—the direction of easy flow of current in an n-type rectifier is opposite to that stated, the emitter and collector of a point-contact transistor cannot be usefully reversed, as implied—and some of the small sections here and there on circuits using u.h.f. valves and those using transistors may have to be re-written in only a few years, the bulk of the book can be studied with much advantage by students of radio and telecommunications. The book deserves to receive serious consideration as a standard textbook.

The layout is good and the illustrations generally straightforward, but the printing leaves much to be desired; in many places the bolder types and suffixes are indistinct, particularly in the figures. The price is in keeping with modern practice.

J. R. T.

An Electronic Programme Clock

A. K. DOBBIE, B.Sc.(Eng.), A.M.I.E.E.†

U.D.C. 681.11:621.385.12

Cold-cathode gas discharge triodes can be switched on or off by timing pulses and this property has been employed to make a programme clock which will give out a series of signals at predetermined times. One of its main uses would be the generation of precise time signals in place of existing multi-contact systems which are driven by phonic motors.

INTRODUCTION

"PROGRAMME Clock" is the term used by clock-makers to denote a clock which is arranged to give a series of signals at a number of predetermined times. Frequently a seven-day cycle is employed, especially for factories in which the times for starting and stopping work and for tea breaks, etc., are announced by bells.

Mechanical programme clocks are made which are capable of selecting any minute in the week, which means that considerable mechanical precision is necessary in order to obtain reasonable accuracy in the time at which the signal is given, but inevitably wear will take place which will reduce the accuracy of the system.

Radio time signals are generated by more precise programme clocks controlled by phonic motors which drive a series of shafts geared to run at different speeds. By operating contacts from cams on the various shafts, it is possible to gate signals so that reasonable accuracy is obtained. These clocks, being mechanical, require regular maintenance and, in particular, the rotating commutator-type contacts which provide the accurate seconds pulses require frequent cleaning.

In connection with quartz clocks an electronic programme clock* has been developed which is not only much more accurate than mechanical clocks but is more versatile and requires no maintenance, and having no moving parts its accuracy is invariable. It is based on the use of cold-cathode gas discharge triodes which can be "switched on" in a matter of microseconds by a short timing pulse. The use of these tubes in an experimental electronic director was described in a previous article.[1]

BASIC TIMING CIRCUIT

The electronic programme clock can best be described by reference initially to the basic timing circuit as set out in Fig. 1.

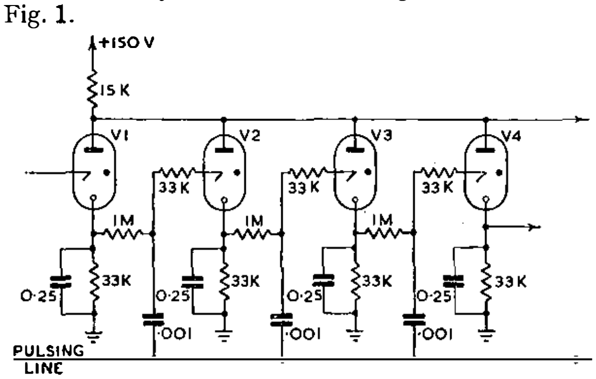

FIG. 1.—BASIC CIRCUIT OF ELECTRONIC PROGRAMME CLOCK.

A number of gas discharge triode tubes are connected to have their anodes in parallel and fed through a single resistor; the cathodes are connected to earth individually, via a resistor and a capacitor, so as to slow down the rise of cathode potential during striking; and the control electrodes are all connected to a common pulsing line. Additionally, each control electrode is connected to the cathode of the preceding valve by a high resistance so that when V1 is conducting its cathode potential of about 50V is applied to the control electrode of V2. A pulse of about 40V amplitude applied to the common pulsing line will then produce a potential of 90V at the control electrode of V2 and only 40V at all the other control electrodes; thus, since a potential of 70V is necessary for ionisation, the pulse will initiate a discharge between the control electrode and cathode of V2 causing the main anode-cathode gap to break down. This will cause a drop in the potential of the common anode line and since the tube which was originally conducting has its cathode at +50V, the potential across that tube will no longer be adequate to maintain the discharge, so it extinguishes. The single pulse has thus extinguished one tube and ignited the next.

Now consider 60 such gas discharge triodes connected together as in Fig. 1, but with the last triode connected back to the first so as to form a ring, and numbered from 0 to 59. If tube 0 is initially conducting and seconds pulses are then applied to the pulsing line, each tube will ignite in turn at the precise second that its number indicates. Since a signal can be taken from the cathode of any tube, it follows that when the ring is continuously operated from seconds pulses, No. 35, for example, will give out a signal once every minute at precisely 35 sec. past each minute.

Since tube 0 can give out a pulse at each precise minute, it can supply minute pulses to a second ring of 60 tubes so that a signal can then be obtained at any chosen minute. In order to obtain a signal at so many seconds past a given minute the cathode potential of the given minute tube can be connected via a high resistance to prime the control electrode of an independent tube and a pulse obtained from the appropriate seconds tube can then be made to ignite the new tube at the required second, so generating a signal at a predetermined minute and second.

PRODUCTION OF TIMING SIGNALS

Fig. 2 shows schematically a clock which will give a signal at 1 hr. 1 min. 2 sec. which lasts for 2 sec., and another signal at 6 hr. 5 min. 7 sec. which lasts until 8 hr. 8 min. 9 sec. The clock is shown as having two rings of 60 tubes and one of 24, so enabling signals at any required second of the day to be obtained. The additional tubes A, B and C generate the first signal, as follows:

Tube A receives a priming potential from the start of the first hour and then receives a pulse at the beginning of the first minute so that it ignites at 1 hr. 1 min. Tube B receives a priming potential from tube A so that it ignites when a pulse arrives at 2 sec. past the minute, so igniting at 1 hr. 1 min. 2 sec. Since tubes A and B have a common anode resistor, tube A extinguishes when tube B ignites. Tube C receives a priming potential from tube B and a pulse at 4 sec. past the minute so that at 1 hr. 1 min. 4 sec. it ignites and by sharing the same common anode resistor of tubes A and B, tube B extinguishes on the igniting of tube C.

The required signal has thus been generated by tube B and the system remains static, with tube C conducting, until tube A again ignites at 1 hr. 1 min. The signal can be taken from tube B cathode to operate an electronic device, or a telephone-type relay may be inserted in the cathode circuit itself.

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

* British Patent application No. 21790/53.

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

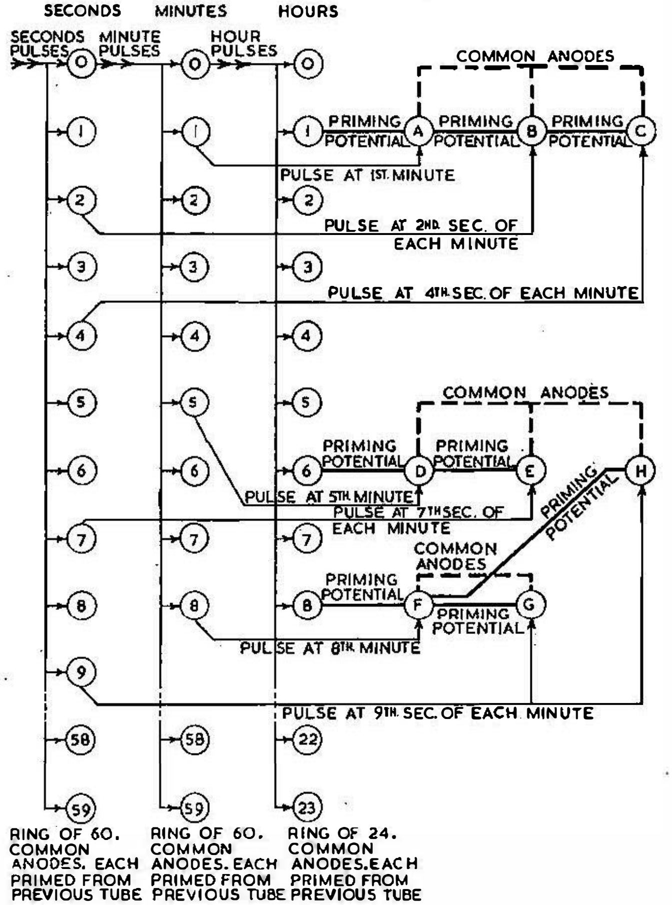

FIG. 2.—SCHEMATIC DIAGRAM OF AN ELECTRONIC PROGRAMME CLOCK.

The second signal generated by the clock in Fig. 2 is obtained as follows. Tube D is primed from the start of the sixth hour and is ignited at 6 hr. 5 min. by a pulse at 5 min. past the hour. Tube E is primed by tube D and receives a pulse at 7 sec. past each minute so that tube E ignites at the required time of 6 hr. 5 min. 7 sec. and, in so doing, extinguishes tube D. Tube F is primed from the start of the eighth hour and receives a pulse at 8 min. past each hour so that it ignites at 8 hr. 8 min. and then proceeds to prime tubes G and H which ignite at precisely 8 hr. 8 min. 9 sec. Tube F is then extinguished by tube G and tube E by tube H. It will be seen that tube E has generated a signal for the required time. Tubes G and H then remain conducting until the cycle recommences.

In practice a ring of 60 tubes would not be used; instead three rings in series consisting of five, four and three tubes would be used since this gives the same count of 60 for many fewer tubes. The arrangement is shown diagrammatically in Fig. 3 for a count of 60 with the necessary connections for obtaining a signal at 27 sec. Tubes 1, 6 and 10 are initially conducting and seconds pulses are supplied to the ring of five, which then generates a pulse every 5 sec. and feeds it to the second ring of four which in turn passes on a pulse every 20 sec. to the ring of three. In order to obtain a signal at 27 sec. tube A is primed from tube 11, which is conducting from 20 to 40 sec., and tube 7, which is conducting from 5 to 10 sec., 25 to 30 sec. and 45 to 50 sec. past each minute, generates a pulse at 5, 25 and 45 sec. so igniting tube A at 25 sec. Tube A then primes tube B from 25 sec. so that pulses from tube 3, which occur at the second second of each 5-sec. period, ignite tube B at 27 sec., so generating the required signal.

A further point in the practical realisation of the system is that tubes in the timing rings are not required to generate pulses, as the circuit conditions for this are different from the conditions for optimum operation in a slow timing ring. Instead an extra tube is used having a small capacitor and a large resistor in its cathode circuit so as to generate a large pulse at the instant of firing. It is primed and fired in the same way as the tube in the ring which has been described as generating the required pulse.

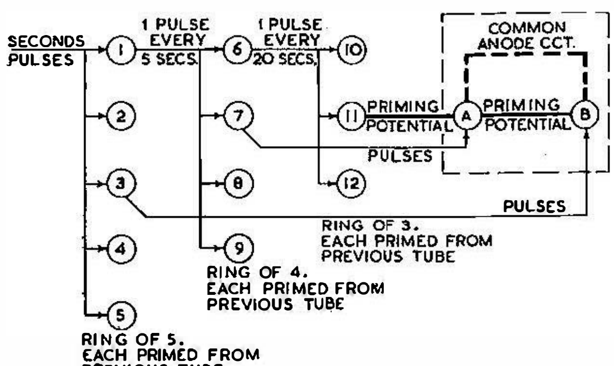

FIG. 3.—SCHEMATIC DIAGRAM OF RINGS OF 5, 4 AND 3 TO OBTAIN THE SAME PERFORMANCE AS A RING OF 60.

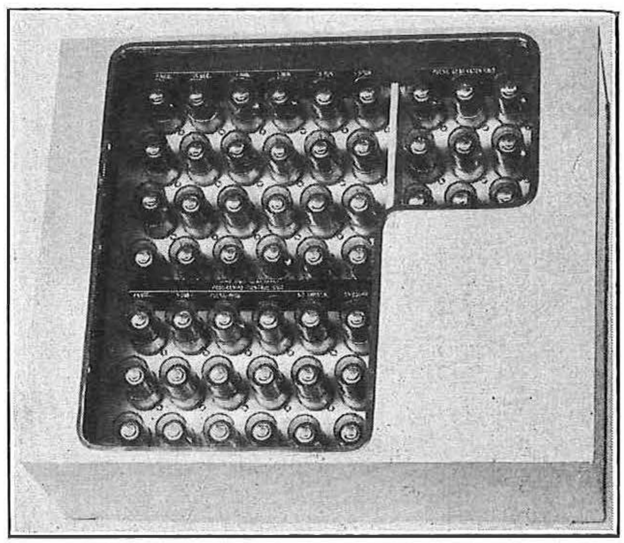

FIG. 4.—THE ELECTRONIC PROGRAMME CLOCK.

Fig. 4 shows a complete electronic programme clock designed to give the modulation programme for the MSF standard frequency transmissions from Rugby, which is at present provided by a phonic motor timing unit.

CONCLUSIONS

When a precise signal is required at an exact hour, the clock described ensures that the tube for that hour will have all the accuracy required (better than 1 millisecond). The electronic equipment provides both a more accurate and more economical means of achieving the desired end than does its mechanical equivalent, and this measure of accuracy and economy persists in the maintenance of, as well as in the provision of, the equipment.

The cold-cathode gas discharge tubes which are used in the programme clock have been on life test for a number of years and appear to have an indefinite life, so that, although a large number of tubes (up to 100) may be used in a single clock giving out a large number of signals, stoppages due to faulty tubes should be almost unknown.

A New Routiner for Outgoing Trunk and Junction Circuits

F. A. KING†

U.D.C. 621.395.365: 621.395.2/.3

This article describes a new routiner which has been developed to enable test calls to be set up, and simple transmission tests to be applied automatically to trunk and junction circuits connected to selector levels.

INTRODUCTION

WITH the introduction of automatic trunk switching, an operator can no longer select a particular circuit in a route connected to a selector level, nor can she identify a faulty circuit in such a route. The consequent need to be able to set up a call and make a simple form of transmission test to replace operator testing, resulted in the development of an Automatic Trunk and Junction Routiner (2,000-type). For use with the routiner, an answering equipment is connected to a selector level at distant exchanges to which circuits are tested, so that signalling and transmission tests in both directions may be made from the routiner. A general view of a suite of five such routiners is shown in Fig. 1.

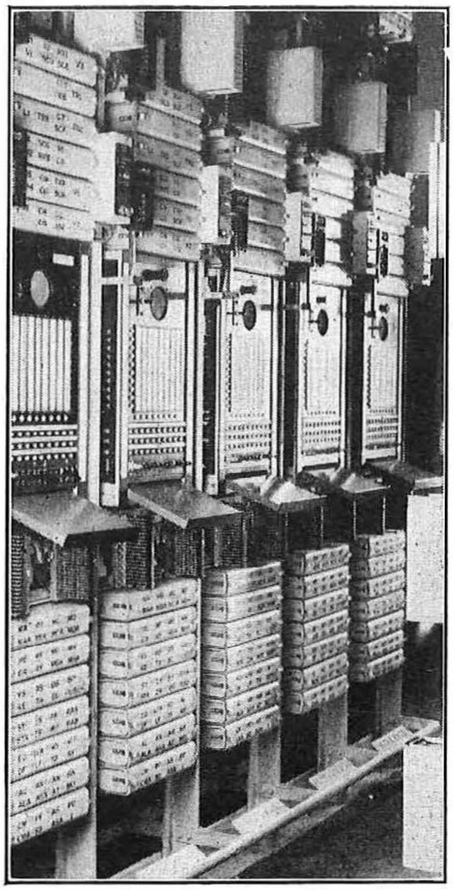

FIG. 1.—SUITE OF FIVE AUTOMATIC TRUNK AND JUNCTION ROUTINERS.

GENERAL DESCRIPTION

Access to trunk circuits is obtained by a two-motion access selector, the bank of which is associated with the multiple used by the trunk test positions.[1] The basic design of the access selector and access control circuits follows established routiner design, but is complicated by the provision of additional facilities not previously called for on this type of routiner. The facilities given are as follows:—

(1) Automatic control of the routiner in conjunction with a docket machine.
(2) Manual control of the routiner.
(3) Discrimination between:—
 (a) Battery- or earth-testing circuits.
 (b) Circuits to automatic or manual centres.
 (c) Transmission testing of routes or groups of circuits.
 (d) Routing requirements for groups of circuits by dialling codes in any combination of 1, 2 or 3 digits.

The routiner test circuit provides for the application of scheduled tests to the following types of trunk or junction circuits:—

(1) *Dialling circuits:* signalling systems A.C. No. 1 and D.C. No. 1; loop dialling.
(2) *Signalling circuits:* signalling system A.C. No. 3; differential signalling; C.B. signalling.

The routiner is mounted on a standard 10 ft. 6 in. by 1 ft. 6 in. rack, and caters for a maximum of 800 trunk or junction circuits by the use of up to eight access selectors, each with 10 vertical and 10 rotary positions. Circuits are connected in groups of 10 (i.e. one group per access selector level), giving flexibility in arranging the available circuits and routes for testing purposes, with a maximum of 80 routes of up to 10 circuits.

The group of trunks or junctions being routined is indicated on a control panel (centre of rack—Fig. 1) by cross reference between the vertical marked by the access selector lamp, and the horizontal level indicated by the access vertical lamp. The individual trunk within the group under test is indicated by the appropriate access "rotary" lamp. Situated beneath the access rotary lamps are the control keys and test-cycle progress and fault lamps.

The test cycle depends on the type of centre, manual or automatic, to which the trunk or junction is routed, and is applied as follows:—

To automatic centres:—

(1) The P-wire is checked for free conditions.
(2) The circuit is seized, and guard conditions checked.
(3) The junction polarity is verified.
(4) Routing digits are sent to line.
(5) The return of "called subscriber answer" (C.S.A.) conditions by the answering equipment is checked.
(6) 1,600 c/s tone at predetermined level is sent to line.
(7) 1,600 c/s tone is received from the distant answering equipment and the level checked.
(8) "Called subscriber release" conditions from the answering equipment are checked.
(9) The circuit is released.

To manual centres:—

(1) The P-wire is checked for free conditions.
(2) The circuit is seized and guard conditions checked.
(3) The junction polarity is verified.
(4) The receipt of C.S.A. conditions from the distant operator is checked.
(5) A verbal announcement of "test call" is repeatedly sent to line.
(6) "Called subscriber release" conditions from the operator are checked.
(7) The circuit is released.

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[1] "Trunk Testing at Zone Centre Exchanges," L. A. Missen, *P.O.E.E.J.*, Vol. 47, p. 17.

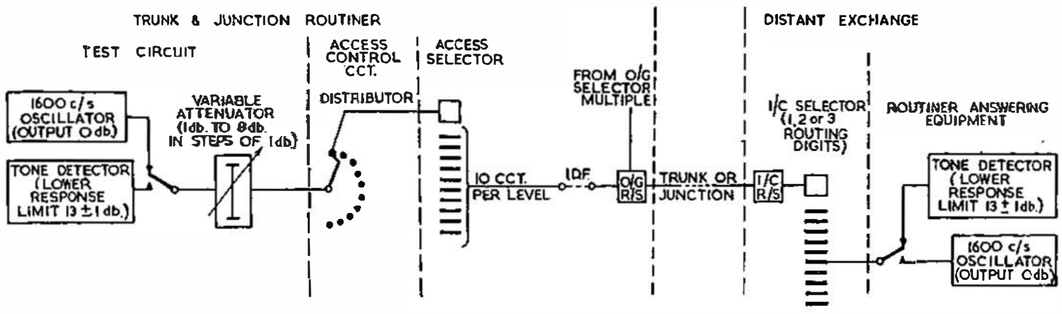

FIG. 2.—BLOCK SCHEMATIC DIAGRAM OF CONNECTIONS FOR TRANSMISSION TESTS.

TRUNKING ARRANGEMENT

Fig. 2 shows the trunking and transmission testing arrangements to automatic centres, with a transmission test being made in the "go" direction. The circuit under test is selected by the positioning of the distributor in the access control circuit, and the access selector, the bank connections of the access selector being wired via the I.D.F. to the appropriate O/G relay set. Routing digits, sent from the test circuit, position the incoming selectors at the distant exchange, and seize the answering equipment connected to that level. Tone at 0 db.* from the routiner test circuit is sent to line via a predetermined value of the variable attenuator. This tone, when received by the distant answering equipment, has been further attenuated by the trunk or junction circuit, and provided the level received is not lower than -13 db. ± 1 db., the tone detector in the answering equipment responds. A transmission test in the "return" direction is then made between the oscillator in the answering equipment and the tone detector in the test circuit. The variable attenuator is only provided at the routiner end, and the same attenuation value is used in both the "go" and "return" directions of each circuit.

OUTLINE OF CIRCUIT OPERATION

In this article no attempt is made to give a complete description of the operation and control of the routiner, but the following details cover the more important features. The routiner has been designed to work from the normal -50V exchange battery, with the exception of the valve heaters which are supplied from a 6V constant-voltage transformer working off A.C. mains.

Test Circuit.

To enable tone to be sent over the trunk or junction for transmission testing purposes, a 1,600 c/s oscillator is provided, consisting of a tuned-grid oscillator valve followed by a buffer output stage and adjusted to give an output of 0 db.

To receive and check the level of 1,600 c/s tone from the distant end, a three-valve tone detector is provided. Tone is amplified in the first stage, rectified by metal rectifiers, and the resultant D.C. applied to the following two valve stages which form a D.C. amplifier. The anode current of the third stage controls a relay, and the overall sensitivity is adjusted so that the tone detector responds to a level of -13 db. $\pm$ 1 db.

At the commencement of each test cycle a "self-check" sequence is performed. This consists of sending tone at 0 db. on a local circuit via a 12 db. attenuator into the tone detector, which responds. Tone at 0 db. level is then passed through a 14 db. attenuator (consisting of the 12 db. attenuator and an additional one of 2 db.) and check is made that the tone detector does not respond. Since a disconnection of the 2 db. attenuator or its switching contacts would negative the latter test, a continuity test of these items is also included as part of the self-check sequence.

On tests to automatic centres it is possible for any of the selector switching stages to return busy conditions. Since this is not a fault condition, the test circuit is arranged to "reset" and re-apply the test cycle if C.S.A. conditions are not received within a specified period. Should these conditions not be received at the second attempt, a routine fault condition is set up.

A monitor amplifier is provided to assist the maintenance staff when manually operating the routiner. This includes three valves, forming a cathode-follower stage to present a high input impedance as the circuit is tapped across the line, followed by a voltage amplifier driving the output stage, which feeds a loudspeaker mounted above the control panel as seen in Fig. 1. The amplifier may be switched on as required, and a volume control enables the output to be adjusted to the desired level. Manual check and calibration of the oscillator and tone detector is facilitated by provision of test jacks, test links and preset variable resistors.

Access Control Circuit.

Manual control and operation of the routiner by keys on the control panel closely follows that of existing routiners using two-motion access selectors. A three position key with a locking handle is also provided which, in the downward position, starts the routiner under manual control and, in the upward position, places the routiner under automatic control in conjunction with a fault recorder, or docket machine.[2] The access selector is non-homing and will normally be positioned on the last circuit tested. With the receipt of a "start" signal from the docket machine control circuit, the access control circuit steps the access selector, positioning it on the next circuit in sequence, and extends marking conditions to print a "start" docket. On completion of printing, the access control signals the test circuit to apply the test cycle. When the circuit has been tested, a "test-cycle finish" signal is returned from the test circuit, and the access control then steps the access selector to the next equipped circuit.

Should a circuit fail to pass the test cycle, the access control extends marking conditions to the docket machine control circuit for recording details of this failure and the access position. On completion of printing, the access control again steps the access selector to the next equipped circuit, and testing continues in this manner until the expiration of the period of automatic routine, when a "stop" signal is received from the docket machine control circuit. In order to give the correct marking conditions for printing a "stop" docket, the access selector must be positioned on an equipped circuit. Thus a "stop" signal is stored under automatic control (or, similarly, by the operation of the appropriate keys to take the routiner over under manual control) and does not become effective until (*a*) the access selector is positioned on a working circuit, and (*b*) the test cycle on that circuit is complete, including the printing of a fault docket should the circuit prove faulty. Following the final sequence of printing the "stop" docket, routining ceases. The routiner can then be operated manually when required, or otherwise is ready to receive the next automatic "start" signal, when the access selector will be positioned

* All tone levels are quoted with reference to 1 mW in 600 ohms.

[2] "The Fault Recorder or Docket Printing Machine." T. F. A. Urben. *P.O.E.E.J.*, Vol. 45, p. 115.

on the next equipped circuit, and testing recommenced as described above. A visual indication of docketing in progress is given by a "Docket Print" lamp.

Access Selector Circuit.

As previously mentioned, the access selector is non-homing. Its other main feature is the number of discriminating facilities provided, viz.:—

(*a*) Battery or earth testing.
(*b*) Automatic or manual distant termination.
(*c*) Transmission loss measurement on circuits to automatic terminations.
(*d*) Routing digits to distant answering relay sets.

All discrimination is effected on a level basis, i.e. groups of 10 circuits, and 10 leads (one per level of the access selector) are provided for each discrimination performed. These leads, together with the discriminating leads from the test

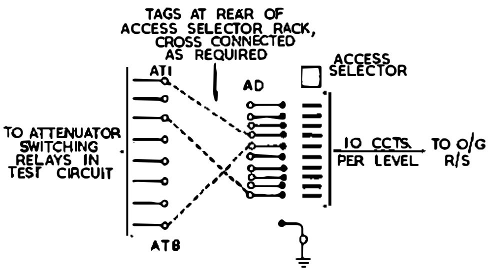

FIG. 3.—DISCRIMINATION FROM VERTICAL MARKING BANK.

circuit, are wired to tags on connection strips mounted at the rear of the access selector rack, and discrimination is obtained by the insertion or omission of straps between the sets of tags as required. Fig. **3** shows how this is effected for attenuator switching to control the level of 1,600 c/s tone used for the transmission test. The AD tags are wired from the access selector vertical marking bank, one per level, and are cross-connected as required to the eight AT tags wired from the test circuit. With no strap inserted the maximum attenuation of 8 db. is in circuit. A strap to AT1 will reduce the attenuation in circuit by 1 db., i.e. to 7 db., and, similarly, strapping to successive tags reduces the attenuation in steps of 1 db. Thus, cross-connection to AT8 reduces the inserted attenuation to zero. The last-mentioned arrangement will permit the routiner to pass as satisfactory a circuit with transmission loss not greater than 13 db. $\pm$ 1 db., whereas the most stringent test, with no strap connected, is for a circuit loss of 5 db. $\pm$ 1 db. Disconnection or omission of the discriminating straps where they should be provided, will therefore apply the most stringent test condition, and tend to be self-revealing by fault indications.

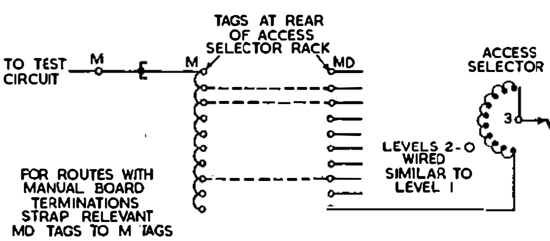

FIG. 4.—DISCRIMINATION FROM BANK MULTIPLE.

Fig. **4** shows how discrimination is effected for circuits with automatic or manual terminations. The contacts of each level served by wiper 3 of the access selector are commoned together, and connected to an MD tag, the MD tags having corresponding M tags which are commoned and connected to the test circuit on the M lead. Insertion of a strap between the relevant MD and M tags of any particular level, allows the discriminating earth from the access selector wiper 3, to be extended to the test circuit M-lead. This indicates a group of 10 circuits with manual terminations, and the appropriate test cycle is applied. This method of discrimination is also used for facilities (*a*) and (*d*).

Answering Relay Set.

This equipment is mounted on a 32-way relay set base and carries, in addition to relays, a 2-valve 1,600 c/s oscillator and a 3-valve tone detector with circuits similar to those used in the routiner.

At small exchanges provision is made for up to three of these relay sets to be fitted on a special shelf, mounted on a relay set rack or M.A.R., the shelf also carrying a 6V constant-voltage transformer working off A.C. mains, to supply the valve heaters. In exceptional circumstances if no A.C. supply is available, an additional relay set carrying a number of barretters can be fitted on the shelf to supply the heaters from the exchange 50V supply. At larger centres shelves with a capacity of up to 10 relay sets are provided, and a larger transformer, fitted between shelves, is used to supply the heaters of one shelf. Thus for each pair of shelves, two transformers are mounted side-by-side, one supplying the upper and one the lower shelf.

The relay sets are connected to outlets from a selector level allocated for testing purposes, and when the routiner sends out the appropriate routing digits over the trunk or junction, it seizes the first free-answering relay set on the level. This relay set then carries out a self-check sequence as previously described for the routiner test circuit. With self-check completed, the relay set returns reversed C.B. conditions to line, giving C.S.A. conditions to the routiner. The routiner then sends a pulse of 1,600 c/s tone via the predetermined attenuator to line, and this tone is further attenuated by the trunk or junction, before being received by the answering relay set. The tone detector in the answering relay set checks that the level of received tone is not lower than -13 db. ± 1 db. If the level of tone received is satisfactory, the answering relay set returns a pulse of 1,600 c/s tone at zero level to line, followed automatically by clearing conditions. The routinerthen releases the answering relay set, which restores to normal.

An unusual feature provided in this relay set is the ability to automatically "busy" itself when failure of the self-check sequence occurs. An alarm delay circuit is started on seizure of the relay set, and failure to return C.S.A. conditions within the delay period results in the operation of a "detector fail" relay. This relay provides a busying earth for the P-wire when the relay set is released, and also gives delayed alarm conditions together with rack and relay set supervisory lamp signals.

As previously stated, the routiner resets itself under non-receipt of C.S.A. conditions, hence the repeated call over the same circuit should seize the next free-answering equipment. This facility prevents a succession of C.S.A. failure dockets being printed by the routiner on one route, due to the failure of an answering relay set on that route.

CONCLUSION

The routiner described in this article was developed in conjunction with Standard Telephones & Cables Ltd. under B.T.T.D.C. procedure.

Only limited experience in the application of the routiner has been obtained so far, but it seems probable that systematic testing, coupled with automatic recording of faults, will draw attention to irregular conditions of an intermittent nature on trunk circuits, which might otherwise escape detection for an appreciable period. Investigation of such faults followed by an overhaul of the circuit concerned, has already produced gratifying results.

The author is indebted to colleagues for their assistance in the preparation of this article.

Automatic Sub-Centres for the New Telex Service

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U.D.C. 621.394.65: 621.394.34

A manually switched Telex service operating over telegraph channels was opened recently, providing service for some 2,000 subscribers, most of whom are connected by direct lines to the appropriate switchboard. For groups of subscribers remote from the nearest manual switching centre it is economical to provide local automatic sub-centres connecting the subscribers to the manual switchboard over a common group of junctions. This article describes the general features of an automatic Telex sub-centre and outlines the circuit elements and their operation.

Introduction

ONE of the problems which had to be considered in the planning of the new manually switched Telex service, which was opened on 15th November, 1954, using exclusively telegraph channels for intercommunication, was that of providing an economic service to groups of subscribers remote from the nearest Telex Centre.

In a wholly manual system, two alternatives are available: either the provision of a small switchboard in the vicinity of the subscribers, or the use of long lines to connect the subscribers to a distant large switchboard. Both of these alternatives are costly and for this reason automatic sub-centres have been developed, so that a group of subscribers can share a common group of telegraph junctions to the nearest Telex manual switchboard.

The scope of application of the automatic sub-centres can be seen from Fig. 1 which shows the U.K. Telex network at Spring, 1955. The six zone centres and the larger provincial centres are equipped with manual switchboards. The diagram shows the disposition of the automatic sub-centres, including those scheduled for installation in the 1955 programme. The approximate number of subscribers connected to the U.K. network (Spring, 1955) is 2,000, of which 200 are served by automatic sub-centres.

The sub-centres, although requiring the use of automatic switching techniques, have been designed with the specific object of providing an economic service to groups of outlying subscribers in an otherwise manually switched service. Full automatisation of the Telex service is a further development which it is intended should be introduced once the service has become well established on a manually switched basis.

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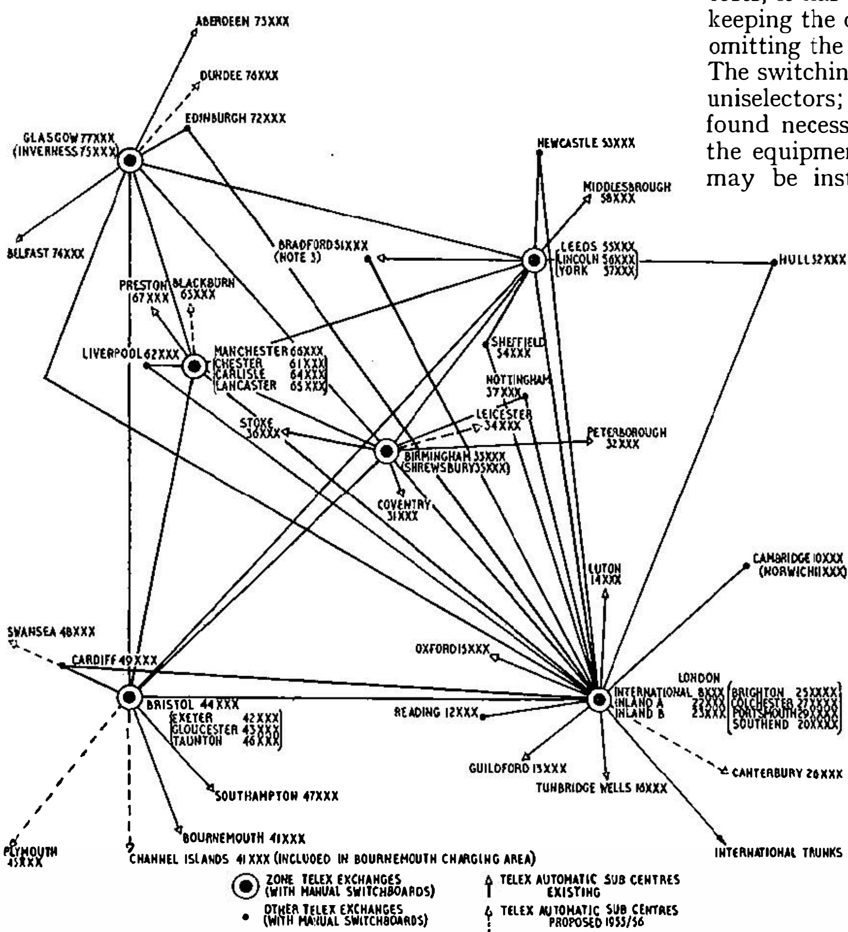


Notes, 1. The Subscribers' Numbering Ranges are shown thus:—Dundee 76xxx.
2. Where a Switchroom serves more than one charging area the additional charging areas are shown in brackets
3. For staffing reasons, service at Bradford is provided by a manual switchboard during day-time and by an automatic sub-centre at night.

FIG. 1.—THE U.K. TELEX NETWORK AT SPRING, 1955.

General Features

To avoid nullifying the savings in line and operating costs, it has been necessary to minimise switching costs by keeping the design as simple as possible without, of course, omitting the safeguards necessary to ensure reliable service. The switching circuits employ only relays and P.O. Type 2 uniselectors; the use of two-motion selectors has not been found necessary, thereby simplifying the maintenance of the equipment—an important point, since the sub-centres may be installed in such accommodation as M.C.V.F. terminals where the staff are not normally required to maintain automatic switching equipment.

Capacity.

Each sub-centre unit is accommodated on a single 4 ft. 6 in. rack 8 ft. 6 in. high and has a maximum capacity of 20 subscribers' lines and 10 junctions. The relay sets are of the jacked-in type so that economic provision can be made for small installations. A sub-centre unit is shown in Fig. 2.

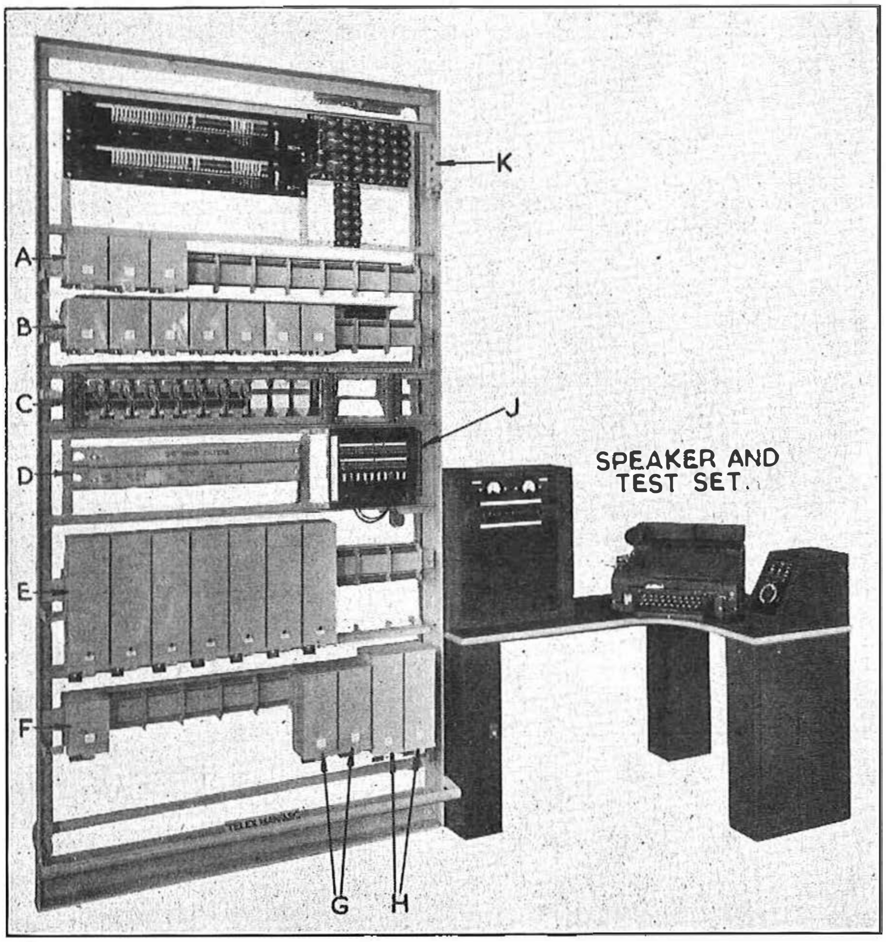
Where the requirements for a particular centre exceed 20 subscribers or 10 junctions, additional units are fitted, the junction group connected to one unit serving only those subscribers connected to that unit.

Trunking.

A block schematic diagram of the sub-centre is shown in Fig. 3.

For outgoing calls, the junction uniselector acts as a linefinder to connect the line to the junction. The junctions are worked as a full availability group, the allotter allotting junctions in cyclic order. Facilities are provided whereby the allotter steps past faulty junctions. The junctions are provided to give a grade of service of 0·02 (1 lost call in 50).

B



A, B—Station Line Circuit Relay Sets. C—Linefinder/Selectors. D—Signal Generator Filters. E—Junction Relay Sets. F—Test Number Relay Sets. G—Allotter Relay Sets (Main and Standby). H—Signal Generator Relay Sets (Main and Standby). J—Test Jack Field. K—Resistor Bulbs.

FIG. 2.—A TYPICAL AUTOMATIC SUB-CENTRE INSTALLATION.

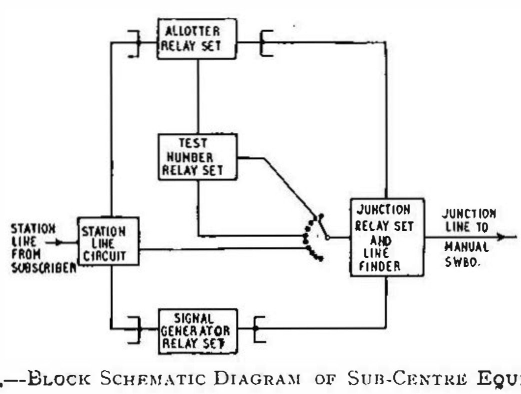


FIG. 3.—BLOCK SCHEMATIC DIAGRAM OF SUB-CENTRE EQUIPMENT.

For incoming calls, a 2-digit numbering scheme in the range 21–20 and 31–30 is used so that the operator can position the wipers on the bank contacts corresponding to the required subscriber's line, by dialling from the switchboard.

The subscribers' lines are allocated to the uniselector bank contacts as follows:—

Contacts 4–13, to subscribers 31–30.
Contacts 15–24, to subscribers 21–20.
Contacts 1 and 14, to test numbers.
Contacts 0, 2 and 3 are spare.

One minor disadvantage of the switching arrangements adopted is that it is necessary to "trombone" local calls between two subscribers served by the same sub-centre, i.e. such a call requires the use of two junctions. This may appear wasteful in the use of line plant, but the volume of such traffic is expected to be very small and insufficient to justify the inclusion of facilities for directly switching local traffic. It is interesting to note that most foreign administrations operating similar services use the "trombone" trunking technique to facilitate the design of small automatic exchanges, because the general experience is that the service is used primarily for long-distance traffic.

A test number relay set is provided so that the switchboard operator can periodically check, by dialling, whether any fault exists which requires engineering attention.

Service Signals.

Simple service signals are provided to give an indication of "engaged" or "number unobtainable," and "out of service" conditions. These signals consist of the LTRS character repeated at ½-sec. and 1½-secs. intervals respectively, and are recognised aurally by the operators since LTRS is a non-printing character. The receipt of the LTRS character causes the receiving cam to make one revolution and the rhythmic sounds produced by repeating the character at the given intervals are readily recognised.

Power Supplies.

To facilitate installation and to assist the circuit design, the equipment is arranged to work from a ±80V telegraph power supply. Although this has required the introduction of uniselectors with coils wound to operate directly from 80V, the increased voltage available, compared with the 50V supply normally used for switching circuits, has facilitated the design of individual circuit elements. In addition, full advantage has been taken of the two polarities available in the design of circuit elements involving discrimination. The ±80V power supply will be drawn from batteries, except for those small installations for which the junction group is routed via a mains operated M.C.V.F. system. Where there is no battery reserve for the M.C.V.F. system it has been decided that the sub-centre equipment will also be supplied direct from a Rectifier 55A, without battery reserve.

Engineering Testing and Maintenance.

The lines and junctions connected to the equipment are routed via a jack panel on the sub-centre rack, to enable engineering access to be gained. For line testing, a Speaker and Test Set will normally be provided. This test set also provides facilities for functional testing of the sub-centre, and the development of special routine testers has not been considered necessary. Spare allotter and signal generator relay sets are available to ensure quick replacements for faulty common equipment.

Numbering Plan for Subscribers.

The numbering plan adopted for the new Telex service is based on the use of numerical routing codes instead of exchange names. This arrangement has been adopted in an attempt to minimise number changes on ultimate automatisation.

The application of this principle results in subscribers served via sub-centres being allotted 5-digit numbers; the first two digits identify the charging area, the third digit identifies the sub-centre unit and the fourth and fifth digits identify the subscriber in the sub-centre multiple.

Signalling System

The system of line signals used is the same as that employed for the manual switchboards and conforms with C.C.I.T. recommendations, i.e. the free-line condition is indicated by positive (start) polarity in both directions, the calling signal is the inversion to negative (stop) in the forward direction; the call connected or answered signal is the inversion to negative polarity in the backward direction, and the clearing signal is positive polarity maintained for at least 300 mS. As an indication that dialling may proceed, a calling signal from the switchboard is acknowledged by a 25 mS pulse of negative polarity returned from the sub-centre. Similarly, to prove the continuity of the junction, on outgoing calls the receipt of the calling signal by the switchboard is acknowledged by the return of a 25 mS pulse of negative polarity towards the sub-centre equipment.

Circuit Elements

Station Line Circuit.

The teleprinter set installed at the subscriber's premises is the same whether service is given via a sub-centre or direct from a switchboard. At the sub-centre the station line is terminated on a station line circuit comprising three relays, (Fig. 4). With the line inthe free (disengaged) condition, the

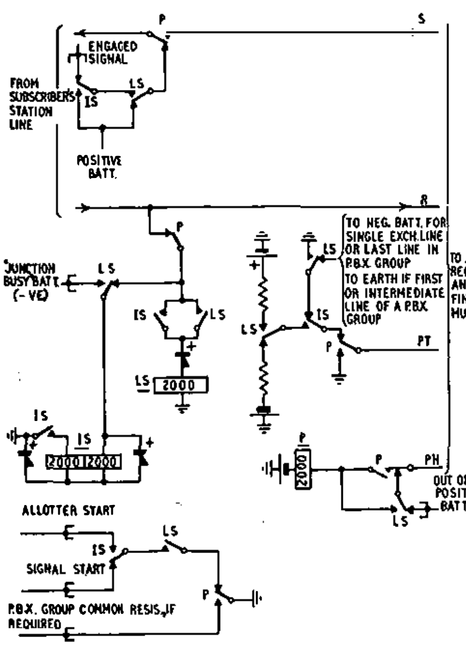


Fig. 4.—The Station Line Circuit.

positive battery from the subscriber's station operates relay IS which connects negative battery to the PT lead to mark the line free in the uniselector multiple so that it can be seized for incoming calls. When the subscriber makes an outgoing call, relay LS operates and connects a positive battery potential to the PT lead to permit seizure by a hunting uniselector acting as a linefinder. Meanwhile, relay IS remains held to the battery connected on the "junction busy" battery lead. If there is no free junction available the "junction busy" battery is disconnected by the allotter and relay IS releases to return the engaged signal to the caller.

In order that maintenance attention can be given to the teleprinter set at the subscriber's premises without risk of interference by incoming calls, an out-of-service facility is provided, in which operation of a switch at the teleprinter station causes the line to be busied to incoming traffic. Operation of the switch connects negative battery to line, causing a junction to be seized and a calling signal given at the switchboard. The call is answered by the operator who then clears, so releasing the junction. On the clear-down, relay IS cannot reoperate since the incoming signal is of negative polarity. With relay IS unoperated, conditions are applied to the PT and PH leads to cause the return of the out-of-service signal to any operator calling the subscriber. The line is restored to service by reconnecting the positive battery at the subscriber's station and so re-operating relay IS in the station line circuit. The out-of-service facility is available to engineering faultsmen only, but the same circuit elements also provide a safeguard against permanent-call faults on station lines needlessly busying junctions.

The sub-centre provides facilities for up to 5 P.B.X. groups. The circuit arrangements do not impose any restriction on the number of lines in each group within the limits of the multiple capacity. However, it is unlikely that sub-centres will be required to provide service to large P.B.X. groups since it would usually be more economical to connect subscribers having sufficient traffic to justify several lines, direct to the parent switchboard. The P.B.X. facilities do not provide for night service, but the circuit

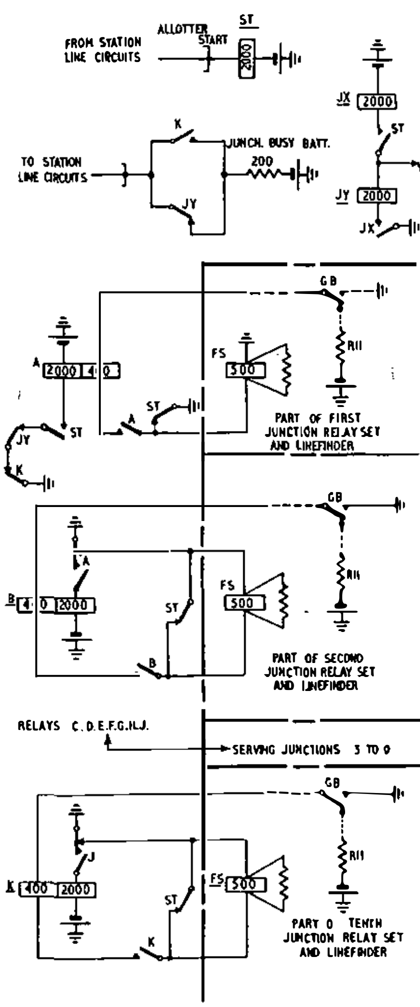


Fig. 5.—Elements of the Allotter Relay Set Circuit.

arrangements ensure that the out-of-service signal is returned to callers only when all lines in the group are out of service.

The station line circuits are jacked-in relay sets and the shelf jacks are permanently wired to the uniselector bank multiples so that an I.D.F. or its equivalent is unnecessary. Strapping to give P.B.X. facilities is effected on the shelf jacks and on tag blocks.

Allotter Circuit.

A relay allotter is used (Fig. **5**). The relay set is of jacked-in type so that for maintenance purposes a spare relay set can be rapidly brought into service. This method of ensuring continuity of service in the event of failure of the allotter is preferred to the alternative of relatively complex automatic changeover arrangements.

The allotter tests the junction relay sets to find a free junction, which is marked by a negative battery, in readiness for the next outgoing call. When a call is made, the continuity of the junction transmission path is proved by checking the return of the 25 mS pulse of negative polarity. If the junction tests faulty the allotter is automatically stepped to the next free junction, which is then tested and, if satisfactory, taken into use for the call. The allotter relay set is so arranged that when the 10th junction has been tested, the allocation cycle recommences with junction No. 1. If the number of junctions connected to the sub-centre is less than 10, straps can be inserted on the shelf jacks of the relay set, to bypass the unwanted relays in the allotter chain.

To ensure that under congestion conditions continuous cycling of the allotter is prevented and the engaged signal is returned to callers, relays JX and JY are included to count the number of "cycles" of the allotter when a call is being set up. Relay JY operates when junction No. 1 has been tested twice for one outgoing call, i.e. all junctions have been tested at least once and have been found either busy or faulty. Relay JY in operating disconnects the "junction busy" battery from the station line circuit thereby causing the return of the engaged signal and the removal of the start condition from the allotter.

Junction Relay Set.

As explained, the junction relay set includes facilities for checking the continuity of the junctions by detecting the return of the 25 mS pulse of negative polarity in response to the calling signal. If the pulse is not received within 500 mS of the initiation of the call over the junction, the junction relay set busies itself to the allotter, which steps to find another free junction. In addition to checking the line continuity, if a calling line has not been found by the uniselector within 500 mS the junction is automatically busied to the allotter, which thereupon steps on. This safeguards the sub-centre against isolation by such faults as failure of the uniselector mechanism in a junction circuit. As a further precaution to guard against such faults as failures in the lamp circuits on the switchboard (such a fault would not prevent the return of the 25 mS negative pulse), as soon as the station line is switched through to the junction, the junction relay set is busied to the allotter, which therefore steps and marks the next free junction. This ensures that the next free junction is offered for the next call.

The holding of the connection is dependent upon signals from the calling subscriber until the operator answers; subsequent holding of the connection is then dependent upon signals from the switchboard. This arrangement allows a subscriber to clear from an unanswered call but also allows the operator to release a junction from a false calling signal, or an out-of-service signal, received from a station line.

For incoming calls, as already explained, 2-digit selection is used, the subscribers being numbered in the ranges 31–30 and 21–20 and the lines arranged in two groups of ten on outlets 4–13 and 15–24 of the uniselector banks. The circuit elements concerned with the positioning of the uniselector wipers during dialling are shown in Fig. **6**.

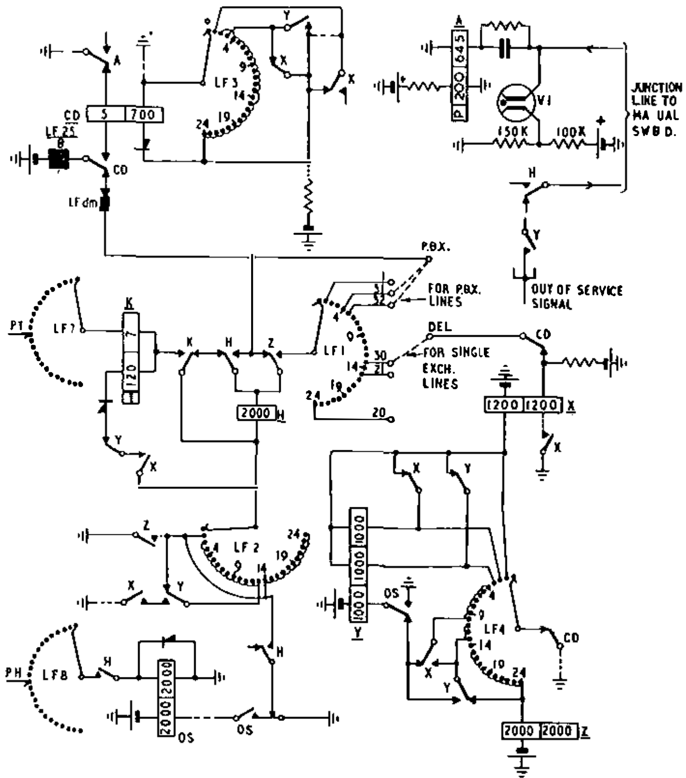


Fig. **6**.—The Junction Relay Set Circuit Elements used for Controlling the Uniselector by Dial Pulses on Incoming Calls.

When the initial digit dialled is 2, the uniselector is stepped to outlet 2 and relays X and Y operate to drive the uniselector to outlet 14 in readiness for the receipt of the next digit. On reaching outlet 14, relay Y releases. If the initial digit is 3 the wipers are stepped to outlet 3, when relay X operates in readiness for the next digit. If a spare "level" (digits "4" to "0") is dialled, relay Y operates and returns the number-unobtainable signal.

The testing element used employs a high-speed relay (suitably polarised by rectifiers) to test for positive battery when acting as a line finder, and for a negative battery when acting as a selector; the latter condition being shown in Fig. **6**.

For action as a selector, the test relay is offered to the outlet during the slow release of relay X following the second digit. A free line is indicated by the operation of relay H on the release of X. If the line is busy, relay X releases and H is unoperated; the engaged signal is returned to the caller.

For out-of-service, or spare, lines the PT lead is marked free, and the PH lead is connected to a positive battery. A calling junction uniselector switches as for a free line but in addition relay OS operates, releasing relay H and disconnecting the outlet, and the out-of-service signal is returned to the calling operator.

To provide the P.B.X. facility, an arc of the uniselector is used so that, by suitable strapping, the uniselector can self-drive over busy early-choice outlets in the group.

A point of interest is the use of a neon lamp (Lamp No. 36) as the supervisory lamp. It is connected so that it is in leak with the signals controlling the holding of the connection, and is arranged to glow when the incoming signal is of negative polarity. The current drain is insufficient to introduce any significant distortion in the line signals. Apart from the increased life expected from this type of lamp, a further advantage is that the passage of teleprinter and dial pulses are readily displayed by the flashing of the lamp.

Signal Generator Relay Set.

The signal generator relay set (Fig. 7) produces not only the two service signals but also the S and Z pulses for use by the junction relay sets to time the return of the 25 mS negative pulse.

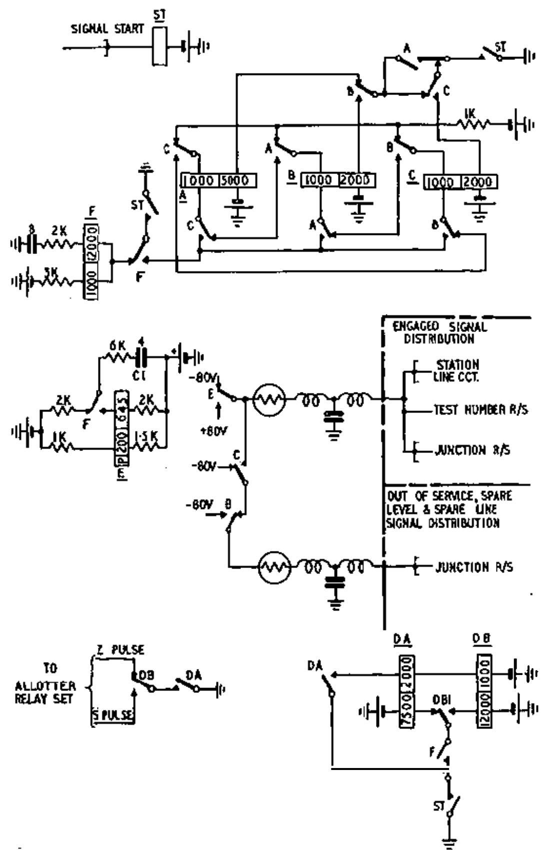


FIG. 7.—CIRCUIT ELEMENTS OF SIGNAL GENERATOR RELAY SET.

The LTRS character was chosen as the basis of the service signals because it is capable of being generated by simple relay circuits. The LTRS character comprises a start element, five marking code elements and the stop element; hence, to produce LTRS character at 500 mS intervals all that is necessary is to produce 20 mS positive pulses at 500 mS intervals. The tolerances which can be allowed in the duration of the 20 mS pulse are not onerous, especially since the signal is to be transmitted over only one telegraph link, i.e. the line distortion to be allowed for is not more than 10 per cent.

The 20 mS pulse is generated by relay E, the contact of which is pulsed whenever relay F operates to discharge capacitor C1 via the 645-ohm winding of relay E. The 200-ohm winding of relay E provides an electrical bias to oppose the action of current in the other winding. Since the two windings are energised from the same battery supply, the pulse duration is not readily influenced by supply voltage variations.

The $\frac{1}{2}$-sec. interval between characters is achieved by the self-interaction of relay F which pulses at a nominal speed of 2 p.p.s. To obtain the $1\frac{1}{2}$ secs. repetition for the out-of-service signal, the relay chain A, B and C is driven by relay F and therefore completes one cycle in $1\frac{1}{2}$ secs. This arrangement ensures that the two service signals always have a repetition interval in the ratio 3 : 1, making it unnecessary to impose close tolerances on the relays timing the intervals.

A further feature of the signal generator circuit is the inclusion of line filters in the common distribution lead, thereby avoiding the need for separate filters in each of the teleprinter lines.

Test Number Relay Set.

To provide facilities so that the switchboard operator can check whether the equipment is functioning satisfactorily, the test number relay set is provided, access being gained to it by dialling digit 1 which steps the uniselector to outlet 1. The test number relay set is arranged to act as a calling equipment connected to outlet 14 of the uniselector multiple, so that when the relay set is seized a call is originated via outlet 14 to seize another junction back to the switchboard. This enables an operator to check, by repeated calls over one junction, that calls are received in correct cyclic order over the remaining junctions. This test provides an effective check of the common equipment in the sub-centre.

ACKNOWLEDGMENTS

Acknowledgment is due to those members of the Telegraph Branch who contributed to the development of the sub-centre equipment and participated in the testing of the experimental model in the Telegraph Branch Development Laboratory. In addition, the helpful co-operation of Standard Telephones & Cables Ltd., who manufactured the initial units, is also acknowledged.

Book Review

"Radio and Television Engineers' Reference Book." Ed. E. Molloy and W. E. Pannett; 36 specialist contributors. George Newnes, Ltd. 1,600 pp. 1,860 diagrams and tables. 70s.

Radio, in both its sound and television aspects, is a vast and rapidly expanding field of engineering and scientific activity, only a fraction of which is likely to be familiar to any one individual. On the other hand, many engineers and scientists engaged in one part of this broad field frequently find it necessary to acquire information relating to other parts of the field; such information is sometimes needed quickly and at times when access to a well-stocked technical library is not possible. The "Radio and Television Engineers' Reference Book" goes a long way to meeting this need; furthermore, it is a useful intermediary between the technical periodical and the specialist text-book. It provides, within a well-organised framework, a series of summaries of current practice and techniques in the various aspects of the radio art.

The summaries include references to published technical literature, many references being as recent as 1953 and 1954; references are also made to the findings and recommendations of the international radio conferences, such as those of the C.C.I.R. (International Radio Consultative Committee).

The general scope of the book can be judged from the following short list of subjects covered:—

Sound and television broadcasting (transmitters, receivers, aerials, power plant, installation, servicing, maintenance).

HF, VHF, UHF and SHF point-to-point radio-relay systems.

Radio navigation and radar.

(*Continued on p. 25*).

Light, Colour and Colour Television

F. J. M. LAVER, B.Sc., M.I.E.E.†

Part 2.—Human Vision and Colour Television

U.D.C. 621.397.5:535.733

In the second and concluding part of the article the geometrical method of representing colour is first explained, and an account then follows of the characteristics of human vision, e.g., acuity and colour judgment, that influence the design of colour-television systems. The article concludes with a brief description of the particular aspects of colour-television transmission that depend upon the colorimetric principles previously stated.

The Geometrical Representation of Colour

The three quantities needed to specify a colour completely can be regarded as the co-ordinates of a point in a "colour space." Fig. **3** shows three orthogonal axes corresponding to the three primaries. The co-ordinates of the point representing a colour C are its

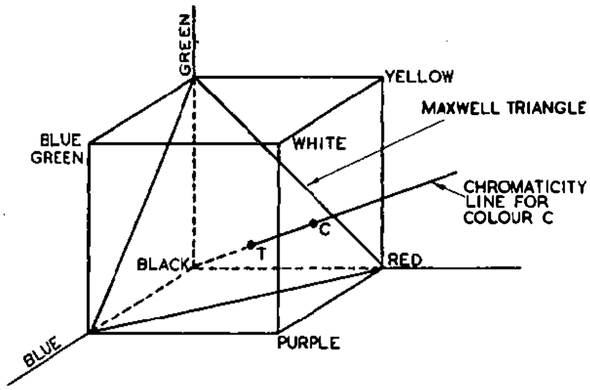


Fig. **3**.—Three-Dimensional Representation of Three-Colour Mixture.

tristimulus values in trichromatic units. Reference white is the point (**1**, **1**, **1**). Changing the luminance only of a given colour moves the corresponding point along a line through the origin: the direction of this line, therefore, represents the chromaticity of the colour. One way of specifying the direction of the line is to state the point at which it intersects some plane of reference, and a convenient plane to choose is that which passes through the three points (**1**, 0, 0), (0, **1**, 0) and (0, 0, **1**) corresponding to the primary colours. These points are the corners of a triangle known, after its originator, as a "Maxwell triangle" (see Fig. **3**). The point of intersection (T) of the chromaticity line and the reference plane can be specified in terms of co-ordinates measured from the corners of the triangle, which correspond to the chromaticity co-ordinates discussed in the first part of this article.* There is, however, no advantage in plotting all three co-ordinates as in the Maxwell triangle; two co-ordinates are sufficient to fix a point, and when two of the chromaticity co-ordinates are given the third is determined, for their sum is unity. It is more convenient to plot two only of the chromaticity co-ordinates on rectangular axes. The resulting "chromaticity diagram," is a projection of the Maxwell triangle on one of the co-ordinate planes of the three-dimensional representation (Fig. **3**). A red-green chromaticity diagram for the spectrum colours is shown in Fig. **4**.

On the chromaticity diagram the colour produced by an additive mixture of two other colours corresponds to a point on the line joining the points corresponding to the component colours. Its position on this line depends on the relative strengths of the two components, and coincides with the position of the centre of gravity of a pair of masses having magnitudes that are proportional to the sums of the tristimulus values of the corresponding colour. Similarly,

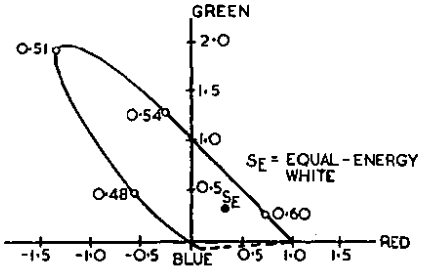


Fig. **4**.—Red-Green Chromaticity Diagram for C.I.E. Spectral Primaries.

the point corresponding to a mixture of three colours, e.g., to a mixture of the three primaries, can fall anywhere within the triangle formed by lines joining the points corresponding to the three components. Colours corresponding to points outside this triangle could be produced only by negative luminance values of one or more of the primaries, and so cannot be physically produced using those particular primaries. The use of negative values in colour specification can be avoided by choosing three hypothetical primary colours forming a triangle that includes all the spectrum colours. The C.I.E. spectrum primaries do not achieve this (see Fig. **4**), and no other realizable primaries can do so. Three hypothetical primaries, designated X, Y and Z, have, therefore, been defined by the C.I.E.; these cannot be produced by physical lights, but chromaticity co-ordinates in terms of X, Y and Z can be derived algebraically from those measured in terms of physical primaries. Although they are non-physical, X, Y and Z can be regarded as super-saturated colours, when X corresponds to super-green, Y to super-red and Z to super-blue. X, Y and Z were carefully chosen to meet three requirements namely that:—

(*a*) The spectrum locus should lie wholly within the triangle XYZ, to avoid the use of negative coefficients.

(*b*) The line XY should largely coincide with the linear portion of the spectrum locus between red and green, so that a useful range of colours would have zero Z coefficients.

(*c*) X and Z should have zero luminosity, so that the luminance of a source specified in terms of X, Y and Z components is given simply by the luminance of the Y component. (No physically possible coloured lights can have zero luminosity of course, but in any system up to two out of three non-physical primaries can be so chosen.)

Fig. **5** is an x-y chromaticity diagram showing the locus of spectrum colours, and also the colour triangle for the primaries R_T, G_T, B_T used in the American colour-television system. This x-y type of diagram is the one commonly used for discussions of colour reproduction. The spectrum locus is everywhere straight or convex, nowhere concave: it follows that the point corresponding to the colour produced by a mixture of spectrum colours must always lie inside the spectrum locus, i.e. no spectrum colour can be produced by mixing other spectrum colours, and no set of spectrum primaries can be chosen which can reproduce all possible colours.

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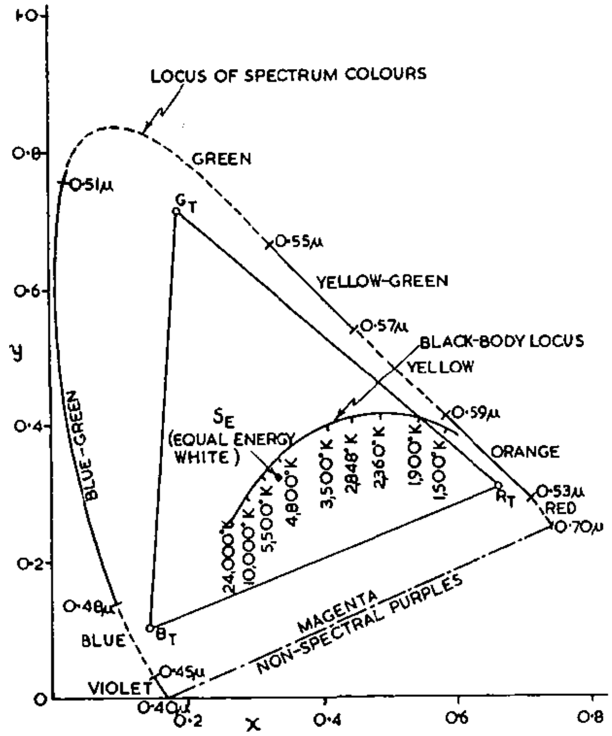

FIG. 5.—x-y CHROMATICITY DIAGRAM SHOWING AMERICAN COLOUR-TELEVISION PRIMARIES R_T, G_T, B_T.

COLOUR TELEVISION AND HUMAN VISION

Certain characteristics of human vision of particular importance to the operation of television systems, both achromatic and coloured, are briefly noted below.

Objects are very largely discerned by the pattern of contrasting luminances which they present to the eye. The smallest increment of luminance that the human eye can detect is known as Fechner's Fraction; it depends to some extent on the absolute luminance as shown in Table 2, below.[5]

TABLE 2

Luminance in Ft. Lamberts	0·001	0·01	0·1	1	10	30
Fechner's Fraction %	6	3·2	1·5	1	0·8	0·8

Visual acuity measures the ability of the eye to see fine detail in terms of the angle subtended at the observer's eye by the smallest distinguishable detail. For black-and-white objects in a good light (40 to 50 ft. lamberts) the average acuity has been found to vary between about 0·4′ and 0·7′ arc for different kinds of test pattern, and a value of 0·5′ arc was obtained in defocusing tests using a picture. Visual acuity increases as the illumination level is increased; but reaches a maximum at some high value of luminance, which depends on the surrounding luminance, and thereafter decreases. It increases as the contrast between the object and its background is increased, and decreases as the time for which the object is displayed is decreased. Tests have indicated that visual acuity improves with increasing viewing distance.[7] This suggests that when large television screens are viewed at the same relative distances as small ones, i.e. at the same multiple of the picture height, the pictures on the large screens will appear to have less definition.

Experiments have also been made to determine the visual acuities that apply for coloured objects displayed against black and against coloured backgrounds. In one set of tests it was found that for luminances between about 1 and 10 ft. lamberts all combinations of red, green and white for detail and background are equally visible. When the background is blue the influence of changes in illumination on acuity is only slightly different from that with other backgrounds. Acuity to blue detail, however, depends largely upon the luminance of the background. Thus, bright blue detail seen against dimly lit background has to be about 50 per cent. larger than details in other colours to be equally visible at equal luminances. At higher values of background luminance however, the difference between details in blue and in other colours becomes very small, and if anything the blue details become slightly the easier to see. It was concluded that in the range of luminances probable on television screens there is unlikely to be any significant difference between the visibility of blue and of other coloured details. Reduced acuity for bright blue detail has been reported by a number of workers.[7,8] In a series of optical tests[9] a colour picture was reproduced by superposing the images from three projectors separately handling the red, green and blue components. The projectors could be independently defocused, and the "acuity for defocus" was measured for each colour. It was found that the acuity for defocus was about the same for the green component as for the whole picture, but about three times poorer for the red component and five times poorer for the blue component. However, when each colour component was viewed separately and at the same luminance there was little difference between the three components.

The preceding paragraph outlines work on the visibility of fine-coloured details. There is a separate problem which considers the degree to which fine detail is seen *as* coloured. Thus, it has been demonstrated that as coloured objects are progressively reduced in size first blue objects and then yellow ones appear to become grey. At this stage red and cyan (blue-green) objects can still be distinguished, and the colours of all objects can be matched by mixtures of only two primary colours, namely, an orange-red and cyan. The chromaticity diagram has, in fact, degenerated from a triangle to a line joining orange-red to cyan. Further reductions in size cause first red and finally cyan objects to appear grey; so that for objects of this size vision is completely achromatic, and the chromaticity diagram has become a single point. These limitations of human vision have been exploited in the American system of colour television by providing only a relatively narrow bandwidth (0·4 Mc/s) for three-colour reproduction using red, green and blue primaries, with a somewhat larger bandwidth (1·3 Mc/s) for two-colour reproduction using orange and cyan primaries, and by making the full bandwidth (4·25 Mc/s) available for black-and-white reproduction only.

The perception of flicker in a television picture is affected by the size of the picture, its luminance, the field frequency, the light/dark ratio and by the colour of the picture and of its surround. Increasing the size of the picture or decreasing its field frequency both increase the perception of flicker. The frequency at which flicker disappears is known as the critical fusion frequency, and is approximately proportional to the logarithm of the luminance over a wide range—the Ferry-Porter law. The light/dark ratio has little effect compared with that of the peak luminance, but clearly the nearer this ratio is to unity the less visible the flicker, which illustrates the value of using phosphors with relatively long decay times. The phosphors currently available allow luminances up to 50 ft. lamberts to be used in a 50-field/sec. television system without excessive flicker. Chromaticity changes alone produce little flicker; thus when two sources of different chromaticity but equal luminance are viewed alternately, flicker does not become apparent until the alternation rate falls below about 4 c/s. In sequential systems of colour television, red, green and blue picture elements are reproduced successively and flicker is mainly produced by the very low luminance of the blue elements relative to the other two.

Choice of Primary Colours for a Colour-Television System

The chromaticities that can be produced by a set of primaries lie within the corresponding colour triangle on the chromaticity diagram. The larger the triangle the greater the range of colours that can be produced. This consideration taken alone suggests the use of pure spectrum primaries, but pure primaries can be produced by existing cathode-ray tube phosphors only by filtering and consequent loss of light. The efficient use of phosphors therefore involves the use of desaturated primaries. Moreover, differences between different observers' judgment of colours can be reduced by making the colour triangle formed by the primaries no larger than is necessary to include the range of colours to be matched, for then the spectra of the original and the reproduced colour are more closely matched.

The chromaticity diagram given in Fig. **5** shows that the colour triangle R_T, G_T, B_T for the American colour-television system's primaries omits a large part of the area included by the spectrum locus. However, the C.I.E. system of colour specification was devised solely for convenience in colorimetric calculations, not for expressing colour judgments, and it turns out that the distribution of distinguishable colours over the *x-y* chromaticity diagram is far from uniform. This is illustrated in Fig. **5** by the varying lengths along the spectrum locus that correspond to the adjacent hue labels. The distances separating points on the diagram which correspond to just distinguishable chromaticities is greatest in the region of $0{\cdot}52\mu$ wavelength and least near wavelengths of $0{\cdot}40\mu$, the ratio between the greatest and smallest distances being about 20/1. Even so, only about one half[3] of all distinguishable chromaticities can be reproduced by mixtures of the American primaries. All hues and all luminances can be synthesized but not all saturations. The deficiencies are greatest in the directions of the saturated green-blues and magentas and among the colours that cannot be reproduced are the pure spectrum colours, some filtered lights, e.g., stained glass windows, and some phosphorescent and fluorescent colours. However, except for a limited range of blue-greens all the colours on the cards of the American "Textile Colour Card Association," and all American printing inks are included.

There are reasons for supposing that deficiencies of reproduction in the saturated green and blue region are not likely to be serious in the operation of a colour-television system. Thus, the fact that the spectrum locus approximates to a straight line between red and green indicates that the colours produced by mixtures of any, or all, of the spectrum colours in this range will be very little less saturated than the monochromatic yellows. Moreover, this range includes those radiations to which the eye is most sensitive (see Fig. **1**, Part **1***), and so red, orange and yellow surfaces of considerable luminance and saturation are common. On the other hand the spectrum locus is very curved in the region between green and cyan and this implies that highly saturated blue-greens can only be produced by radiations confined to a narrow range of wavelengths, which restricts the luminance of saturated blue-green surfaces. Moreover the absorption curves of blue-green pigments and dyes are not, in fact, highly selective and highly saturated green and blue-green surfaces are rare. Similar considerations apply to the blue region of the locus. Furthermore, the eye is very insensitive to blue light so that saturated blue surfaces are very dark and so inconspicuous; increased lightness involves decreased saturation, and brings the corresponding chromaticities inside the R_T, G_T, B_T colour triangle. In fact, it seems unlikely that the chromaticities of any natural objects will be found to lie outside the range of the American television primaries.

* *P.O.E.E.J.*, Vol. 47, p. 222.

Individual Colour Judgments

It was noted above that individual observers differed somewhat in their appraisal of colour mixtures, and, of course, the colour-specification data used to set up a colour-television system would be related to a hypothetical average, or "standard," observer. An isolated colour-television viewer would be able to take up his personal differences in colour perception by adjusting the relative gains of the three colour-channels in his receiver. For group viewing, some compromise will be necessary but the importance of its effect on colour reproduction is not yet known.

The appraisal of colour reproduction is affected by a number of physical and psychological factors. Thus, a colour-television viewer will usually have to judge the reproduced colours against his recollection of the original, since he will rarely be able to compare reproduction and original. When a direct comparison might be made, as for some standard article, the article displayed before the camera will probably be treated to make its colour reproduction satisfactory to the average viewer. Again, the reproduced image is usually smaller than the original, and is surrounded by borders beyond which it bears no resemblance to the original scene. A viewer's colour judgment also depends on the state of adaptation of his eye: thus, a yellow patch can be made to look green by first adapting the eye to a red light. Smaller changes in colour perception are produced by changes in the ambient lighting of the viewing room,[10] e.g., from daylight to artificial light. Faithful colour reproduction would require a colour-television system to produce, for an observer whose eyes were adapted to the viewing conditions at the receiver, the same colour perception as that produced by the original scene for an observer whose eyes were adapted to the viewing conditions there. However, experience in many fields of colour reproduction shows that there is no merit in precise colour-fidelity, for the picture that pleases is not usually the most accurate[11]; and economic considerations require that a colour-television system for broadcasting should not be planned to do more than produce an image that pleases some specified proportion of its viewers.

Colour Television

The notes which follow are limited to those aspects of colour-television system design that depend upon colorimetric principles.

A colour-television camera contains three photo-electric units each with a different spectral sensitivity which produce electrical signals at the three output terminals of the camera. The three camera signals are required to be proportional to the tristimulus values of the scene in terms of the primary colours used at the receiver. To meet this requirement would involve spectral sensitivities with negative portions, i.e. wavelength regions over which the electrical signal was of reversed polarity. These negative regions correspond approximately in magnitude and location to parts of the chromaticity diagram outside the receiver's primary colour triangle but inside the spectrum locus. Negative responses cannot be directly produced from a photo-electric unit, but they can be simulated by combining the signals from the three camera units by linear addition or subtraction—a process called "matrixing" by analogy with the operation used in vector algebra to change from one co-ordinate system to another. Thus, if the camera has actual spectral sensitivities that correspond to a set of primaries (R_1) (G_1) (B_1) its direct output signals will correspond to the tristimulus values R_1, G_1, B_1 of the colour before it, and if the receiver primaries are (R_2) (G_2) (B_2) then the tristimulus values R_2, G_2, B_2 of the colour in terms of these primaries are given by:—

$$R_2 = K_1R_1 + K_2G_1 + K_3B_1$$
$$G_2 = K_4R_1 + K_5G_1 + K_6B_1$$
$$B_2 = K_7R_1 + K_8G_1 + K_9B_1$$

where K_1 to K_9 are constants that depend only upon the chromaticities of the receiver primaries and the tristimulus values of its reference white in terms of the camera primaries. The possibility of matrixing at first appears to offer complete freedom of choice of camera primaries for a given set of receiver primaries. However, although the camera output signals can be added or subtracted as required, the noise powers from the camera outputs always add, which degrades the signal-to-noise ratios of signals produced by subtraction in the matrix network.

Any departure from the correct theoretical spectral sensitivities in the camera reduces the colour fidelity of the system to an extent that depends, among other things, upon the difference between the colour of the studio lighting and the reference white chosen for the system. The colour of a lighting source is often specified in terms of the temperature of a black-body radiator having the same chromaticity, and the locus of black-body chromaticities is shown in Fig. 5. The "colour-temperatures" of some common sources are: candle flame 1,930°K, gas-filled tungsten lamp 2,800-3,000°K, carbon arc 3,800°K, the sun 5,000°K, and north-sky light 10,000-20,000°K. The light from a fluorescent lamp may not be represented by a point near the black-body locus and so its colour cannot be specified by a colour-temperature.

The three electrical signals produced by the colour-television camera represent the tristimulus values of the scene before the camera. These signals may be transmitted directly to the receivers, or they may be first transformed into an alternative set of three parameters describing the colour in the scene. Thus, the three final signals might correspond to total luminance and two chromaticity co-ordinates or, alternatively, to total luminance and two "chrominance" signals which jointly represent the chromaticity differences between the colour and reference white. Again, the three parameters could be total luminance, hue and saturation.

The three final colour signals can be sent simultaneously by using three separate carriers, i.e. by frequency-division-multiplex, or sequentially using a single carrier, i.e. by time-division-multiplex, and field-sequential, line-sequential and dot-sequential systems have all been tried. At the present time the most promising technique uses frequency division, with one signal corresponding to total luminance, and two chrominance signals.

The cathode-ray tubes used to reproduce television pictures have a power-law characteristic relating light output to control-signal voltage, the exponent of the signal voltage being commonly represented by the Greek letter γ. In monochrome systems it is usual for the signals to be "gamma corrected," i.e. raised to power $1/\gamma$, before transmission, allowance being made for the camera's own characteristic. The three signal channels of a colour-television system may well have different gamma characteristics and this will lead to colour errors. Again, in a monochrome system it is usual for somewhat less gamma correction to be applied at the transmitter than is required to restore the overall system to linearity, for this increases the effective signal-to-noise ratio and expands the highlight tones in the reproduction. In a colour system, however, undercorrection has the effects of increasing the saturation of desaturated colours and changing the hues of saturated colours; and even with exact gamma correction in each colour channel the reproduced luminances of colours similar to the system primaries are less than they should be.

A colour-television system which exploits the inability of the eye to see colour in fine details will use different bandwidths for the three components of the complete colour signal. Thus, in the American standard system the luminance signal bandwidth is 4·25 Mc/s and the two chrominance signals have bandwidths of 1·3 Mc/s and 0·4 Mc/s. The narrower the bandwidth of a channel the longer is its transmission-time delay and the slower its rate of response to a sudden transition. It is, therefore, necessary to delay the signals in the wideband channels, usually by means of lengths of low-velocity cable. However, the differing build-up times remain, and their effects will depend upon the type of signal adopted for transmitting the colour information. In the American system, for instance, when there is a sudden change in chromaticity in the scene before the camera, the point on the chromaticity diagram corresponding to the reproduced chromaticity does not move along the straight line joining the initial and final chromaticities but follows a somewhat wandering route. There are also luminance perturbations preceding and following the change, more particularly when saturated colours are involved.

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Book Review

"Radio and Television Engineers' Reference Book"—*continued from p.* 21.

Industrial television.
Sound recording and reproduction.
Amateur radio equipment.

In addition to the foregoing there are sections dealing with the basic formulae and calculations of electro-magnetic theory and electron-optics, units and symbols, tables of frequency allocations, and a section on radio measurements. Other sections deal with the materials and components used in radio systems, e.g. resistors, capacitors, inductors, transformers, microphones, loudspeakers, oscilloscopes, transmission lines, waveguides, aerials.

Instances of the up-to-date nature of the treatment can be seen from the following items selected at random: transistors, ferrite-rod aerials, Band III (174-216 Mc/s) television systems, broad-band radio-relay system design, F.M. sound broadcasting, projection television systems and colour television systems.

A reference book covering such a wide range is likely to have some errors and omissions which the specialist engineer looking at the section or sections describing his own field will no doubt readily find; this, however, is a severe test and engineers looking for help outside their specialist fields will often find this book of considerable assistance.

The book is to be commended to both practising and student engineers for the mass of up-to-date information, clearly presented in a compact and readily usable form, which it contains.

W. J. B.

Post Office Quartz Oscillators for Use in Time and Frequency Standardisation Abroad

J. S. McCLEMENTS†

U.D.C. 621.373.421.13:549.514.51

In 1953 the Post Office was asked to supply several quartz crystal oscillators to America and Canada for use as time and frequency standards. This article stresses the growing importance of such standards, and briefly describes the uses and principles of calibration of oscillator clocks at an observatory. The article concludes with a description of the installations carried out in America and Canada.

Introduction

THE last two decades have witnessed rapid expansion in the fields of electronics, radio navigational aids, radar and telecommunications, these arts having received especial impetus from the impact of the last war. Each new development has been quickly followed by demands which have required large-scale production of units, and systems. Large-scale manufacture and operation has, in the main, only been achieved by the exercise of economies in materials and time, which in their turn have required more rigid control on all permissible working tolerances. Considering the field of communications, many channels are now provided economically on either cable or radio links, by the maximum loading of the allocated band of the frequency spectrum; this has required a better knowledge and stricter control of operational frequency. Similar conditions apply in air transport and military air operations, where both time and frequency have to be accurately known. Laboratories of either government or commercial establishments, developing high-precision electronic equipment, time pulse techniques, or quartz crystals, require accurate knowledge of frequency and time, as do also the astronomical observatories in studying the movements of the solar and star systems of the galaxy.

The common factors in the above activities are time and frequency, and an ever-increasing demand arises throughout the world for high-precision reference standards of these factors. The importance attached to such standards by all the leading powers can be seen in the establishments which they have set up in various countries, operating by international agreement, to radiate standard reference frequencies and time signals. Great Britain is responsible for providing a standard frequency coverage over Western Europe and North Africa. These transmissions are radiated for the National Physical Laboratory from the Post Office Radio Station at Rugby, as are also daily time signals under the control of the Royal Greenwich Observatory. The United States of America provides standard frequency and time service transmissions from the National Bureau of Standards station at Beltsville, Maryland, with another station covering the Pacific zone situated at Maui, Territory of Hawaii; other time signals under the control of the U.S. Naval Observatory at Washington are radiated from Annapolis, Maryland, Mare Island, California, the Canal Zone and Pearl Harbour. Canada and Australia emit time signals, and standard frequency services are maintained by Italy, South Africa, Japan and Belgium. It will be evident, therefore, that the system is already extensive; it is also expanding, and much effort is constantly being applied to improve the accuracy of all signals transmitted.

The British Post Office has been concerned with the development of high-grade quartz-crystal-controlled oscillators for many years and maintains a Primary Frequency Standard at its Dollis Hill establishment. Such high-stability oscillators can be employed with equal facility as either frequency or time standards and, in the past, equipments embodying these oscillators have been supplied to the National Physical Laboratory, Teddington, and observatories of the United Kingdom and Commonwealth. The most recent orders for a number of oscillators for clock control were placed with the Post Office in 1953 by the U.S. Naval Observatory in Washington, the Dominion Observatory of Canada and the National Research Council of Canada. In order that advantage of Post Office experience could be obtained, the author was assigned the job of superintending the installation work abroad and, with the equipment, travelled to Washington in air transport provided by the U.S. Naval authorities. The Canadian authorities arranged for their equipment also to be flown across using a Royal Canadian Air Force plane. The work of installation in America and Canada required a period of five weeks, during which time five quartz oscillators were set in operation. Arrangements such as these for the overseas installation of quartz oscillators, undoubtedly a tribute to the Post Office, are something of a precedent, and as such have prompted this article.

Many Post Office engineers will be already acquainted with the use of crystal-controlled oscillators on coaxial cable and carrier systems, but the more specialised uses in observatories are less known; as two of the establishments in America and Canada are observatories, it is thought that a brief survey of their function in frequency standardisation could usefully precede a description of the overseas itinerary.

Chronometers

The duties of an observatory are many and varied, but one of their main functions is the maintenance of a time service. Prior to the introduction of quartz clocks, the passage of time was marked at the observatory by pendulum clocks; in these, the swing of the pendulum may have had a period of half, one, or two seconds, corresponding respectively to frequencies of two, one, or a half, oscillations per second. The periods marked by these oscillations were integrated via the clock escapements to indicate periods of minutes and hours, on dials. In the quartz clock the slow beat of the pendulum has been replaced by an oscillation rate of 100,000 per second produced by a vibrating quartz crystal. The periods defined by each crystal oscillation, more accurate in time than those of the pendulum, may be integrated by electronic means to measure periods of minutes and hours, as in the case of the pendulum clock. Fig. 1 shows in block schematic form the way this can be

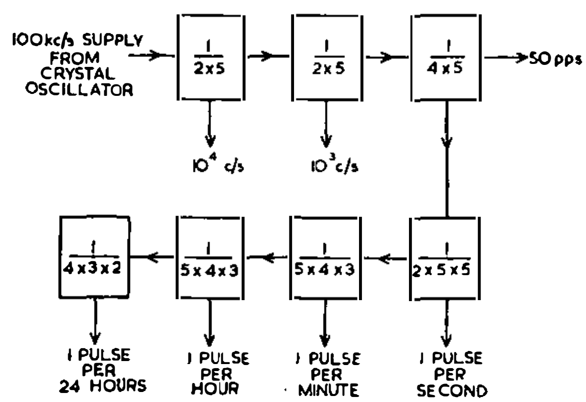

FIG. 1.—BLOCK SCHEMATIC DIAGRAM SHOWING PRODUCTION OF TIME PULSES BY ELECTRONIC FREQUENCY DIVISION.

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achieved using a chain of electronic dividers driven by the 100 kc/s crystal. Division down to 50 c/s would probably be effected by multivibrator-type dividers, from which frequency it is simple to continue down to seconds, minutes and even days by counter-type dividers, probably employing cold cathode gas triode valves. Some establishments may use the 1,000 c/s supply to control a phonic motor clock from which second and minute pulses are obtained from cam-operated contacts. The accuracy of this arrangement is, however, inferior to the electronic chain.

Time and Frequency Standardisation

In checking the frequency of an oscillator in cycles per second or the time-keeping properties of a quartz clock, reference has to be made to the fundamental unit of time, and for this information recourse is made to data issued by one of the astronomical observatories already referred to. In Great Britain the Royal Greenwich Observatory is responsible for the determination of standard time and the emission of time signals.

The basis of time measurement at an observatory is, in general, the period of rotation of the Earth, and although this period is now known to vary cyclically throughout the year, no error in principle will be involved if for the purpose of this description the Earth's rotational period is considered to be uniform. Consider an observer on the equator noting the position of the sun overhead and at the same time starting some type of chronometer; if he now waits until the sun appears again in the same position overhead and then notes his chronometer reading, the time difference so observed corresponds roughly to 24 hours. In practice, instrumental measurements are effected which eliminate the human and positional errors which would be present in the rough observation described. For instance the sun is not used as the marker in space, because the disc subtends a comparatively large arc at the observational point and hence does not provide a precise point reference; also, because of the sun's closeness to the Earth when considered on an astronomical basis, the daily progress of the Earth in its orbit round the sun means that the Earth would rotate through an angle of more than 360° during the period between observations. To counter these sources of inaccuracy, the measurements are effected against certain selected stars, which are so distant that they provide a point source of light for reference, and do not show any apparent shift in space when viewed from either end of the Earth's orbit. The time so determined is known as sidereal time, and requires modification by a constant factor if solar, or sun, time is to be expressed.

For many years past these stellar observations have been effected using what is known as a "transit telescope." This telescope can swing only in the plane of the meridian. It is the duty of the observer to ensure that for any particular star the instrument is set to catch the star image in its field, and during transit (i.e., the apparent passage of the star across the field), to hold the image bisected by an adjustable reference line. While the transit adjustment is in progress electrical circuits associated with the telescope transmit a series of pulses which are recorded on a tape chronograph; simultaneously, a series of pulses marking minutes and seconds from the local quartz clock of the observatory are impressed on the tape. The time relationship between the local clock and the mean time of transit of the star can now be determined. At the end of another sidereal day a similar relationship can be established for the same star if observational conditions are suitable, and the new comparison will show whether the local clock has gained or lost in time in terms of the Earth's period of rotation, and hence whether the driving crystal frequency is above or below its nominal value. Such measurements are carried out over periods of years, thus enabling the long-term time-keeping properties of the clocks to be established. Because of the relatively large scatter of the transit measurements during any one night, some considerable time must elapse before the trend of clock performance is determined. Once this is established the time service is maintained by extrapolation of the clock performance (confirmed by the use of several clocks), and only small adjustments are made from time to time which tend to steer the clock time in accordance with the trend of astronomical observations. These measurements are the limiting factor on the absolute determination of time, and hence frequency, which at present is of the order of one part in one hundred million (i.e., approximately one millisecond per day). The Royal Greenwich Observatory is bringing into use a new stellar observing device known as a "Photographic Zenith Tube" (PZT); this employs a mercury pool by which the light from the star under observation is reflected on to a photographic plate, thus eliminating setting errors and operators' personal errors. Several images of the star are impressed on the plate, each of which can be fixed in time in terms of the local clocks, and hence an accurate time of the mean transit across the meridian determined. The method should improve accuracy of time determination by one order of 10.

In practice, the determination of time at an observatory is not so simple as described. The work is very exacting and requires much intricate mathematical computation because of the many variable factors involved. Mention has already been made of the variations in rate of the Earth's daily rotation; by modern quartz clock standards these variations are too large to be ignored and the astronomers are adopting a new time system called "Ephemeris Time" which is based on the rotation of the Earth round the Sun. This longer time base is independent of the Earth's short-term variations and hence provides a time reference which is more uniform than that obtainable from daily measurements.

Once the frequency of the crystal oscillator controlling the clock has been determined, other clocks and oscillators can be standardised by direct comparison using frequency measurements or time-pulse technique. By the use of radio transmissions of time signals or standard frequencies, the clocks and oscillators of establishments remote from the observatory can similarly be standardised. It is current practice for each observatory to measure the time signals of other observatories in terms of its own clocks; thus an international monitoring service on time is maintained. The effectiveness of each station is limited by its time and frequency measuring capabilities, and hence a continual search goes on for improved methods and equipment.

The Crystal Oscillators

The oscillators supplied by the Post Office for Observatory and Frequency Standards use Essen ring-type crystals, of nominal frequency 100 kc/s. The frequency of this type of crystal varies with temperature in accordance with a parabolic law and it is practice to mount the crystal in a thermostatically controlled oven, the temperature of which coincides with the apex temperature of the crystal (i.e., the frequency of the crystal rises to a maximum as temperature is increased and then falls again for further increases in temperature; the point of maximum frequency is known as the "apex" or "turn-over" temperature). Controlling the crystal at this temperature, where the frequency/temperature coefficient is effectively zero, ensures that the oscillator frequency is not affected by changes in ambient temperature. The crystal has a high "Q" value, $\omega L/R$, usually in the region of one and a half to two million, which endows the oscillatory circuit with a large phase/frequency coefficient. This means that only a small frequency change is required to compensate any circuit phase changes; these usually arise from power supply and temperature variations and are kept to a minimum by choice of components. The combined result of the above is an oscillator which is practically independent of changes in temperature and power supplies.

A view of the oscillator with cover removed is shown in Fig. 2. The oven which houses the ring-type quartz crystal is in the centre of the panel, to the left of which is the unit controlling the temperature of the oven. On the right is an amplifier unit which maintains crystal oscillation.

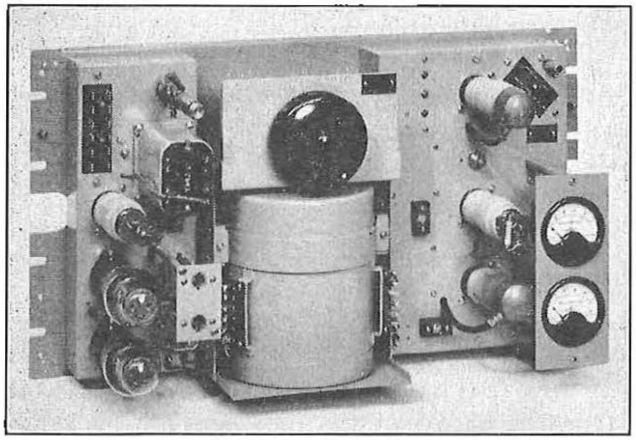

FIG. 2.—THE OSCILLATOR WITH COVER REMOVED.

Continuity of power supply is essential for the satisfactory long-term operation of the oscillators as clocks, and some form of stand-by supply to cover mains failure is always necessary. In preparing the oscillators for overseas installation, as much of the circuit testing and alignment as possible was carried out in the laboratory at Dollis Hill, thus leaving the minimum amount of testing at the final location.

INSTALLATION WORK IN AMERICA AND CANADA

American Installation.

The first oscillator was installed at the U.S. Naval Observatory in Washington, transport having been provided on a plane of the Fleet Logistic Air Wing (U.S. Navy). Over the Atlantic the average cruising speed was 330 m.p.h. at a height of 20,000 ft., conditions being very steady, so that no undue precautions were required in stowing the crystals. Two crystals were carried, and in accordance with Post Office practice, the crystal units were housed in ballasted carrying cases as a protection against vibration and shock; these cases contained battery-operated test oscillators which enabled the activity (i.e., quality) of the crystals to be determined at any time. The journey continued by road from the Navy Air Base to Washington, a distance of about 70 miles.

The Naval Observatory buildings are extensive, laboratories, observing domes and workshops ringing the main building which houses the time department. The observing equipment consists of two Photographic Zenith Tubes, arranged to photograph the same star simultaneously, and affording, as a result, a high degree of accuracy.

A special room was allocated at the observatory in which the Post Office crystal oscillators were to be mounted. The room, situated on the main ground floor corridor of the building is provided with a door having a glass inspection panel, through which members of the public (who pass through the observatory in large numbers) can view the new clock-controlling oscillators. The room is arranged to house three oscillators, each of which is mounted on a large block of concrete that floats on helical springs, and so forms an effective shock-proof support. The stand-by power supply for each oscillator is provided by a small D.C./A.C. rotary converter. When the mains supply fails a relay releases and starts up the converter which is powered by batteries; at the same time the input to the oscillator power unit is switched from the mains terminals to the output of the converter, which supplies 115V A.C. (the nominal supply voltage in Washington). The H.T. supply to the oscillator is maintained during the running-up period of the converter by a large reservoir capacitor in the power unit. This method of providing stand-by power is current practice in the Post Office for Frequency Standards.

When the first oscillator had been set up its frequency was checked against existing standards at the observatory and the results showed that little change had taken place in the operating frequency of the oscillator during the journey from England. Subsequent frequency comparisons demonstrated that the Post Office oscillator had considerably higher stability (frequency/time) than those already in use at the observatory. It was intended that the remaining oscillators would be installed by the staff of the observatory, and at the time of writing, a second oscillator has been installed.

Canadian Installations.

After completion of the work at Washington, the author flew to Ottawa carrying one crystal as a spare against four projected installations in Canada. The Canadian apparatus had previously been flown to Ottawa, Ontario, in charge of a Canadian official who also took personal custody of the associated quartz crystal units.

The first installation was made at the Dominion Observatory in Ottawa where the time department of the observatory is equipped with one Photographic Zenith Tube of the same design as at Washington, and several oscillators using GT plate-type crystals. Prior to the introduction of these oscillators, timekeeping had been maintained by pendulum clocks housed in special vaults 20 ft. below ground level. The Post Office oscillator was given the honour of occupying one of these vaults, an ideal situation free from vibration and of even temperature. Stand-by power supplies for the oscillator were provided by battery-operated vibrator units of the type used on the Canadian Pacific railway cars for lighting purposes. On checking the oscillator against the local standards it was found that the frequency was within one part in 10^8 of the value measured at Dollis Hill.

The remaining three oscillators were installed in two departments of the National Research Council of Canada, an organisation with very extensive scope which ranges from research projects undertaken for industry and medicine, to military commitments. Two oscillators were set up at the Physics Division, and one at the Division of Radio and Electrical Engineering. At both divisions the installation work progressed smoothly, but at the time no final arrangements had been made for stand-by power supplies for the oscillators. The behaviour of the oscillators at the Physics Division was excellent and an effective demonstration of the frequency stability was afforded by having two oscillators of the same type together. The installation of the last oscillator at the Radio and Electrical Engineering Division concluded the work done in Ottawa, which in all had taken a little over three weeks.

ACKNOWLEDGMENTS

It is a pleasure to record particularly warm appreciation of the hospitality and kindly assistance given to the author by the staff in Washington and Ottawa. Special thanks are due to Dr. W. Markowitz of the Washington Naval Observatory, to Dr. C. S. Beals of the Dominion Observatory, and to Dr. J. T. Henderson and Mr. C. F. Pattenson of the National Research Council.

Short-Wave Directional Aerial-Systems*

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Part 2.—Further types of Aerial; Ground Effects; Impedance Matching

U.D.C. 621.396.677.4.029.58

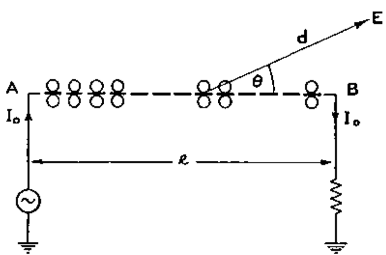
The second and concluding Part of this article explains the principles of travelling-wave aerials and mentions the design factors applicable to those of the rhombic and inverted-V types. The effect of ground surfaces on short-wave transmission is then briefly discussed. Finally, reference is made to the Multiple Steerable Unit Antenna (M.U.S.A.) used for transatlantic short-wave radio reception.

Travelling-Wave Aerials

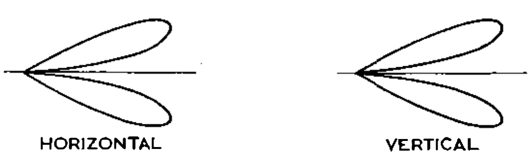
Radiation from a Long Wire.

THE types of aerials already considered are "standing-wave" or resonant aerials; in each case the radiating (or collecting) elements do not form parts of closed circuits and the operation of the aerial is based on the setting up of standing waves on the radiators. The aerials now to be discussed are "travelling-wave" aerials, in which the aerial configuration is such that a current flows through the aerial system. Such aerials consist basically of long straight wires, and are best understood by first considering the radiating properties of a single long wire.

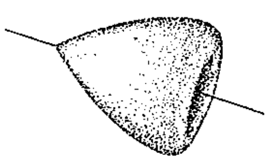
The single wire can be considered as consisting of a large number of short dipoles, where each dipole has a polar diagram as shown in Fig. **9**(*a*). Since current is flowing



(a) DERIVATION OF POLAR DIAGRAMS



(b) PLANE POLAR DIAGRAMS



(c) THREE-DIMENSIONAL POLAR DIAGRAM

Fig. 9.—Radiation due to a Long Wire.

through the wire from end A to end B it is seen that the current in each dipole lags in phase behind the preceding dipole. The wire thus acts as an end-fire array of dipoles, with the result that maximum radiation occurs in a direction not perpendicular to the line AB but at an angle inclined away from the perpendicular towards end B. Assuming the velocity of the radiated wave in space to equal the phase velocity of the current in the wire, it will be seen from the discussion in Part 1‡ that the maximum value of the "array factor" occurs in the direction AB; but since the radiation from a dipole is zero in this direction the total radiation in this direction is also zero. The radiation due to a wire of length l, expressed as the field strength E at a distance d and at an angle θ to the wire, is given by the following expression,

$$E = 60\,\frac{I_0}{d}\sin\theta\,.\,\frac{\sin\dfrac{\pi l}{\lambda}\,.\,k}{\dfrac{\pi l}{\lambda}\,.\,k}$$

where, I_0 = current in the wire, and $k = (1 - \cos\theta)$ This expression yields a polar diagram consisting of two lobes symmetrically disposed about the line of the wire, the angle the lobes make to the wire depending on the wire length; this polar diagram applies to any plane, e.g. horizontal and vertical as shown in Fig. **9**(*b*). The complete three-dimensional polar diagram thus consists of a hollow cone as shown in Fig. **9**(*c*). The angle of maximum radiation varies with the length of the wire—as the length of the wire is increased the angle decreases, but less and less rapidly. Thus, by increasing the length of the wire the angle of maximum radiation becomes less and less dependent on frequency, e.g. doubling the signal frequency for a wire two wavelengths long changes the angle by about 12°, whereas for a wire five wavelengths long the change is 4°.

The Rhombic Aerial.

Four equal long wires arranged in the form of a rhombus as shown in Fig. **10**(*a*), with feeder and terminating impedance connected as indicated, constitute a rhombic aerial.[3] The dimensions of a rhombic aerial are expressed in terms of the length of side in wavelengths and half the included angle (usually referred to as the semi-side-angle). The figure shows the individual horizontal polar diagrams of the four wires, and it can be seen that by choosing the appropriate value for the half side-angle one of each pair of lobes augments radiation in the forward direction. The value of the half side-angle is dependent on the side-length of the rhombic aerial, the relationship being similar to that already indicated for the long wire aerial. Fig. **11** illustrates the formulation of the equation for determining the horizontal polar diagram of the rhombic aerial. The long wires comprising the sides are numbered 1, 2, 3 and 4, and for convenience the length of each side is $2l$. The equation expresses the total field, in a direction making an angle θ with the forward direction, by summing the contributions of the four individual wires, and it will be seen that the expressions in brackets are in fact similar to that quoted for the long wire aerial with the appropriate values of angle inserted, i.e. $(\theta - \alpha)$ for wires 1 and 3 and $(\theta + \alpha)$ for wires

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‡ *P.O.E.E.J.*, Vol. 47, p. 214.

[3] E. Bruce, A. C. Beck, L. R. Lowry. "Horizontal Rhombic Antennas," *Proc.I.R.E.*, Vol. 23, p. 24, 1935.

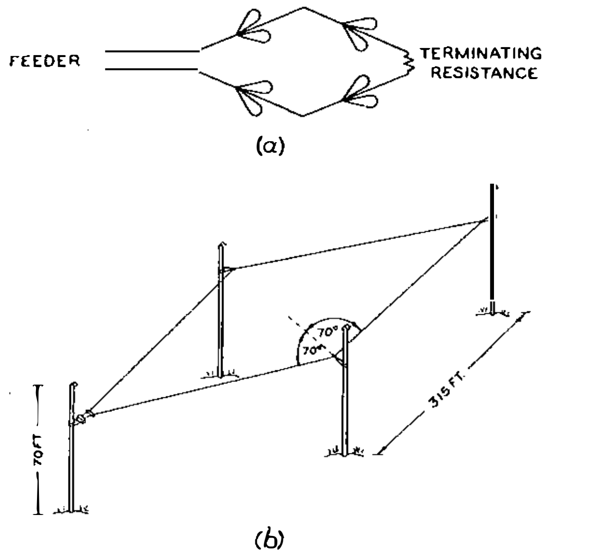
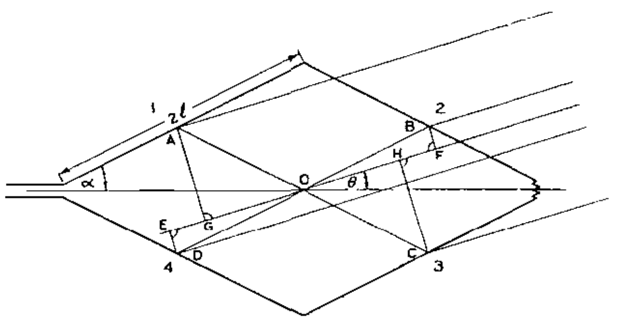


Fig. 10.—Principle of Operation and Pictorial View of Rhombic Aerial.



$$E_T \propto E\left\{\sin(\theta-\alpha)\,\frac{\sin\frac{2\pi l}{\lambda}\left[1-\cos(\theta-\alpha)\right]}{\frac{2\pi l}{\lambda}\left[1-\cos(\theta-\alpha)\right]}\right\}\angle\frac{2\pi l}{\lambda}-OG^\circ$$

$$+\,E\left\{\sin(\theta+\alpha)\,\frac{\sin\frac{2\pi l}{\lambda}\left[1-\cos(\theta+\alpha)\right]}{\frac{2\pi l}{\lambda}\left[1-\cos(\theta+\alpha)\right]}\right\}\angle-\frac{2\pi l}{\lambda}+OF^\circ$$

$$+\,E\left\{\sin(\theta-\alpha)\,\frac{\sin\frac{2\pi l}{\lambda}\left[1-\cos(\theta-\alpha)\right]}{\frac{2\pi l}{\lambda}\left[1-\cos(\theta-\alpha)\right]}\right\}\angle-\frac{2\pi l}{\lambda}+OH^\circ$$

$$+\,E\left\{\sin(\theta+\alpha)\,\frac{\sin\frac{2\pi l}{\lambda}\left[1-\cos(\theta+\alpha)\right]}{\frac{2\pi l}{\lambda}\left[1-\cos(\theta+\alpha)\right]}\right\}\angle\frac{2\pi l}{\lambda}-OE^\circ$$

$$OG^\circ = OH^\circ = \frac{2\pi l}{\lambda}\cos(\alpha+\theta) \qquad OF^\circ = OE^\circ = \frac{2\pi l}{\lambda}\cos(\alpha-\theta)$$

Fig. 11.—Rhombic Aerial Radiation Equation.

2 and 4. Allowance must be made for the phase relations between the currents in the wires, and this is most conveniently done by referring the phase of each current to the centre of the aerial—thus for wire 1 the current at point A leads $2\pi l/\lambda$ in front of 0, so that for a direction θ the phase of the field component due to wire 1 is

$$2\pi\,.\,\frac{l}{\lambda}-2\pi\,.\,\frac{OG}{\lambda}\quad\text{or, }2\pi\,.\,\frac{l}{\lambda}\left[1-\cos(\theta+\alpha)\right]$$

Similar phase relations are shown for the other wires.

It has already been shown that the angle of maximum radiation for a long wire does not vary very much with the length of the wire provided the length is not less than four or five wavelengths. Thus, the addition of the contributions of the four wires can be maintained over a range of frequencies; this is illustrated in Fig. 12, which shows the effect on the horizontal polar diagram when a rhombic aerial of side-length 6 wavelengths and semi-side-angle 70° is operated at lower frequencies corresponding to 2 and 4 wavelengths in one side-length, e.g. 100 metre side-length rhombic aerial operated at 18 Mc/s, 12 Mc/s and 6 Mc/s. A view of a typical rhombic aerial, with principal dimensions, is shown in Fig. 10(*b*). Such an aerial would have a forward gain of about 15 db. relative to a half-wave dipole over the frequency range 10 to 30 Mc/s.

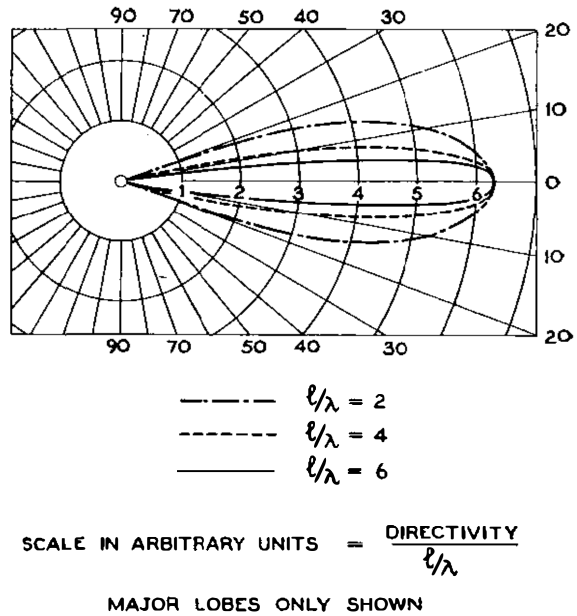


Fig. 12.—Free-space Horizontal Polar Diagrams of Rhombic Aerial (Semi-side-angle = 70°).

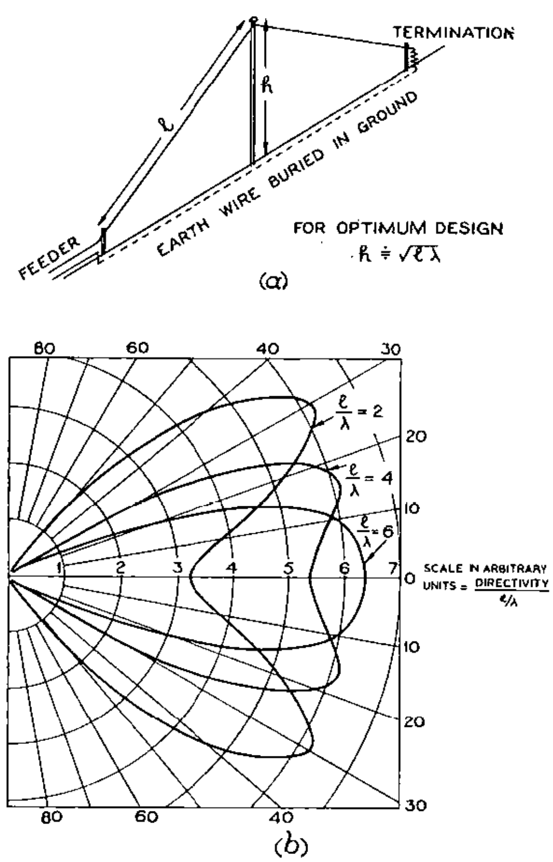


Fig. 13.—Pictorial View and Horizontal Polar Diagram of Inverted-V Aerial.

The Inverted-V Aerial.

The inverted-V aerial, shown in Fig. **13**(*a*), is closely related to the rhombic aerial, but differs in that it is used for vertically polarised transmissions whereas the rhombic is horizontally polarised. The inverted-V forms half a rhombic and the other half is provided by the virtual image due to the ground reflection. The considerations which apply to the horizontal polar diagram of the rhombic aerial apply equally well to the vertical polar diagram of the inverted-V aerial except in so far as the mirror image is imperfect due to finite ground conductivity. The horizontal polar diagram of the inverted-V aerial (which is similar, of course, to the free space vertical polar diagram of the rhombic aerial) can be deduced as before from considerations of the polar diagrams of the individual wires—again the addition of the contributions of the wires is almost unaffected by changes of frequency provided the side-length is not less than 4 or 5 wavelengths.

Other Types of Aerials

Other types of short-wave aerials have been developed, many of them named after their inventors, which at first sight may appear to have little in common with the aerials which have been considered, but the same fundamental principles already discussed underlie each design. As an example, the Franklin array will be considered briefly, but it is pointed out that any other type of array can be treated the same way.

A Franklin array is a vertically polarised aerial-system, consisting of a broadside array of long vertical wires, energised from the base, in which alternate current loops of the standing waves are suppressed, leaving only loops with currents in the same phase; thus, each long wire functions as a vertical array of vertical half-wave dipoles. The complete array is, therefore, a narrow-band aerial system having directivity in both the horizontal and the vertical plane. The suppression of the alternate loops can be achieved in various ways, that shown in Fig. **14**(*a*) being

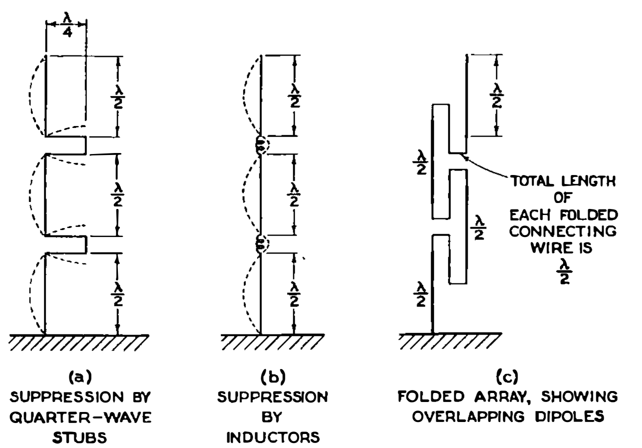


Fig. **14**.—Principle of Franklin Arrays.

by folding that portion of the wire carrying the unwanted phase so that the radiation from it is zero, thus leaving several half-wave dipoles all energised in the same phase. Another method is simply to replace the folded portions of wire by inductors of the appropriate value to produce the required phase reversal, as shown in Fig. **14**(*b*). A third method having several advantages is shown in Fig. **14**(*c*); by this means the in-phase dipoles are made to overlap to a certain extent compared with the arrangement shown in Fig. **14**(*a*). Franklin arrays may be 300 to 400 ft. high and are usually supported from triatics between stayed steel masts. The array as described is bi-directional, but can be made directional by adding a reflector curtain one-quarter wavelength behind the driven array.

Consideration similar to that applied above to the Franklin array can be applied to other types of short-wave aerial.

Effect of Ground

So far, consideration has been confined in general to free-space polar diagrams, that is, polar diagrams deduced from a consideration of the aerial alone with no surfaces or object capable of influencing the transmission of radio waves within a distance of many wavelengths. However, since wavelengths in the short-wave band lie in the range of 10 to 100 metres, it is clear that in the vertical plane at least, short-wave aerials in practice can never be more than a few wavelengths from one surface, namely, the ground, and frequently within only a fraction of a wavelength. Thus, while free-space polar diagrams are a legitimate indication of the performance of an aerial when considering horizontal polar diagrams, it is necessary in order to deduce vertical polar diagrams to allow for the presence of the ground.

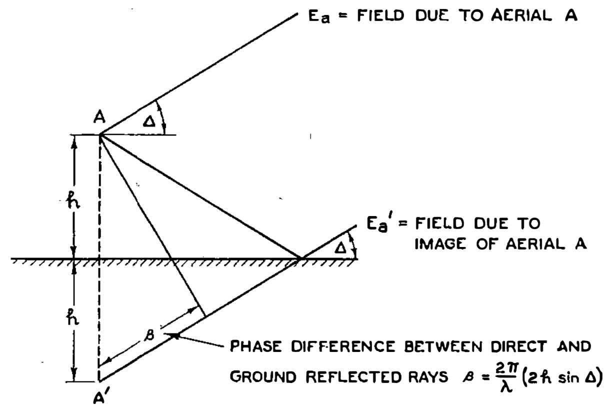


Fig. **15**.—Derivation of Height Function.
(Aerial erected over Plane Earth having Perfect Conductivity.)

In Fig. **15** an aerial A is shown erected at height h above a plane earth having perfect conductivity. The field at a distant point in a direction at an angle $\triangle$ above the horizontal is denoted by E_a. A ray reflected from the ground produces a field at the same point, denoted by E'_a, which may be considered as emanating from a source A′ which is the image of A. E'_a will, in general, be similar to E_a in amplitude, but will differ in phase by an amount $\beta = (2\pi/\lambda)\ (2h \sin \triangle)$ due to the difference in path lengths, and by a further amount (α) which is the change of phase due to reflection.

Thus, the total field $E_R = \sqrt{E_a^2 + E'^2_a + 2E_a E'_a \cos(\beta + \alpha)}$. For horizontally polarised transmissions a 180° phase change occurs on reflection, i.e., $\alpha = \pi$, so that the expression simplifies to

$$E_R = 2\ E_a \sin\left(\frac{2\pi h}{\lambda} \sin \triangle\right)$$

The factor $2 \sin [(2\pi h/\lambda) \sin \triangle]$ is termed the height factor, for obvious reasons, and the vertical polar diagram of a horizontally polarised aerial at a height h is determined by multiplying its free-space vertical polar diagram by the height factor. The result for a rhombic aerial erected at a height of 1·2 wavelengths above ground is shown in Fig. **16**—the major lobe is inclined at an angle of 10° to the horizontal. Consideration of the expression for height factor will show that a maximum value occurs when

$$\frac{2\pi h}{\lambda} \sin \triangle = \frac{\pi}{2}, \quad \text{i.e. } \frac{h}{\lambda} = \frac{1}{4 \sin \triangle}$$

When $h/\lambda = 1{\cdot}2$, $\sin \triangle = 1/4{\cdot}8$ whence, $\triangle = 12°$. If, on the other hand, the major lobe were required to be directed at 6° to the horizontal, the formula for h/λ shows that the height should be about 2·4 wavelengths. The wide-band properties of the rhombic aerial have been referred to

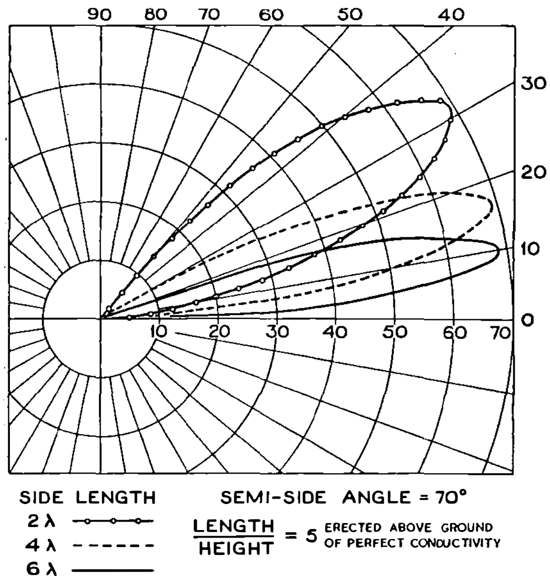


FIG. 16.—VERTICAL RADIATION PATTERN, RHOMBIC AERIAL.

earlier in connection with horizontal polar diagrams—Fig. **16** shows how the vertical polar diagram of a rhombic aerial of side length 6λ, semi-side-angle 70°, erected at a height $1{\cdot}2\lambda$ above ground, is affected by operation at lower frequencies. It is of interest to note that the increase of angle of inclination with decrease of frequency is a desirable feature in that it corresponds very well with the increase of wave arrival angle with decrease of frequency referred to in the discussion on propagation in Part 1.

The vertical polar diagrams of other types of horizontally polarised aerials are determined in the same way, by multiplying the free-space vertical polar diagram by the height factor. In the case of vertically polarised aerials the same height factor is used for vertical angles up to about 10°, but above this value the factor becomes $2 \cos [(2\pi h/\lambda) \sin \triangle]$, due to the fact that in these cases no phase change occurs on reflection, i.e., $\alpha = 0$.

MULTIPLE UNIT STEERABLE ANTENNA

As discussed in Part 1, propagation conditions are such that the vertical incoming angle of a received signal is by no means constant and, in practice, changes of many degrees can occur in a short space of time while operating on one frequency. Under such conditions, signals are usually travelling by two or more paths, for example, over a two-hop path arriving at a low angle to the horizontal and over three- or even four-hop paths arriving at higher angles. In general, all the arrival angles would be within the major lobe of the vertical polar diagram of the normal type of receiving aerial, e.g., a rhombic, and consequently all the signals travelling by different paths would be supplied to the receiving equipment, resulting in interference effects between the signals. Consequently there is a great advantage in using a system in which the vertical polar diagram is narrower than that of a rhombic aerial and adjusting the vertical angle of the major lobe to correspond to that of the prevalent incoming signal at any given time, thereby cutting out the other signals. Such a system, termed the Multiple Unit Steerable Antenna, or M.U.S.A., is in use on the transatlantic radio circuits received at Cooling Radio Station.[4] Briefly, it consists of an end-fire array of 16 rhombic aerials in which the effective phase difference between adjacent aerials can be varied, the amount being the same for all aerials. The principle is illustrated in Fig. **17**.

[4] A. J. Gill. Chairman's address to the Radio Section of the Institution of Electrical Engineers, *Proc.I.E.E.*, Vol. 84, p. 257, 1939.

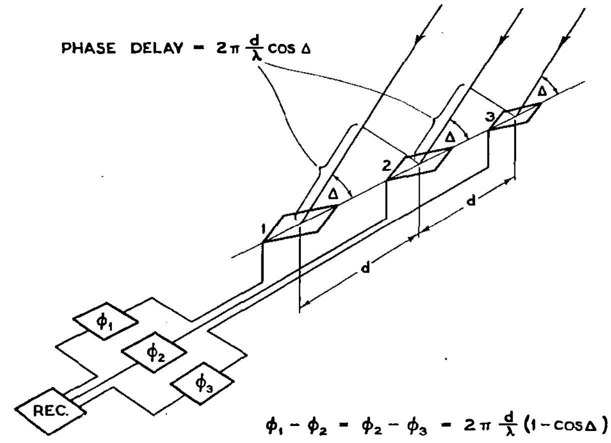


FIG. 17.—MULTIPLE UNIT STEERABLE ANTENNA SYSTEM.
(Principle of Operation.)

Considering a signal arriving at an angle $\triangle$ to the ground, there is a phase difference between the voltages at two adjacent aerials of $(2\pi d/\lambda) \cos \triangle$. Taking into account the different lengths of transmission line to the receiving station, the phase difference at the receiver input is $(2\pi d/\lambda)(1 - \cos \triangle)$. By introducing a phase shift of this value, but of opposite sign in the receiver (at the intermediate frequency stage for convenience), the overall system can be made to yield a maximum response at the vertical angle $\triangle$. The intermediate-frequency phase-shifting arrangement is made continuously variable so that the vertical angle of maximum response is also smoothly variable. Four independent receivers are provided, one of which, the monitor receiver, repeatedly sweeps through the whole of the vertical angle range every two seconds; the other three receivers are available for traffic and are set to the optimum vertical angle as indicated by the monitor receiver.

IMPEDANCE MATCHING

In general, the input impedance of a short-wave aerial cannot be made solely resistive except at specific frequencies and, as discussed earlier, the effect of a large reactive component is to cause difficulty in providing an effective match to the transmitter (and hence an efficient power transfer) without incurring significant power losses in the matching network. For resonant aerials the impedance is usually critically dependent upon frequency, and the consequential reduced efficiency of the matching arrangements for frequencies some way removed from the resonant frequency is a further factor limiting the useful band-width of the aerial, in addition to the deterioration of the polar diagram. For non-resonant aerials the variation of impedance with frequency is usually less severe, and the resulting mismatch when such an aerial is connected to a source having a constant impedance of the appropriate value is not greater than about 50 per cent. over a wide frequency range. The impedance/frequency characteristic of a simple rhombic aerial is shown in Fig. **18**(*a*). The variations are due to the characteristic impedance of the aerial (regarded as a transmission line) not being constant throughout its length, e.g., the initial spacing of the aerial wires may correspond to the characteristic impedance of 600 ohms, but at the side poles the characteristic impedance may be as high as 1,200 ohms. A useful improvement can be realised by forming the sides of the rhombic aerial not from a single wire but from two or three wires, spaced at the side poles in a vertical plane and brought together at the front and back poles, as shown in Fig. **18**(*b*). The spacing between the wires is controlled by spacers, usually about three between adjacent poles. The improved impedance/frequency characteristic obtainable with such a three-wire rhombic aerial is shown in Fig. **18**(*c*).

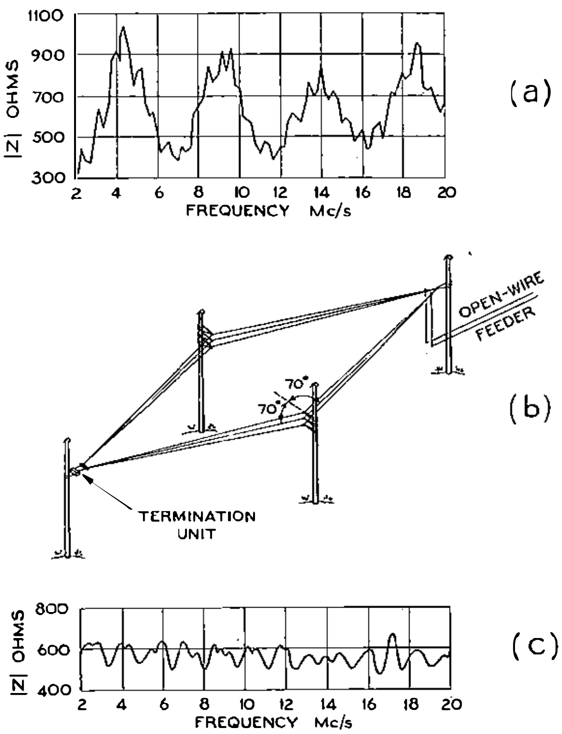


FIG. 18.—IMPEDANCE/FREQUENCY CHARACTERISTIC OF SINGLE-WIRE AND THREE-WIRE RHOMBIC AERIALS.

For connection between the aerial-systems and the radio station equipment it is generally most economical to provide two-wire balanced transmission lines having a characteristic impedance of 600 ohms. In some circumstances the provision of a four-wire balanced transmission line, having a characteristic impedance of 300 ohms, is justified. In general, transmitting equipments are provided with balanced outputs and can be arranged to feed directly into 600-ohm or 300-ohm transmission lines. Receiving equipments usually employ unbalanced input impedances, and for receiving installations balanced/unbalanced impedance transformations are provided at the station end of the balanced transmission lines, with coaxial cables from the transformers to the receivers—the use of coaxial cable simplifies the internal distribution arrangements.

Where the aerial is terminated at the end remote from the aerial feeder, considerations of mismatch similar to those discussed above also apply. For example, a typical rhombic aerial would normally be terminated with a 600-ohm resistive impedance, either a resistor for a receiving aerial or a 600-ohm iron-wire transmission line for a transmitting aerial, the latter being a termination having a high power-handling capacity. The use of a termination of constant value results in mismatches of up to 50 per cent. at certain frequencies, and these mismatches give rise to reflected currents which flow in the opposite direction to the main aerial current. Such reflected currents give rise to radiation in the same way as does the main current, but in the opposite direction, and at reduced levels depending on the relative magnitude of the forward and reflected currents. In other words, the aerial radiates to some extent in the backward direction (similarly in reception the aerial responds to signals arriving from the backward direction). It is very desirable from the aspect of reducing interference between services that the "front-to-back ratio" of an aerial should be adequate at all frequencies within its operational band, and the provision of a suitable termination is a factor in achieving this.

When a terminated type of aerial is used for reception the far-end termination can be replaced by a second feeder line to the station, so that either end of the aerial can be regarded as the feeder end; with this arrangement, in effect two aerials, with lines of shoot 180° apart, are available for the receiving equipment from the one-aerial installation.

CONCLUSION

It has not been possible to include more than the broad outline of the principles underlying the development of short-wave aerials. Thus, discussion of polar diagrams has been restricted in each case to the consideration of the major lobe only, apart from the reference to rearward lobes arising from reflected currents. In point of fact, however, the full solutions of the mathematical expressions for polar diagrams show a number of unwanted lobes at various horizontal and vertical angles, and one of the problems confronting the aerial development engineer is the reduction of such unwanted lobes for reasons which will briefly be discussed.

In the early days of radio communication, when receivers were less sensitive and fewer transmissions existed, the main requirement of a receiving aerial was that it should possess high gain in the direction of arrival of the signal which it was desired to intercept. The performance in other directions was relatively unimportant since, by virtue of the wide frequency spacings then possible, interference from unwanted transmissions rarely occurred. Modern requirements, however, are much more stringent as a result of the severe congestion of transmissions in the high-frequency spectrum, and the criterion of receiving aerial performance has tended to become the ratio of wanted to unwanted signal voltages delivered to the receiver terminals, rather than the magnitude of the wanted signal voltage. Clearly, an aerial cannot discriminate against unwanted signals arriving from much the same direction as the wanted signal, but the polar diagram can be shaped to reduce lobes in other directions, thus giving protection against unwanted off-course signals. Some reduction in the gain of an aerial may result from this process, but the lower received voltage is usually compensated by the much improved sensitivity of the modern communication receiver. The limit to which gain can be sacrificed for this purpose is set by the requirement that, to avoid degradation of signal-to-noise ratio, the radio noise from the aerial should override that of the associated receiver.

Other problems are concerned with the provision of steerable directivity both in azimuth and zenith, the solutions to which involve the phasing of unit aerials and the consequential creation of further unwanted lobes. Some control over the amplitude of such unwanted lobes can be exercised by tapering the field contributions made by the various unit aerials of an array.[5,6]

In order to be able to calculate polar diagrams at all, certain assumptions have to be made, such as a perfect ground plane, uniform current distribution, uniform mutual impedance throughout an array and, for a receiving aerial, the existence of perfectly plane polarised waves. These assumptions are, however, usually justified when the intention is to compare the relative performances of different aerial-systems. Even with such assumptions the solution of aerial problems is often a complicated mathematical process, and the actual response of an aerial under operational conditions is even more complex.

[5] C. L. Dolph. "A Current Distribution for Broadside Arrays which Optimises the Relationship between Beam Width and Side Lobe Level," *Proc.I.R.E.*, Vol. 34, p. 335, 1935.

[6] D. Barbiere. "A Method for Calculating the Current Distribution of Tchebycheff Arrays," *Proc.I.R.E.*, Vol. 40, p. 78, 1952.

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Experiments in Cleaning Exchange Equipment by Blowing

A. W. RANCE and
P. C. CROSS†

U.D.C. 621.395.72.004.5: 621.61

The authors describe a method of cleaning automatic exchange equipment in situ by blowing, including the use of shrouding bags with vacuum extraction of dust. A method of cleaning individual switches and relay sets is also described.

Introduction

EXTENSIVE building alterations, involving the removal of internal and external brick walls and changes in the position of a number of doors and windows, have taken place recently at Southend exchange, and in spite of the usual precautions with temporary screens of sisal paper and with dust-sheets, considerable brick dust escaped into the apparatus rooms. Further dust was caused by the decorators and equipment contractors, especially with the pulling out of old cables and the running of new. During these operations vacuum cleaners had been used in the normal way, but these remove dust only from accessible places where the nozzle can be brought to within ½ in. or so of the dust, or where a disturbing brush can be used. These restrictions apply especially where the dirt has accumulated over many years and sticks on the bank and other wiring, and on inaccessible ledges.

Blowing the dust away seemed the only feasible method, provided means of collecting or trapping it could be devised, and it was decided to experiment first on the double-sided line and final units which were installed in 1928. In these, five shelves of uniselectors are mounted on one side, on two gates, hinged on each end of the rack and swinging out from the centre. The final selectors, with space for four shelves of eight switches, are fitted on the other, non-hinged side.

Cleaning Methods for Rack-mounted Equipment

Shrouding Bag at Rear.

It appeared desirable to limit the equipment blown at one time to the smallest practicable unit on which a bag could be fitted at the rear of the rack and closely enough to prevent much dust escaping around the edges of the bag. A half-shelf of 10 uniselectors and associated equipment provided such a unit, and the rack construction permitted wood strips, 2 in. by 1 in. by about 2 ft. long and slightly tapered at one end, to be wedged in position and a dust-bag slipped over and tied with tapes to the rack ironwork. The bag, of medium texture fabric similar to lightweight tent cloth, was about 4 ft. long and terminated around the nozzle of a low-power commercial vacuum cleaner.

At first, a hand blower was used, but a vacuum cleaner of the type mentioned, but used as a blower, was found to be just as effective and almost as convenient. To reduce the blow-back of dust into the room it was found best to commence with the nozzle 2 ft., or so, away from the equipment and then gradually bring it close to the equipment directing the stream of air at various angles to effectively remove the dust and dirt. The L and K relay covers were removed. Fig. 1 shows the principle; the value of the comparatively large bag is that some of the blown air can more readily escape through the material, thus allowing for the fact that vacuum cleaners handle less air in suction than in blowing.

For the final selectors the arrangement of cabling, etc., made it more difficult to limit operations to small units and in this case the bag was arranged to cover all four shelves of the rack. The selector covers were kept in place to avoid reflection of air from the back plates.

†The authors are, respectively, Executive Engineer and Assistant Engineer, Southend Telephone Area.

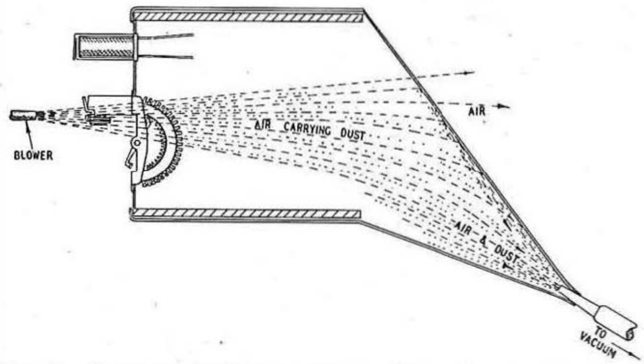


Fig. 1.—Cleaning of Uniselectors Using Shrouding Bag at Rear Only.

Shrouding Bags at Front and Rear.

Although much of the equipment in the main exchange and two of the satellites was cleaned satisfactorily by the method described, a slight blow back into the room was inevitable, to the probable detriment of other equipment and discomfort of the staff. A front bag with a flexible plastic window and a hole for the blowing nozzle was next tried, as shown in Figs. 2 and 3, and this proved very successful. The bag was of ample size to permit freedom in pointing the airflow in any direction required. In place of the wood strips an iron frame was used for holding the rear bag. Two U-shaped strips with two inside lugs formed at each end enabled the strips to be clipped over, and firmly located on, the rack. They were held apart by four riveted strips and the bag was a tight enough fit for the framework to grip the rack. The front bag was fitted to a rectangular iron frame held by two coil springs through the rack to the back frame.

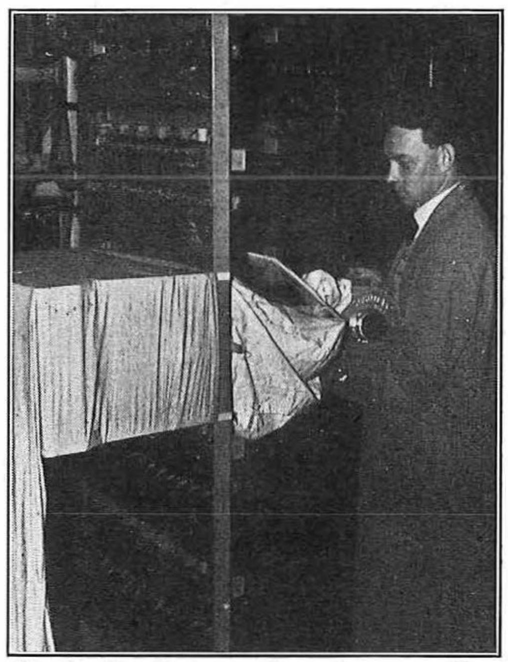


Fig. 2.—The Rear and Front Shrouding Bags.

Fig. 3.—The Front Shrouding Bag with Plastic Window.

Effect on Faults

From an appearance standpoint the result of cleaning rack-mounted equipment was certainly very striking, but some doubt was felt as to the overall effect on the fault rate. Prior to the experiments the 3,135 old-type uniselectors at Southend exchange had been subjected to a functional rotation test every 10 days and an average of 50 faults a week was being found, as compared with four reported faults a week. Immediately after the cleaning an extra rotation test was made and the 10-day routine also continued. The number of routine faults increased appreciably, though no actual record was kept for the four weeks or so during and subsequent to the blowing. The reported faults, however, increased to six or seven a week and then dropped within a few weeks to an average of 2½. The 10-day routine was still continued and was finding some 15 faults a week after a few weeks and 10 a week after a few months. In the final selectors the normally low fault rate, both reported and routine, was not appreciably affected, either during or subsequent to the blowing.

It is considered that under normal maintenance conditions, excluding the special difficulties following building and equipment contractors' operations, the cleaning of an exchange by this method is unlikely to produce a marked reduction in faults. It may be useful in old exchanges, however, especially as dust and dirt account for some 30 per cent. of exchange faults in the old-type single-contact equipment.

Cleaning Individual Items

The facility of cleaning by blowing has been introduced in the Southend exchange apparatus repair room. All switches and relay sets taken into this room for repair or overhaul are first placed in a special box and the dust removed by the blower. The box, as illustrated in Fig. 4, is fitted against a window and has a sliding panel at the back in place of a window pane so that the dust can be blown straight out of the room. It has been found that apparatus thus cleaned can be put back into service without additional contact cleaning and without any increased fault rate.

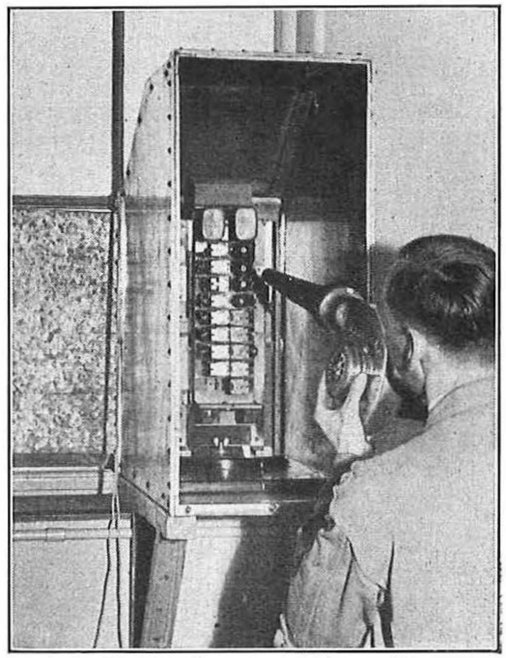


Fig. 4.—Cleaning a Relay Set.

Conclusion

The blowing method of cleaning could no doubt be applied successfully to other types and layouts of rack-mounted equipment, but difficulties may be encountered, e.g., obstruction from vertical cabling, and much ingenuity is required in making the front and back bags a reasonably dust-tight fit. If, however, the suction airflow could more nearly equal the blowing airflow there should be a much reduced tendency for dust to escape into the room. Unless the filter bag of a vacuum cleaner is new or recently brushed, its presence may reduce the airflow by up to 50 per cent. and hence the use of two vacuum cleaners on the suction side should prove an advantage.

Acknowledgment

The authors wish to acknowledge the part played by Messrs. R. Wyndham and L. A. Crogman, of Southend exchange, who originated a number of the ideas incorporated in these experiments.

Book Received

"Electronic Semi-Conductors." (In German.) E. A. Spenke, Springer-Verlag, Berlin. 379 pp. 184 ill. DM 34.50.

The first part of this book reproduces, in an amplified form, five lectures which the author gave before various audiences during the years 1950 to 1953 in order to facilitate the understanding of rectifiers and transistors, but without making use of oversimplification. In addition to a general survey of conduction processes in electronic semi-conductors in the first lecture, it seemed necessary to give, as far as possible, a comprehensive picture of the idea of "points of disturbance" and "holes," which cause the beginner considerable difficulty. Only the fourth and fifth lectures are concerned particularly with rectifiers and transistors. A characteristic feature of a theoretical study of semi-conductors lies in the fact that an effective understanding of this subject demands quite extensive knowledge of atomic physics, wave mechanics, statistics, thermodynamics and crystallography. In this connection the second part of the book tries to help the beginner in that the subjects mentioned are again treated as simply as possible but without superficiality. The author believes that in the last chapters even the more advanced student will find certain aspects of the subject which have not hitherto been set down with equal clarity elsewhere.

The London—Isle-of-Wight Television Link, Stage One

T. KILVINGTON, B.Sc. (Eng.), M.I.E.E.†

U.D.C. 621.397.26:621.396.65(422.8).

The initial television service to the Isle of Wight has been provided by direct pick-up of signals from the London transmission on receivers sited near Alton, Hants, and thence by transmission over a 40-mile microwave link to Rowridge, I.o.W., where it is radiated from a B.B.C. transmitter. The author outlines the equipment provided and mentions some of the special problems which had to be overcome.

INTRODUCTION

STAGE 1 of the London–Isle-of-Wight television link was brought into service on 18th October, 1954, when daily test transmissions commenced from the B.B.C. television station at Rowridge, on the island. The official opening date for full programme service was 12th November. This link is the second Post Office application of the "direct-pick-up" technique which was first used for the service to Belfast[1]; that is, the technique whereby signals radiated from one of the B.B.C.'s existing transmitters are picked up at a suitable point and passed on to feed another transmitter. Whereas, for the Belfast service, the signals are passed on from the pick-up point by a relatively short length of cable, for the Isle-of-Wight service the onward transmission is by microwave radio link over a distance of about 40 miles. The use of direct pick-up for the Isle-of-Wight link is a temporary expedient that enabled the service to be established more rapidly than if a fully engineered radio link had been provided all the way. Preparations for the installation of the complete two-way microwave radio link between London and Rowridge (Stage 2) are, however, well advanced and it is expected that such a link will be brought into service towards the end of this year.

PICK-UP OF LONDON TRANSMISSION

The choice of site for the direct-pick-up point was governed by the requirements of the final microwave link. By careful examination of the contour maps and the drawing of many route profiles, it was found that the final circuit between Museum Exchange, in London, and Rowridge, could be provided in two hops, but only if the intermediate station was situated on a relatively small "island" of land above the 700-ft. contour about three miles north of Alton, in Hampshire. Even then it would be necessary to mount the aerials at 300 ft. above ground level for the direction towards the Isle-of-Wight, and at 200 ft. for the London direction, in order to meet the ground-clearance requirements of the two propagation paths. In spite of the disadvantages of a tall mast it was decided to go ahead with the scheme on this basis rather than choose an alternative route that would have required two intermediate stations. A suitable site was, therefore, acquired within the permissible area and is known as "Golden Pot," this being the name of a local hostelry, the nearest named point on the ordnance survey map. Field tests indicated that this was also a very suitable point for picking up signals from Alexandra Palace, a field strength of some 500 microvolts per metre at 40 ft. above ground level being available under normal conditions. In addition, during the limited period of the trials which were carried out, practically no fading or interference was observed. It was not possible to carry out any microwave propagation trials over the route because of the need for a high mast, but theory and previous experience indicated that the performance should be satisfactory.

The direct-pick-up receivers, two of which are provided, are similar to those employed at Belfast, but with a number of modifications that have been incorporated as a result of the experience gained in Northern Ireland. The aerials for picking up the signals from Alexandra Palace are four-element Yagi arrays mounted at heights of 80 ft. and 120 ft., respectively, on the 325-ft. mast carrying the microwave dishes. With the much greater signal strength available and the comparative freedom from fading, the receivers have a very much easier task to perform than those at Belfast.

MICROWAVE LINK EQUIPMENT

The microwave equipment for the link has been recovered from the Dollis Hill-Castleton experimental link. It may be recalled that this link, which was used to convey signals to the Wenvoe transmitter of the B.B.C. for the first four months of its public service, contained three microwave sections. The transmitters and receivers from the Hook-Wotton-under-Edge link, the microwave section most remote from London, were brought back to the laboratories at Dollis Hill for general overhaul and for the incorporation of certain modifications before being installed at the new sites. The main change that has been made is in the system of standby provision. As originally built, the equipment comprised working and standby transmitters and receivers, operating on the same frequency, with switches to change to the standby in the event of a failure of the working unit. Automatic changeover was not provided, hence the apparatus could not be left running unattended. For the new link it was decided to use "channel changeover," i.e., two channels would be provided, and in the event of a fault developing in the equipment in use at either end of the link the service would be transferred to the spare channel. In practice both channels are arranged to be working and transmitting signals simultaneously so that the only changeover necessary is at the output of the link. Both outputs are available to the B.B.C. operator who can, therefore, effect the changeover without assistance from Post Office staff. To operate the link in this way requires the use of a second microwave frequency and it was decided to use 3,930 and 4,070 Mc/s, the same frequencies that were used (but on different hops) for the Wenvoe link. Band-pass filters for these frequencies were available and it was found that pairs of these filters, as originally designed, could be combined with the aid of Y-junctions to form satisfactory branching filters. These branching filters enable the two transmitters at Golden Pot to be worked into a common waveguide feeder and paraboloidal aerial; and, similarly, a single aerial at Rowridge is able to serve the two receivers. A schematic diagram of the link is shown in Fig. 1, and Fig. 2 shows the radio equipment at Golden Pot.

The transmitters which were recovered from an intermediate station on the Wenvoe link will not handle a video frequency input but require signals at the intermediate frequency of 60 Mc/s. For the present link, therefore, modulators, accepting the video signals from the direct-pick-up receivers and giving out frequency-modulated signals in the required band, have been provided. The frequency stability of the signal so obtained is rather better than that of the Wenvoe link in which a klystron giving

† Assistant Staff Engineer, Radio Experimental and Development Branch, E.-in-C.'s Office.

[1] Kilvington, T., "Television Service to Belfast," *P.O.E.E.J.*, Vol. 46, p. 130.

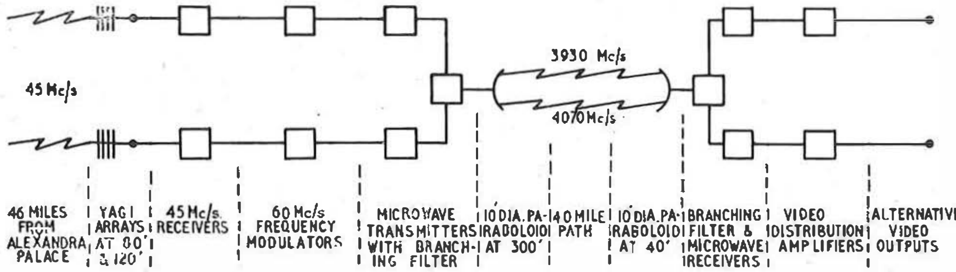


FIG. 1.—BLOCK SCHEMATIC DIAGRAM OF STAGE 1 RADIO LINK BETWEEN LONDON AND ISLE-OF-WIGHT.

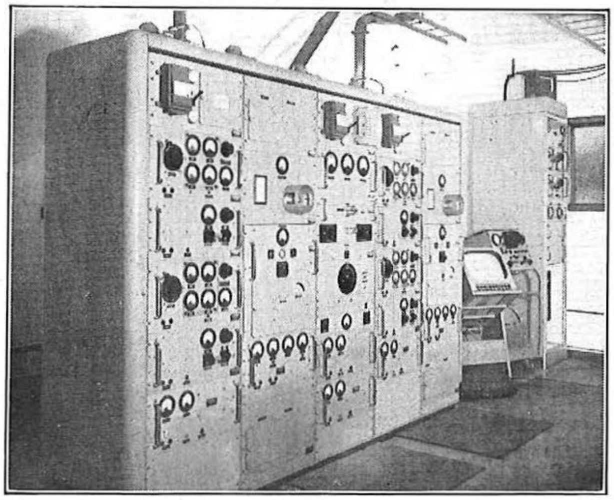


FIG. 2.—RADIO EQUIPMENT AT GOLDEN POT. THE LEFT-HAND CABINET CONTAINS THE TWO MICROWAVE TRANSMITTERS; THE SMALLER, RIGHT-HAND CABINET CONTAINS DIRECT-PICK-UP EQUIPMENT AND MODULATORS.

direct modulation of the microwave frequency was employed at the sending end. This change, together with improvements that have been made in the automatic frequency control units on both transmitters and receivers, and the adoption of two-channel working, has improved the overall reliability of the equipment, and it is hoped that, after an initial period of careful observation, it will be possible to dispense with attendance at the Post Office equipment and rely simply on regular maintenance visits.

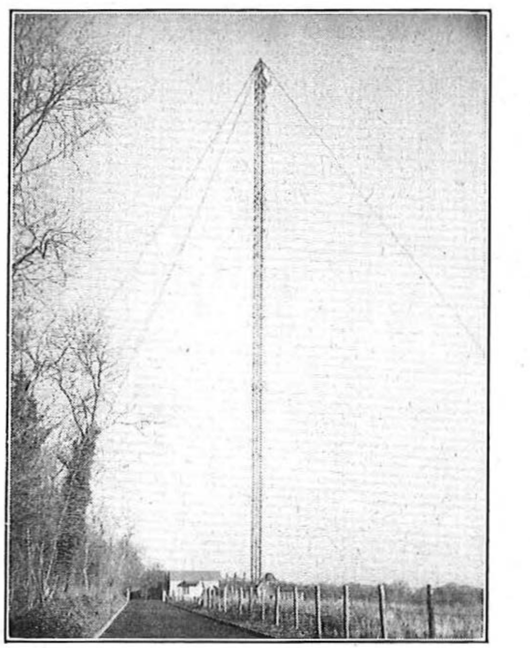


FIG. 3.—THE STATION AT GOLDEN POT.

AERIALS AND BUILDINGS

Fig. 3 gives a general view of the Golden Pot site. The mast provided is a 5-ft. square section, stayed, lattice steel mast, 325 ft. high, which happened to be available within the Post Office. Initially, it carries a single paraboloidal aerial near the top, facing in the Isle-of-Wight direction. In due course another dish will be added at about the same height, together with two at about 200 ft. pointing in the London direction. Two of these extra dishes can be seen at the base of the mast. The four dishes will serve for the channels to be provided in both the go and return directions. The waveguide feeder, made of copper, has a different coefficient of expansion from the mast itself and precautions have, therefore, had to be taken to avoid undue strain in the guide due to temperature changes. At the top it is clamped solidly to the mast, but it is free to slide in the fittings which hold it to the mast at intervals on the downward run. So that the clamp at the top shall not have to carry the full weight, an upward thrust is applied to the guide at the bottom by means of a lever and counterweight which can move to take up vertical movement of the guide relative to the mast.

At Rowridge, the two Post Office aerials will finally be supported on the B.B.C. mast but, as the latter is not yet available, a single dish is at present mounted about 40 ft. above ground level on a self-supporting, 200-ft., lattice steel tower erected by the Post Office. This tower is one that was formerly erected at St. Albans Radio Station; it is also being used by the B.B.C. to support the transmitting aerial until their own higher mast is available. When the final mast is erected and the services transferred to it, the tower will be dismantled.

The paraboloidal dishes used at the two stations are interesting inasmuch as they were produced from flat sheets by spinning. To cope with such large-diameter spinnings the manufacturer who produced them had to construct a well in the factory floor so that the spinning lathe would take the required diameter of former and blank. Aluminium sheet was not available in sizes large enough for the blanks so these had first to be fabricated by welding two smaller sheets together. The former used for the first few spinnings was built up from hundreds of pieces of hard wood, assembled and turned to shape, but for later samples (the Post Office having other uses for these dishes besides the Isle-of-Wight link) a metal former has been made.

The station at Golden Pot comprises three B1-type timber buildings, one for the radio equipment, one for the standby diesel power generator, and one for stores and welfare accommodation. The latter is provided on a rather generous scale as it was originally thought that the station would have to be staffed during the whole period of Stage 1 operation. The receiving equipment at Rowridge is housed in a room set aside for Post Office link equipment in the B.B.C. building. As the frequency of the Rowridge transmitter, 56·75 Mc/s vision carrier, falls within the intermediate frequency band of the link equipment, it is necessary to have very thorough screening of the equipment room and this has been provided by the B.B.C. who are also supplying power and other services.

CONCLUSION

At the time of writing the link has been in service for about two months and has given very satisfactory service. No fading has been observed on the microwave part of the link. The direct-pick-up signal has faded out on two occasions for periods of about 10 minutes, but at other times has remained strong and steady. Under normal conditions the signal/noise ratio on the microwave link is about 50 db., giving a margin of at least 30 db. against fading, while on the direct-pick-up link there is a margin of some 20 db. before the signal becomes unusable.

ACKNOWLEDGMENT

The author would like to pay tribute to all those who assisted in establishing the link, and particularly to the staff of the Home Counties Region who played their part in the project with the greatest enthusiasm.

Telephone Service for a Polio Sufferer

U.D.C. 621.395.721.1

DURING the last few years much interest has been given to the problem of providing aids for the disabled. These are often very simple devices but, if they help the disabled person to perform tasks alone where previously aid had to be sought, the morale value is immeasurable.

A note from the Edinburgh Area published recently showed how telephone service was given to a patient in an iron lung.* An equally interesting problem, involving an ex-patient who happily has been out of an iron lung for some time, was recently posed by St. Bartholomew's Hospital to the London Telecommunications Region. This lady, who until a short time ago was a part-time worker at the hospital, is completely paralysed in one arm and partially so in the other. She wished to use the telephone but was unable to hold it to her ear; she could, however, just manage to remove and replace the handset. Bart's supplied pictures from a magazine showing how our American colleagues had tackled a similar problem. None of the devices illustrated seemed really suitable; the most promising showed the telephone held permanently in the speaking position by a steel rod, with a weight to be removed and replaced instead of the handset.

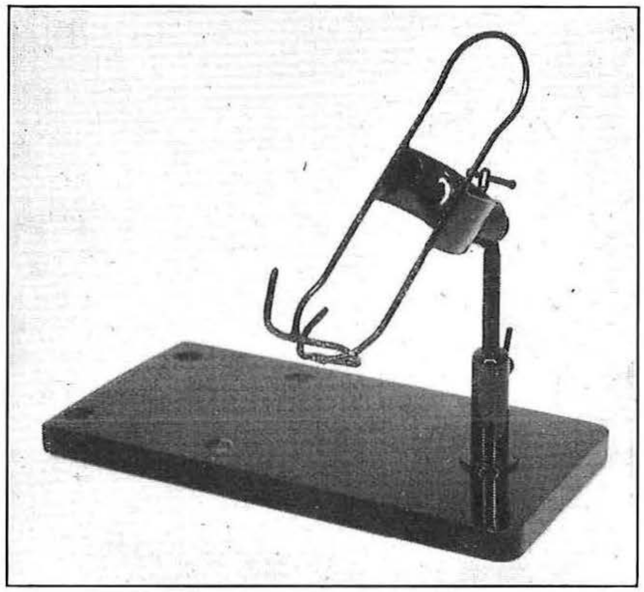
This problem followed closely on another which had resulted in the production of a lazy arm arrangement for a one-armed subscriber. With this, the telephone and lazy arm are in a fixed position with the handset clamped on the arm. To make or receive a call the user pulls the handset towards him and the resulting reduction in width of the lattice operates the switchhook. This method was rejected for the polio case mainly because it would not have looked well in domestic surroundings.

A scheme involving a hinged arm on which the handset was clamped was then tried. This was abandoned owing to the difficulty of getting a suitable clamping for the handset which would allow it to rest normally on the telephone and take up a comfortable speaking position when in use. It also suffered from the objection that the telephone could not be used in the normal manner by other people.

Throughout it had been in mind that the best arrangement would be one which left the telephone unchanged for ordinary use. This was approved by the lady herself who wanted the telephone to be, if possible, unaltered for others to use and for any "gadgetry" concerned to be as unobtrusive as possible. It seemed that the best way to do this would be to provide a cradle to hold the telephone when in use.

The photographs show the solution reached. An adjustable cradle mounted on a plinth holds the handset in the speaking position; rubber studs on the base of the plinth keep it firmly in the desired position. Only the most simple movements are necessary to put the handset in the cradle and remove it when the call is finished. The design ensures that the handset takes up the same position in the cradle every time. The cradle is adjustable for height and has a ball and socket head which allows it to be set to a comfortable speaking position.

*P.O.E.E.J. Regional Notes. Vol. 46, p. 153.



THE PLINTH AND ADJUSTABLE CRADLE.

METHOD OF USING HANDSET IN ADJUSTABLE CRADLE.

The whole makes an unobtrusive setting for the telephone, and, as can be seen, there is no telephone attachment of any kind. The base is of hardwood, ebony finished, and the pillar is mild steel stove-enamelled black. The cradle is fabricated from Sifbronze wire and bronze sheet and is covered with black P.V.C.

The whole of the work, including a considerable amount of final design detail, was carried out by the L.T.R. Power Section.

A. L. T.

Noise Interference from External Sources

D. W. R. COBBE, A.M.I.E.E.†

U.D.C. 621.396.823: 621.3.013.71

The author gives a simplified, non-mathematical account of power line induction on communication circuits, explaining how it gives rise to circuit noise and the steps taken to suppress this type of interference. A number of unusual cases recently experienced are also outlined.

Introduction

CIRCUIT noise interference at audio frequencies from sources external to the Post Office (viz., power lines, electrified railways, trolley vehicles and tramway systems, etc.) has fortunately never been a serious problem, but the number of cases has risen slightly in recent years, and may well continue to do so with the increasing rate of erection of power lines, particularly in Scotland.

This article is intended to give a general account of the phenomenon and some details of particular cases which have recently occurred, so that the various possible causes may be more generally understood. The treatment is deliberately simplified and non-mathematical. In the main, interference from power lines will be discussed since these give rise to the majority of cases.

Magnetic Induction

All cases of noise interference so far known in this country have been caused through magnetic induction. Therefore, electric (i.e. capacitive) coupling is not dealt with in this article.

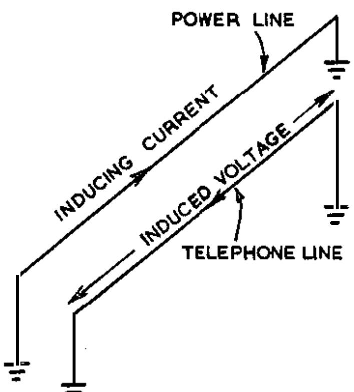


FIG. 1.—INDUCTION OF A LONGITUDINAL VOLTAGE IN A TELEPHONE LINE.

Fig. **1** shows how a longitudinal voltage may be induced into a telephone line. The power and telephone circuits are depicted as loop circuits (each having earth-return) situated side-by-side. The two loops have, therefore, a mutual inductance, and the relationship between induced voltage and inducing current is $E = \omega MI$, with the usual notation. As a matter of interest, the mutual inductance for two such circuits close together is about 2 mH/km.

The complication of the distribution of power current in the earth will be ignored in this simplified treatment except to say that the current tends to spread out laterally and in depth so that the cross-sectional area of the return path is made large and the resistance of this path thereby reduced. The higher the earth resistivity, the greater will be the spread. The extent of the spread is, however, restricted by the fact that the larger the loop, the larger the self-inductance. The actual path taken is therefore that which gives the lowest self-impedance.

Power lines do not, of course, normally provide current to earth as shown, but there are circumstances, as will now be explained, in which Fig. **1** does represent the practical conditions.

3rd Harmonic Induction.

Reference to Fig. **2** shows the phase relationships of the three phase voltages or currents in a 3-phase line. Also shown (dotted) is the 3rd harmonic of phase I taken to be rising through zero with phase 1. It can be seen that the dotted curve also represents the third harmonics of the other two phases. (For each phase, the harmonic bears the same

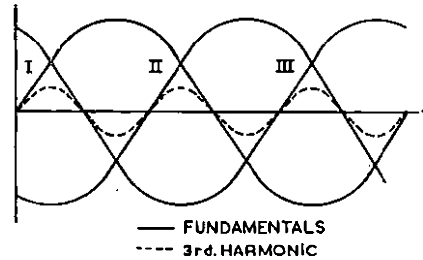


FIG. 2.—PHASE RELATIONSHIPS IN A 3-PHASE POWER LINE.

phase relationship to its fundamental as for phase 1.) Thus, the third harmonics of each phase are all in phase, and hence, so far as third harmonics are concerned, each of the line wires will at any instant be at the same potential relative to earth. The three line wires may therefore be considered as being in parallel, i.e. as one wire taking a current which returns to earth via the distributed capacitance of the line wires, or perhaps through a distant neutral earthing point. This current does, of course, suffer attenuation and phase change along the length of the power line, but its inductive effect is as illustrated in Fig. **1**. Similar effects are produced by frequencies which are multiples of the third harmonic.

Transverse Noise Voltages.

Before discussing further the induction of longitudinal voltages it will be explained that, in general, circuit noise is produced by transverse voltages between the wires of the telephone line and not by the longitudinal voltages as such. Most telephone circuits have two wires fairly close together relative to their distance from the source of interference. Further, transpositions (and crossings) will largely reduce the effect of the small difference in induced voltage, depicted as δE in Fig. **3**, and, substantially, the same induced longitudinal voltage exists in each wire.

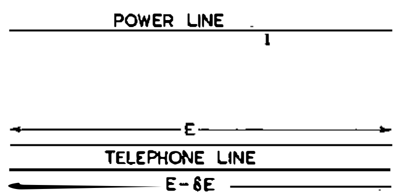
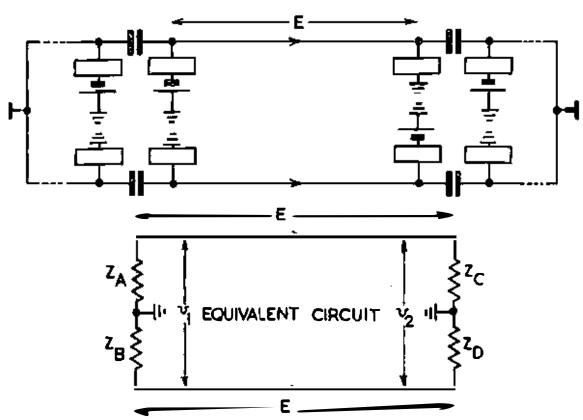


FIG. 3.—VOLTAGES INDUCED IN EACH WIRE OF A TELEPHONE CIRCUIT.



If $Z_A = Z_B$ and $Z_C = Z_D$, then $v_1 = v_2 = 0$

FIG. 4.—A TYPICAL TELEPHONE CIRCUIT AND ITS EQUIVALENT, SHOWING INDUCED VOLTAGES.

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Fig. **4** shows a telephone circuit, with typical terminations, in which equal voltages, E, are induced in each wire. Provided that each terminal equipment and the line are perfectly balanced, no transverse voltage will appear at any point. In practice, the major part of the unbalance occurs in the terminal equipment, not in the line, and is either inherent in the design or, with a balanced design, is due to the necessary manufacturing tolerances on the equipment. Unbalance causes the appearance of a transverse voltage, v, across the pair, a fraction of which appears as noise across the terminals of the receiver.

Longitudinal Voltages.

Reverting now to the methods by which longitudinal voltages may appear on telephone lines, normal load currents and harmonics (other than third harmonics) will also produce such voltages. This may most easily be appreciated by considering each wire of a 3-phase power line as carrying a current with earth return; the total earth current, i.e. the vector sum of the three phase currents will, of course, be zero. Each wire and earth constitutes a loop and each of these loops will have a slightly different mutual inductance with a telephone wire due to the spacing of the power wires. Thus a residual voltage will be induced in the telephone line, and this voltage will necessarily be longitudinal in character since all inducing currents are longitudinal.

Earth currents may also be produced in a power line by single-phase spurs attached to 3-phase lines. This increases the distributed capacitance to earth of two wires, and the three capacitance (charging) currents no longer balance, thus giving rise to an earth current. In theory, unbalanced loads could unbalance the phase voltages, and hence the charging currents in a line, but this effect has not been known to cause serious trouble.

Noise Interference Tests

Having considered the manner in which voltages are induced in telephone circuits, the three main tests usually made when investigating a case of noise interference can be described, and the reasons for them given. These tests are made using a psophometer. The psophometer is a valve-voltmeter incorporating a network having an attenuation/frequency characteristic which takes account of the relative interference effects of different frequencies. It may be used with, or without, this network,

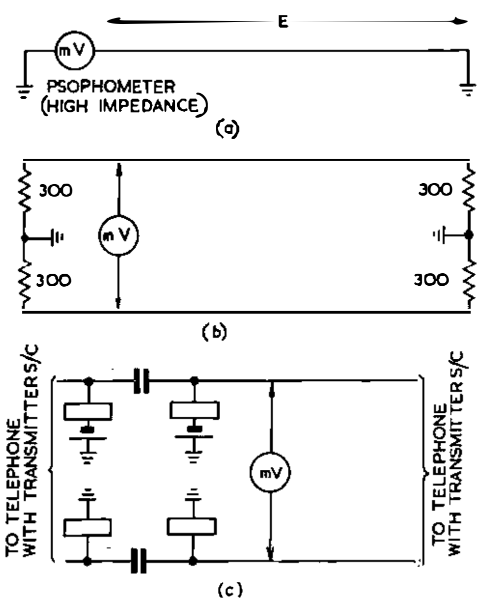


Fig. **5**.—Connections of Psophometer for the Three Tests Made When Investigating Noise Interference.

the readings being designated "weighted" and "flat," respectively.

The three standard measurements are depicted in Fig. **5** and are as follows:—

(*a*) A longitudinal voltage measurement.
(*b*) A transverse "terminated" measurement.
(*c*) A transverse measurement across the circuit when a call has been set up and the telephone transmitters muffled, or preferably short-circuited.

Test (*a*) gives the value of induced longitudinal voltage and, although no limits are laid down for its value, experience shows that circuits are liable to give rise to complaints unless the longitudinal weighted value is less than 200 mV.

Test (*b*) is made with a balanced 600 ohm termination at each end and gives an indication of the extent to which the noise across the circuit could be reduced if perfectly balanced terminal equipment were installed. This is an indication only, since the termination used is an artificial one of fixed impedance, whereas the impedance to earth of equipment varies considerably.

Test (*c*) gives the value of the noise voltage across the circuit under working conditions. Experience has shown that this should not exceed about 1 mV (weighted).

Tests (*a*) and (*c*) have shown that reasonably balanced equipment may be expected to give a longitudinal to transverse ratio of 200 : 1, although actual ratios found in practice vary between wide limits.

Effect of Resistive Earth Coupling.

It is often difficult to be sure whether a voltage measured as shown in Fig. **5** is due to induction or earth-resistance coupling. Consider, as in Fig. **6**, current flowing into (or

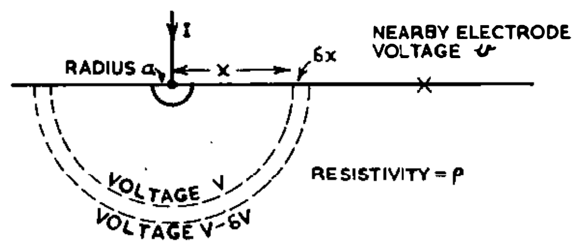


Fig. **6**.—Earth-Resistance Coupling.

from) an earth electrode. Round the electrode there will be equipotential surfaces—the simple case of hemispheres is illustrated—and there will be a voltage drop *in the earth* as current crosses the thin shells of earth formed by successive surfaces. (Elementary calculus will enable those interested to confirm that the resistance to earth of a hemispherical electrode, considering the current flowing to infinity, is $\rho/2\pi r$, where ρ is the resistivity of the soil and r the radius of the electrode.) Thus, on the surface of the earth another electrode will pick up a voltage, shown as v, due to the first electrode. If this second electrode is a "telephone" earth, then in effect a longitudinal voltage has appeared between this earth and the remote one.

Methods of Reducing Noise

General Method.

Fortunately, there is available a relatively simple and cheap method of overcoming many noise troubles. As stated earlier, noise is primarily due (*a*) to the presence of a longitudinal voltage and the flow of current, and (*b*) to the unbalanced earth impedances of the two wires of the circuit. Therefore, if an inductor with two balanced windings is placed in series with the telephone line as shown in Fig. **7**, the connections can be made so that an impedance is offered to longitudinal currents; furthermore, since the two

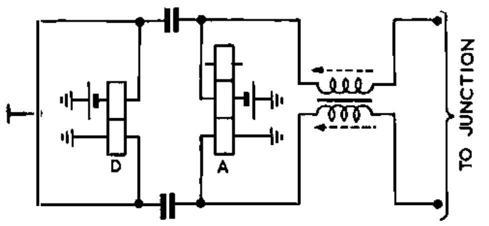


FIG. 7.—USE OF AN INDUCTOR TO SUPPRESS NOISE.

windings are on the same core, there will be a "transformer" action tending to equalise the impedances of the two longitudinal circuits. The inductor will, however, have no effect on loop dialling or speech signals, since for both conditions there will be no resultant flux in the core.

Two designs of inductor are in current use, one where the D.C. flowing in the circuit is loop and the other where the D.C. is flowing along both wires in the same direction. In the latter case, the core of the inductor is permanently fluxed and a larger core is necessary to prevent saturation.

Noise Due to Non-linear Circuit Components.

Curiously enough, the most common and therefore most serious of all noise interference troubles has been due not so much to the presence of extraneous voltages on the Post Office line as to the effect produced by the equipment. Fig. **8**(*a*) shows the ringing circuit used in one form of shared-

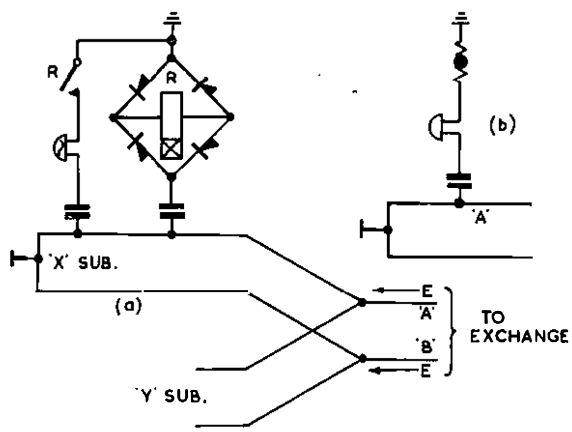


FIG. 8.—RINGING CIRCUITS USED IN TWO TYPES OF SHARED-SERVICE SUBSCRIBERS' INSTRUMENT.

service, where rectifiers are used in the earth path. Such a circuit having a longitudinal voltage impressed on it at a frequency of 50 c/s can give rise to serious noise, even though the waveform of the induced voltage is quite pure and therefore virtually inaudible, since 1·5 to 2 volts (longitudinal) will produce a wealth of harmonics (i.e. noise) due to the non-linear action of the rectifiers.

The cure for this trouble is, fortunately, simple in that replacing the rectifier circuit by a thermistor element (Fig. **8**(*b*)) removes the "source" of the trouble. Thermistors are not entirely reliable, however, where vibrator ringers are employed; and at such exchanges it may be necessary to introduce a machine ringer or perhaps include inductance in the earth path.

False Engaged Test Arising from Noise Induction.

Another effect related to noise interference is sometimes caused by induction at 50 c/s. If a junction, or perhaps a subscriber's circuit, has induced in it a longitudinal voltage, and if the transmission bridge in the answering circuit is of the capacitor type, then there will be a small A.C. voltage on both the tip and ring of the cord circuit, relative to earth, when the answering plug has been inserted. The engaged test consists in connecting to the tip of the cord circuit an impedance to earth (this may include the exchange battery), this unbalances the circuit and a noise is heard which is interpreted as a click, although the circuit being tested may be free.

Two methods may be employed to reduce this trouble. The first has been successfully applied to the P.M.B.X. 1A test circuit. The modification is shown in Fig. **9** and is

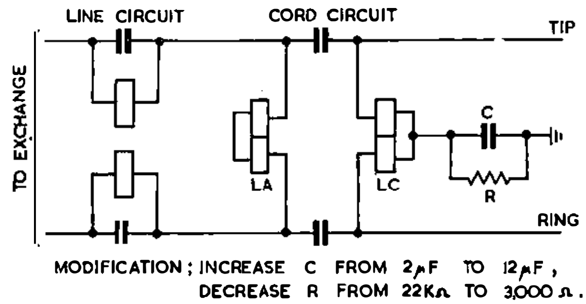


FIG. 9.—MODIFICATION OF P.M.B.X. 1A CORD CIRCUIT TO REDUCE FALSE ENGAGED TESTS.

designed to reduce the impedance to earth at the tip and ring and so reduce the effect of the applied unbalance. The second method is to replace the capacitor bridge by a transformer bridge. The induced voltage on the line is thereby isolated from the cord circuit and any unbalance on the latter has therefore no detrimental effect. This method could of course be applied to the P.M.B.X. 1A exchange line circuit if redesigned.

SPECIAL NOISE INTERFERENCE INVESTIGATIONS

Many of the cases investigated have resulted from long parallelisms between Post Office junction circuits and 11 kV, 33 kV or 132 kV 3-phase power lines; or from the connection of single-phase spurs. In general, the use of inductors in the telephone pair effects a cure. Occasionally, severe noise has been found to be due to unbalance on the telephone circuit caused by a fault condition, e.g., low insulation on one leg or short-circuited turns on a line relay.

The cases which will now be described, however, are those of an unusual or experimental nature.

Power Line With Earthed Neutral.

In the first of these, a 22-kV line was fed by a star-connected auto transformer which in turn was fed by a star-connected alternator. Thus any third harmonics produced by the alternator had a local path for circulation and on the line side the path was completed through the capacitance of the line wires. In this case it was only necessary to remove the earth connection from the neutral point of the alternator to prevent the initial circulation of harmonic currents and so reduce the noise induced into parallel Post Office circuits to a tolerable level.

Power Line With One Phase Earthed.

In the second case (Fig. **10** refers), a 3-phase line was working with one phase earthed (instead of the neutral as is customary). A parallelism with ordinary overhead exchange lines existed over a two-mile section near the earthing point. A relatively large power network including cable existed beyond the parallelism, and the wire capacitance to earth of this network is depicted as C. Thus due to the earthing of one phase, the capacitance currents to earth were not balanced (see vector diagram) and the resultant earth current caused interference. By moving the power line earth to a point at the far end of the exposure, the currents were made to travel along the earthed phase to the feeding point, and then along the two "live" phases,

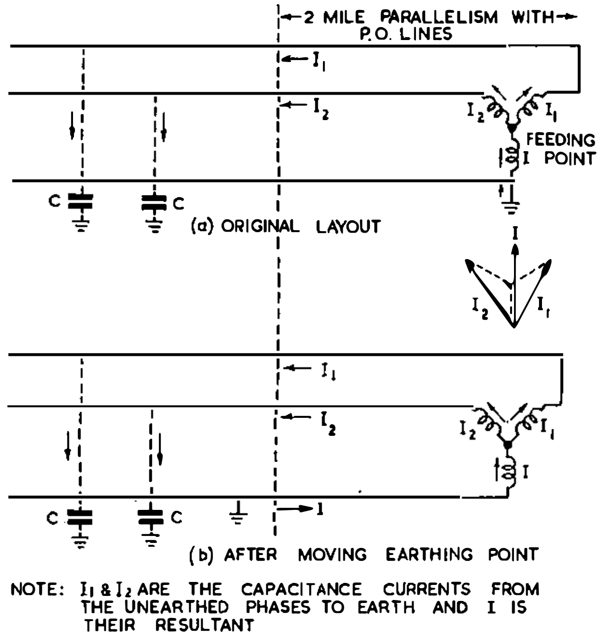


FIG. 10.—INTERFERENCE DUE TO PARALLELISM OF TELEPHONE CIRCUIT AND 3-PHASE SYSTEM WITH ONE PHASE EARTHED.

so traversing the parallelism once in each direction, and causing a cancellation of the external field over this section. This cure was remarkably effective.

Submarine Power Cable.

An investigation of an experimental nature was conducted concerning submarine power cables to the Isle of Wight energised with current flowing along the three conductors in parallel and returning via earth, or rather sea. The intention was to confirm theoretical evidence that interference with cross-Channel communication cables would be negligible when the B.E.A. submarine power link with France was completed. Sea-water has a very low resistivity and the return current should therefore remain close to the cable, so that the external field is small. The measured values of voltage on a Post Office submarine cable were in fact very low.

Electric Traction System.

An investigation undertaken with the co-operation of the British Transport Commission took place at Lancaster when the Lancaster-Morecambe-Heysham line was electrified with 6·6 kV A.C. single-phase at 50 c/s. In such a system the current is fed by a catenary, and rail return is used. In fact, due to the low resistance of the rails to earth, the major part of the current leaves the rails when the train is some distance from the feeding point. More important perhaps is that, to retain the advantages of D.C. traction motors, the A.C. is converted to D.C. by mercury arc rectifiers on the trains. The rectification results for practical purposes in the production of all the odd harmonics of 50 c/s up to about 5,000 c/s. With a stationary rectifier load of some 60 amps., induced voltage measurements on parallel overhead railway telephone lines were made with the following surprising results. At 50 c/s—28 volts; at 150 c/s—9·5 volts; all the odd frequencies were present at values gradually reducing to 2·2 volts at 1,050 c/s; then at almost constant level to nearly 3,000 c/s, when the magnitude of the induced harmonics began to reduce rapidly. When it is considered that any single one of these frequencies at these magnitudes would be sufficient to cause serious interference on, say, a U.A.X. junction circuit, it is clear that telephone circuits could not be expected to work unless (*a*) no earth connections were made, (*b*) the pairs were cabled for good balance and (*c*) the sheath of the cable was designed to provide good screening. Furthermore, in practice the loading per train would be up to 200 amps. Fortunately, Post Office junctions over this route are well removed from the route of the railway and, moreover, the Post Office route has a large number of cables on it thus providing a good screen.

Screening by Metallic-Sheathed Cables.

Another investigation of interest has been conducted into the possibility of reducing or dispensing with the lead used for cable sheathing.

Where circuits are in cable having a metallic sheath under the influence of a magnetic field, the sheath will also have induced in it a longitudinal voltage. The sheath has a very low resistance and hence a relatively large current will flow, in accordance with Lenz's Law, in such a direction that its field will reduce the inducing field. This reduction results in a reduction of the voltage induced in the conductors within the cable.

Evidently, if polythene-sheathed cables were to be used the screening effect would be lost. A survey of induced voltages on cables in several areas in the Home Counties Region where induced voltages were expected showed, however, that no general objection could be raised to plastic sheaths on the grounds of loss of screening. In a limited number of individual cases such as the Lancaster—Morecambe route already mentioned, such a change might be detrimental, but this would be the exception rather than the rule.

ACKNOWLEDGMENTS

It is desired to acknowledge the assistance given by Mr. D. C. Jones in the conduct of the investigations described in this article.

Book Review

"Radio Laboratory Handbook." M. G. Scroggie, B.Sc., M.I.E.E. Iliffe. 436 pp. 299 ill. Price 25s.

This, the sixth edition of Mr. Scroggie's book, is not just a reprint of the earlier ones; the book has been substantially re-written and is now presented enlarged in format as well as in the quantity of subject matter. The author directs the book not only at the professional worker in the radio field but also at the keen amateur working at home, and he has succeeded in producing a readable volume which is neither too dull and boring nor too elementary in its approach to the subject.

The engineer setting up a new laboratory, or the amateur adapting his garden shed for experimental purposes, will find much valuable advice on the best way of laying out his premises and equipment; on heating, lighting and the avoidance of radio interference. But the main body of the book is devoted to measurements and the equipment for making them. As the author points out in his preface, the availability of ready-made test equipment has increased a hundredfold since the first edition was published in 1938 and this is reflected in the contents of the book which contains many more illustrations and descriptions of proprietary instruments.

After discussing the fundamental principles of measurement, chapters are devoted to signal sources, indicators, standards and composite instruments such as bridges. The methods of using the equipment are then described and a useful chapter on dealing with results follows. This points out some of the pitfalls that may be encountered in interpreting the results of measurements. The book concludes with a useful reference section dealing with many varied subjects from such items as details of the M.K.S. system of units to the frequency allocations of British television stations.

T. K.

The Transistor

J. R. TILLMAN, Ph.D., A.R.C.S., and F. F. ROBERTS, B.Sc. (Eng.), A.M.I.E.E.†

Part 5.—Properties and Limitations

U.D.C. 621.314.7

The properties of transistors are presented, and explained in terms of the structure of the units. The removal of the limitations of present units—restricted frequency response and speed of switching, small power output, inability to function at elevated temperatures, and uncertain reliability—depend on factors and techniques which are becoming understood.

Static and Small-Signal (A.C.) Properties

Point-Contact Types.

The presentation of the properties of the early point-contact transistors took the form of static voltage-current relationships, analogous to those commonly used for thermionic valves. However, because the transistor is better understood as a current-controlled rather than a voltage-controlled device, the characteristics were shown with emitter current as the most important independent variable (cf. the control grid voltage for the thermionic valve). With the transistor considered as a four-terminal network, a knowledge of the relationships between the four quantities, emitter current, I_e, emitter-base voltage, V_{eb}, collector current, I_c, and collector-base voltage, V_{cb}, completely define the low-frequency properties. Their presentation took the form shown in Fig. **18**(*a*) and (*b*).

The key features of Fig. **18**(*a*), which shows V_{cb} against I_c for a series of equally spaced values of I_e, are:—

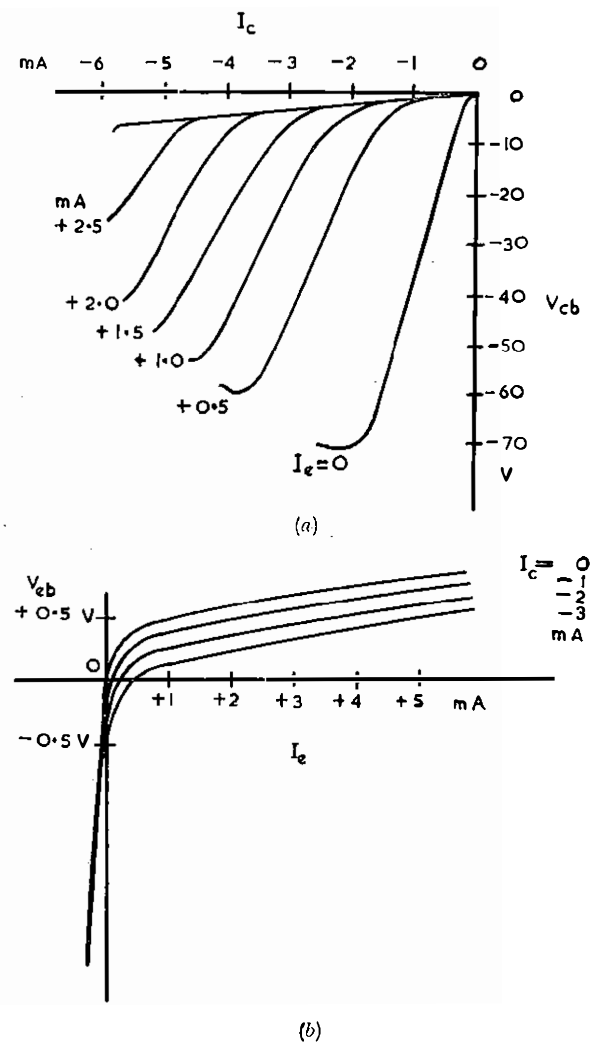


Fig. **18**.—Relationship between (*a*) V_{cb} and I_c, and (*b*) V_{eb} and I_e for a Typical Point-Contact Transistor.

(i) The finite value I_{co}, of I_c, when the emitter current is zero, whose dependency on voltage resembles qualitatively that of a point-contact diode under reverse bias; I_{co} is typically 1-2 mA at $V_{cb} = -10$V.

(ii) The approximately equal spacing between, and approximate parallelism of, the successive curves.

(iii) The inability of the collector to withstand more than a limited voltage without (ii) ceasing to apply. 50V can usually be withstood.

On the other hand the key features of Fig. **18**(*b*), which shows V_{eb} against I_e for a series of equally spaced values of I_c, are:—

(i) The resemblance between the curve for $I_c = 0$ and that for a point-contact diode biased in the forward direction.

(ii) The existence of a set of displaced curves rather than a coincident family; the display shows the inherent feedback in the transistor.

Two additional sets of curves were sometimes shown, of V_{eb} against I_c for a series of values of I_e, and V_{cb} against I_e for a series of values of I_c, but they contain no information not deducible from the first two sets.

Although the user of the point-contact transistor must refer to the sets of curves for large-signal applications, he can summarise the small-signal properties at any desired working point in terms of four differential parameters (cf. g_m and R_a of a triode valve). The four parameters can be chosen in several ways. Those of Fig. **19** are applicable to any linear 4-terminal network and are simply derived from the sets of curves, thus:—

$r_{11} = (\partial V_{eb}/\partial I_e)_{I_c}$ and $r_{12} = (\partial V_{eb}/\partial I_c)_{I_e}$ from Fig. **18**(*b*),
and $r_{21} = (\partial V_{cb}/\partial I_e)_{I_c}$ and $r_{22} = (\partial V_{cb}/\partial I_c)_{I_e}$ from Fig. **18**(*a*).

Those of Fig. **20** (already shown as Fig. **6**(*c*) in Part 2,[1] but reproduced here) are more commonly used when low-frequency amplifiers are being designed; they are derived from those of Fig. **19**, as follows:—

$$r_e = r_{11} - r_{12}, \quad r_b = r_{12}, \quad r_c = r_{22} - r_{12}$$
$$\text{and, } \alpha_{ce} = r_{21}/r_{22} = (\partial I_c/\partial I_e)_{V_{cb}}.$$

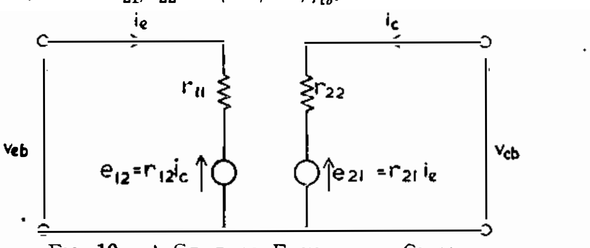


Fig. **19**.—A General Equivalent Circuit.
(Note: v_{eb}, v_{cb}, i_c and i_e are alternating quantities.)

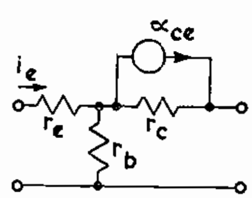


Fig. **20**.—An Equivalent Circuit of a Transistor

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

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

Typical values at $I_e = 1$ mA, $V_{cb} = -10$V are,
$r_e = 100\text{-}300\ \Omega$, $r_b \simeq 100\ \Omega$, $r_c \simeq 10\text{k}\Omega$ and $\alpha_{ce} = 1\cdot5\text{-}2\cdot5$.

The fact that α_{ce} exceeds unity leads to instability when r_b is large and the external resistance connected to the emitter is small—so much so that the use of the base terminal as the input is severely limited for small signal applications.

The parameters are however dependent on the working point chosen, r_b perhaps less so than the others. α_{ce} commonly shows a peak at some small value of I_e, as in Fig. 21. r_e falls with increasing I_e, and r_c shows wide variations with changes of I_c.

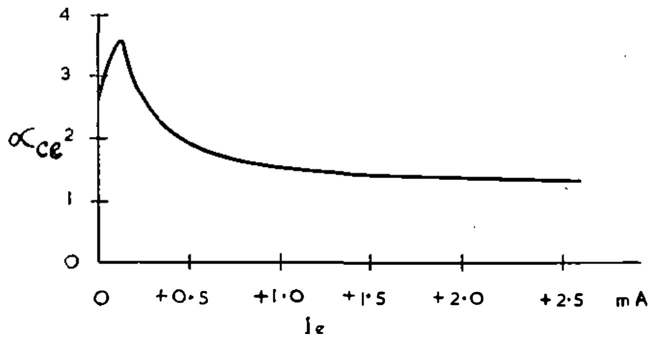


FIG. 21.—RELATIONSHIP BETWEEN α_{ce} AND I_e FOR A TYPICAL POINT-CONTACT TRANSISTOR.

The small-signal parameters are also frequency-dependent; only the dependence of α_{ce} is usually of any importance however. It can, for some purposes, be sufficiently well expressed by the relationship

$$(\alpha_{ce})_f = \alpha_{ceo}/(1 + jf/f_{\alpha ce})$$

where $f_{\alpha ce}$ is that frequency at which α_{ce} has fallen to 0·707 ($= 1/\sqrt{2}$) of its value, α_{ceo}, at low frequencies. $f_{\alpha ce}$ is very dependent on the emitter-collector spacing and has ranged at least from 0·1 Mc/s to 10 Mc/s for different types. The frequency-dependence of α_{ce} controls the high-frequency performance of point-contact transistors; the capacitances, and any frequency-dependence of the other parameters, are relatively negligible.

Junction Types.

When the static properties of junction transistors are represented in the same way as described for point-contact units, several marked differences appear. The curves of V_{cb} against I_c are much more nearly parallel to the voltage axis (i.e. r_c is very high, of the order of 1 MΩ), they are very uniformly spaced (i.e. α_{ce} remains constant) at intervals slightly less than those of I_e (that is, α_{ce} is nearly unity, typically 0·90-0·99) and I_{co} is small (a few μA). The curves for V_{eb} against I_e show r_{11} ($= r_e + r_b$) and r_{12} ($= r_b$) to be hardly distinguishable and each to have a value in the range 100-1000Ω. The presentation therefore conveys little quantitative information of value to users.

Because $\alpha_{ce} < 1$, the base can always be used as the input terminal, offering considerable circuit advantages. A better presentation of static properties is then that of V_{ce} against I_c for equal increments of I_b (which equals the difference between I_e and I_c), as in Fig. 22. The set of curves (which refer to currently available units) shows that the current gain, $\alpha_{cb} = (\partial I_c/\partial I_b)_{r_{ce}}$, can be large (e.g. 10-100), being in fact $\alpha_{ce}/(1 - \alpha_{ce})$, and that $r_{ce} \simeq (\partial V_{ce}/\partial I_c)_{I_b}$ is moderately large (e.g., 10–100 kΩ), being in fact $\simeq r_{cb}/\alpha_{cb}$ (r_{cb} being the sum of r_c and r_b and therefore, for a junction unit, closely equal to r_c). Linearity of I_c with I_b is still good, provided the collector voltage is not made to exceed some limit (now commonly 10–50V).

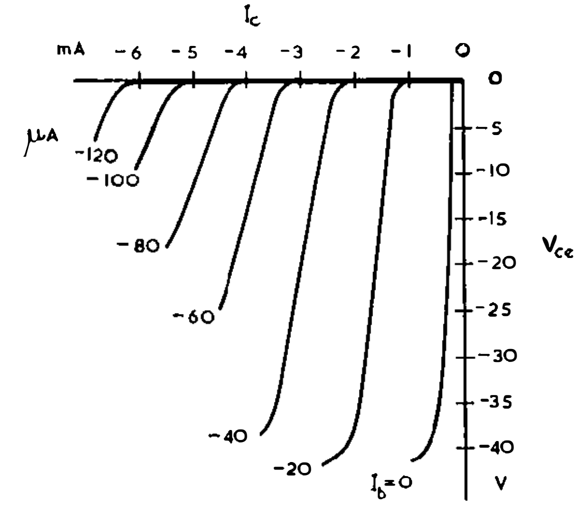


FIG. 22.—RELATIONSHIP BETWEEN V_{ce} AND I_c FOR A TYPICAL P-N-P JUNCTION TRANSISTOR.

The lower limit of V_{ce}, consistent with the retention of high values of α_{cb} and r_{ce} and good linearity is no more than 0·2V, a feature which distinguishes the performance of junction units from that of point-contact units and very markedly so from that of thermionic valves and which is of much value to designers of hearing aids.

The dependence of α_{ce} on frequency can once again be represented approximately as $(\alpha_{ce})_f = \alpha_{ceo}/(1 + jf/f_{\alpha ce})$, with $f_{\alpha ce}$ typically 0·1 Mc/s–10 Mc/s. However, $(\alpha_{cb})_f \simeq \alpha_{cbo}/(1 + jf/f_{\alpha cb})$, where $f_{\alpha cb} \simeq f_{\alpha ce}/\alpha_{cb}$ may be as low as a few kc/s. Other considerations show that the parameter $f_{\alpha cb}$ varies inversely with the effective lifetime τ_m of minority carriers in the base region (allowing for both surface and volume recombination); thus $f_{\alpha cb} \simeq 1/2\pi\tau_m$. It must not be assumed, however, that the frequency response of an amplifying stage using base-input is determined solely by $f_{\alpha cb}$. If the input circuit behaves more nearly like a constant voltage generator than a constant current generator, the response can be much improved and, if $r_b \to 0$, can approach that of α_{ce}; linearity is sacrificed, however. The collector-base capacitance, C_{cb}, of junction transistors varies with collector voltage V_{cb} (roughly as $V_{cb}^{-\frac{1}{2}}$ for alloy units and as $V_{cb}^{-\frac{1}{3}}$ for grown units), being 10–30 pF at $V_{cb} = -10$V for low-power units of either type. With base input the collector-emitter capacitance is about α_{cb} times greater. It is not usual, however, for the capacitance in conjunction with the collector load to set the upper limit of usable frequency of signal for a grounded emitter stage.

The common-base connection (emitter input and collector output) offers advantages where response at high frequencies is required and transformer coupling between stages is permissible; its backward transmission is small so long as it is determined only by the ratio r_b/r_c. The common-emitter connection (base input and collector output) offers advantages where negative feedback is to be applied over two or more stages, R–C interstage coupling being compatible with power gain; its backward transmission is also small. The common-collector connection, though resembling the cathode follower when used with base input (see table of Part 1[2]) can have large backward transmission.

NOISE

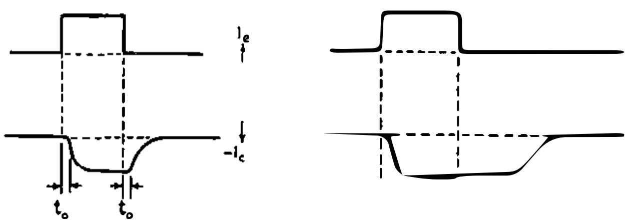
The noise output from a transistor amplifier exceeds that which, after allowing for the gain of the amplifier, can be accounted for by the thermal noise inherent in the resistance of the input signal source. The excess noise power per unit

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

bandwidth varies approximately inversely with frequency, thereby differing again from thermal noise. Junction transistors are much less noisy than point-contact units. Typical values of the noise power, expressed as $(\mu V)^2$ per c/s at 1 kc/s across a load of 1,000 ohms in the collector circuit of a grounded-base transistor with a 500-ohm generator resistance in the emitter circuit, are 0·002 for junction units and 5 for point-contact units. Individual units may differ from the mean of their type by up to 10 db.

The Transient Response of Transistors

The small-signal transient behaviour, e.g., the collector current change resulting from a small step change of emitter current, is deducible from the small-signal parameters and a full knowledge of the variation of α with frequency. It is preferable, however, to consider it qualitatively from first principles. The step of emitter current causes additional minority carriers to be injected into the bulk germanium (of a point-contact unit) or base layer (of a junction unit). The carriers drift or diffuse to the collector, but not all by paths taking equal times and very few by paths taking less than some minimum, t_0 (typically 0·1 μS). Hence, there is no appreciable collector response for a time t_0, after which the collector current rises to its steady state value (see Fig. **23**(*a*)) in a way determined by the geometry of the unit



(*a*) (*b*)

Fig. **23**.—The Transient Responses of Typical Transistors for (*a*) a Small Output Signal; and (*b*) a Large Output signal.

(I_e and I_c are not necessarily to the same scale.)

and by the relative contributions of drift and diffusion. To a first approximation the rise, beginning at t_0, can be expressed in the form $1 - e^{-t/t_1}$ where t_1 is a time-constant $\simeq 1/2\pi f_\alpha$. The same form of response is obtained for small negative-going as for small positive-going steps, provided I_e is never made negative.

If, however, the impedance, R_L, of the collector load, or the current change through it, is so large as to cause the collector-base voltage to fall to a very low value following a positive step of emitter current ΔI_e (i.e. $R_L\alpha\Delta I_e$ exceeds the effective supply voltage V_{eff} to the collector circuit), the steady state may be reached more quickly, but when, later, an equal negative step, $-\Delta I_e$, is applied to the emitter (restoring the emitter current to its initial value), the collector current recovers much more slowly than before, for the following reasons. The injected minority carrier current ΔI_e divides into two parts; the first $V_{eff}/\alpha R_L$ accounts for the increase of collector current V_{eff}/R_L while the remainder $(\Delta I_e - V_{eff}/\alpha R_L)$ results in an increase in the density of excess minority carriers in the base material, limited by the rate of recombination taking place there. When the emitter current is restored to its initial value the concentration of minority carriers close to the collector is so high as to maintain the collector current, I_c, initially at V_{eff}/R_L. As the concentration falls, by virtue of losses to I_c and through recombination, there comes a time, dependent on the magnitude of the previous excess current $(\Delta I_e - V_{eff}/\alpha R_L)$, when it is unable to maintain $I_c = V_{eff}/R_L$. Even then the subsequent return of collector current to its initial value may be slower than that applying for very small steps. Fig. **23**(*b*) typifies the response of junction units; for point-contact units the decay sets in earlier and less abruptly. The behaviour described is called hole-storage when point-contact or p-n-p junction units are involved (it would be electron-storage with n-p-n units) and limits the speed of switching in many circuits.

Temperature Dependence of Parameters and Power Handling Capacity

Some of the important properties of both point-contact and junction transistors are temperature sensitive; those already quoted refer to a temperature of about 20°C. Thus I_{co} of a point-contact unit may be twice as great at 50°C and of a junction unit ten times as great; the change may not be important in single-stage applications but can be very important in multi-stage direct-coupled circuits. r_c falls, perhaps by a factor of two, for both point-contact and junction units when the temperature is raised to 50°C. The current gain, α, of point-contact units is only slightly temperature-dependent over the range 20–50°C, but α_{cb} of some junction transistors, more particularly those made by the growing process, increases by as much as a factor of two, though for some alloy units the increase is very small.

At still higher temperatures, usually in the range 70–100°C (where intrinsic conduction in the germanium begins to play a significant part), one or more of the three parameters I_{co}, r_c and α show very marked changes, rendering operation of germanium transistors difficult, if not impossible, for most applications.

When a transistor is dissipating power at its collector contact or junction, heating occurs in that region. Because the maximum temperature which can be tolerated here is dependent on what has just been said and may be only 70–80°C for a junction unit, the allowable dissipation is dependent both on the ambient temperature and on the rate at which heat is removed (usually mainly by conduction) from the region. The different designs and mountings of junction transistor available result in a considerable range of heat transfer characteristics and hence of permissible collector dissipation. Typical values, for an ambient temperature of 50°C, range over 10–100 mW. Higher dissipations can be tolerated for short periods, e.g., up to 0·1 sec. Permanent damage, as opposed to instantaneous loss of properties and recovery on cooling, can result however if the temperature of the collector region rises so much as to modify the forming of a collector of a point-contact unit, to damage the base, emitter or collector connections to a grown junction unit, or, in an alloyed unit, to re-melt the indium and leave the junction less perfect than it was after its final processing. The low melting point of indium renders the alloyed units particularly susceptible to permanent damage by overheating.

The permissible dissipation of junction units is being increased, in units under development, by one or more of several means: the improvement of the thermal contact between the collector-base region and the outside case, the fitting of cooling fins, liquid cooling, the provision of good thermal connection between the case and any chassis in which the transistor is to be used, and the use of greater areas. The means are less applicable to point-contact units.

Reproducibility of Units

The equipment designer requires the spread of the parameters of any one type of transistor to be no greater, in general, than those of thermionic valves; the gap between this requirement and what can be achieved in large-scale production is steadily being reduced. The parameters which are most difficult to control in point-contact units are α, f_α and r_c; the first being dependent on the electrical forming of the collector, on the effective spacing, and on the lifetime of minority carriers as determined by the bulk and surface properties of the germanium; f_α is dependent on the effective spacing; and r_c on the forming of the collector. The parameters α_{cb}, $f_{\alpha ce}$, both of which are dependent on the base thickness, and r_{cb} are the most difficult to control in junction units; the effective lifetime of minority carriers in the base layer controls both α_{cb} and $f_{\alpha cb}$ ($\simeq f_{\alpha ce}/\alpha_{cb}$). The dimensions and centring of the emitter and collector of alloy units also influence the parameters, including the α's and f_α's and C_{cb}. The resistivity of the materials controls r_b, C_{cb} and the maximum usable collector voltage.

Reliability and Life

Early claims for the point-contact transistor quoted expected lives of up to 70,000 hours. Later work showed that there were many causes of failure which, for the constructions adopted, would generally set a much lower limit to life. The major causes appear to be of mechanical origin, and it has yet to be shown that any design suitable for large-scale production has overcome them. Their elimination is more difficult in units having very close emitter-collector spacings (i.e. the units of most use in applications to radio engineering and high-speed switching). The point-contact unit is very susceptible to mechanical shock, unless the contacts are embedded in a supporting medium, e.g., of wax, resin or highly viscous liquid. Differential thermal expansion is also a cause of failure. So far there has been little evidence that the ambient atmosphere which can reach the surface of the germanium adjacent to the contacts in some, not fully hermetically-sealed, constructions, has been a direct factor in deciding the life of units, but it may well be a major indirect factor by way of the mechanical changes it can induce in the supporting medium.

Mechanical considerations are of less importance in deciding the life of alloy junction units, though they may be significant for the grown unit, particularly in respect of its base connection. Of more importance has been the effect of water vapour and other contamination of the surface at and near the peripheries of the two junctions. Some contaminants can render the unit extremely sensitive to high relative humidities, reducing α and r_{cb}, and increasing I_{co} even when the collector voltage is low. High humidity alone will much reduce the maximum usable collector-base voltage. Hence encapsulation, other than in truly hermetically-sealed enclosures, invites ultimate failure due to the ingress of water vapour.

It is not yet clear what effects will determine the ultimate life of units which have been properly prepared and sealed in an inert atmosphere; one may be the diffusion of impurities in the electric field at the collector junction at the temperature prevailing there. Because it may be necessary, for mechanical and thermal reasons, to support the delicate germanium wafer or filament by means of wax, etc., the deterioration of the electrical properties of the supporting medium may set an earlier limit to the life of the unit.

Possible Ways of Overcoming Present Limitations

The chief limitations of germanium transistors as at present designed and manufactured are in respect of frequency response, power handling capacity and maximum ambient temperature. Noise prevents the use of point-contact units for low-level low-frequency amplification, for which purpose it can also be troublesome in junction units.

The possibilities of increasing the power handling capacity have already been discussed, but the use of alternative semiconductors capable of giving transistor action at much higher temperatures (e.g., 150°C) will automatically allow greater dissipation for any given structure at any given ambient temperature. Of the alternative materials, most interest attaches, at the present time, to silicon. Whereas the energy required to break a valence bond and thereby create a hole-electron pair is only 0·72 eV (electron-volts) for germanium (see Part 2), it is about 1·1 eV for silicon; as a result, silicon, doped with an amount of donor or acceptor impurity suitable for good transistor material, does not become "intrinsic" until the temperature is raised above 200°C. The technology of silicon for transistors is, however, more difficult than that of germanium, because of its higher melting point ($\simeq$ 1,400°C) and its liability to crystallise with an insufficiently perfect structure; it may be that the establishment of an efficient chemical purification process will ease the preparation of single crystals. The mobilities of holes and electrons in silicon are less than those in germanium (by factors of about 4 and 2 respectively); for given dimensions, therefore, silicon transistors are expected to be inferior in frequency and transient response. Some silicon transistors have recently been marketed in the U.S.A.

Although no other *element* appears to offer prospects as a transistor material, the silicon-germanium alloys and some compounds do. The alloys offer properties intermediate between those of the two elements, but there are new difficulties in preparing suitably doped monocrystals. True binary compounds or even ternary compounds offer possibilities which are being investigated in many laboratories. Most of the compounds between elements of groups III and V of the Periodic Table have a crystal structure similar to that of germanium and qualitatively comparable electrical properties; some, e.g., gallium arsenide ($GaAs$) offer prospects of use at temperatures up to perhaps 100°C. Transistor action has been observed in galena (PbS), a compound between elements of group IV and group VI, having a different crystal structure; but it and similar compounds are more suited to detectors of long-wave infra-red radiation than to transistors. Several ternary compounds, e.g., $CuInSe_2$ may have properties suitable for transistors up to some temperature above 20°C.

The problem of increasing the upper frequency limit of point-contact transistors is largely the mechanical one of consistently placing and maintaining the two contacts very close together. Electrical forming can make the effective spacing much less than the apparent spacing and units with $f_\alpha > 50$ Mc/s can be made, but the overall control under conditions of large-scale production appears extremely difficult.

The parameter $f_{\alpha ce}$ of junction units varies inversely as the square of the effective thickness, W, of the base layer through which the minority carriers have to diffuse. Methods of reducing W well below the value (0·001–0·002 in.) commonly used in both grown and alloy units, have been described. For grown units, a straightforward refinement of the method described in Part 4[3] can suffice and units with $f_{\alpha ce}$ up to 25 Mc/s have been made; but the base resistance, r_b, is much increased, as is the difficulty of making a reliable connection to the base region. For alloy units, a depression (of diameter about 0·05 in.) can be drilled in the wafer, for instance by an ultrasonic tool, to reduce the local thickness. After a light etch to remove the superficial damage caused, one indium pellet is alloyed in the bottom of the depression and another on the flat face of the wafer at a position immediately opposite the first pellet. Units made in this way have had $f_{\alpha ce} > 10$ Mc/s; r_b was little increased. The depression can also be obtained by electrolytic etching using a fine jet, as in the first part of the process of making surface barrier transistors (see Part 4).

The parameter $f_{\alpha cb}$ can be increased only if τ_m (the effective lifetime of minority carriers in the base region) is reduced; but a reduction of W, comparable to that considered above, is then required to maintain α_{cb} unchanged.

A new limitation arises when the base layer is made very thin and the collector is alloyed or electrodeposited. In any

[3] *P.O.E.E.J.*, Vol. 47, p. 217.

transistor the reverse bias across the collector-base junction, V_{cb}, causes the withdrawal of both electrons and holes from a region, known as a depletion layer, whose dielectric properties give rise to the collector-base capacitance, already stated to be proportional to $V_{cb}{}^{\frac{1}{3}}$ (i.e. the thickness of the layer is proportional to $V_{cb}{}^{\frac{1}{3}}$). In an alloy or surface barrier transistor the depletion layer is almost entirely within the base layer and at some value of V_{cb} the depletion layer extends the whole way across to the emitter. For thin-based units the break-through can occur when $V_{cb} < 10$V, severely limiting the voltage and power handling capacity of high-frequency units so made. In such units, as V_{cb} is increased from a low value, the effective thickness of the base material decreases and both $f_{\alpha ce}$ and α_{ce} increase, the more so as the break-through voltage is approached. The thin-based grown unit need not be so susceptible to break-through at high collector voltages, because most of the expansion of the depletion layer can be made to take place in the collector material, but as has been said, it has other drawbacks.

Recently a structure having a very thin base layer, but able to withstand a large collector voltage, has been described. It can be looked upon as having had its collector depletion layer thickened by the addition of an intrinsic layer between the base (through which the carriers diffuse) and the collector material. The frequency response is not appreciably worsened by the fact that the carriers have to traverse the intrinsic layer, because their transit takes place by drift in a time which can be made short compared with that taken to diffuse across the very thin base layer, the more so as V_{cb} is increased. Methods of making transistors of this structure, designated p-n-i-p or n-p-i-n (i for intrinsic material), in quantity, have yet to be described, but experimental units suggest the possibility of $f_{\alpha ce} > 100$ Mc/s.

The mechanism responsible for the low-frequency noise in point-contact and junction transistors is not well understood. Some positive correlation has been found empirically between the noise power and the value of I_{co} for noisy junction units, and improvements in the crystalline perfection of the germanium and in the cleanliness during processing and hermetic sealing appear to be leading to consistently quieter units.

Concluding Remarks

The properties of the junction transistors presently available make it possible for some telecommunication equipment to be designed around them, as Part 6 will show. An extension of their use to wider fields will depend upon the development of units having not only adequate reliability but in addition either higher power ratings or better high-frequency and transient responses, or both. There are signs that the overriding requirement of reliability is being approached by the techniques adopted for some recent low-power low-frequency units.

The properties of point-contact units suggest possible uses in radio-frequency and high-speed switching circuits, but the consistency and reliability of the units so far available leave much to be desired. It is not yet clear how far either the basic difficulties can be overcome, particularly in large-scale production, or the improved junction units may oust the point-contact type in the fields still open to it.

Part 6.—Applications

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U.D.C. 621.314.7:621.375.4 + 621.373.52

Transistor circuits demand new methods of design. So far the junction transistor promises to be more useful than the point-contact transistor in transmission equipment, as shown by the examples described of its use in experimental audio and music amplifiers and in a crystal-controlled oscillator. Both types of transistor have fields of application to switching.

Introduction

It is convenient to divide transistor applications into two classes, amplification and switching. The first requires a linear relationship between input and output, and the second requires well-defined end-states.

In the design of amplifiers using thermionic valves, various practices have become well established because they suit the particular properties of the thermionic valve; it does not follow, however, that they can be successfully applied to a new device such as the transistor. In the early days of transistor circuit design it was natural to seek inspiration from circuits using valves, and the principle of duality was used to develop a systematic procedure for converting valve circuits to transistor circuits. The method proved of little use, however, because the transistor is not a sufficiently perfect dual of a thermionic valve, and because impracticable component values frequently arose. Instead, the design of transistor circuits is best approached as a new branch of electronics.

Amplifiers using transistors are different from valve amplifiers mainly because the transistor is a current-operated device, and the circuit impedances are generally much lower than those encountered in valve circuits. In addition, backward transmission cannot be neglected in transistor circuits, whereas it usually can in thermionic valve amplifiers. Generally, transistor circuits require more powerful methods of circuit analysis than do thermionic valve circuits, because more parameters are needed to specify a transistor.

In switching circuits, transistors differ from valves in three main respects—their comparatively slow speed of operation (at present) due to minority-carrier storage, the versatility of the point-contact unit as a bi-stable circuit, and the low bottoming voltage of the collector (at which collector current becomes independent of emitter current). Typically, bottoming voltages are <1V for point-contact units and <0·1V for junction units. Early work on switching circuits used the point-contact transistor almost invariably, because it was available and because a single unit can be used to produce a bi-stable circuit. The junction transistor, however, is now coming into use in switching applications; two units are necessary to make a bi-stable circuit. The junction transistor may, because of its greater reliability, eventually supplant the point-contact unit in many switching applications.

Basic Details of a Transistor Amplifier

Fig. 24 shows a simple transistor amplifier using, as is common, the collector as the output electrode; it is assumed that the input electrode (base or emitter) is driven from a constant-current generator. Fig. 25 shows a family of collector characteristics plotted for fixed values of input current (compare Fig. 22 of Part 5). By applying a suitable bias current, I_1, at the input and a suitable steady collector

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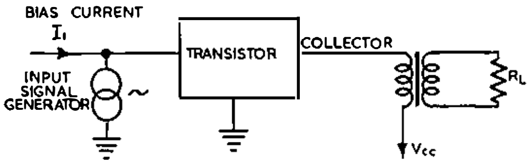


FIG. 24.—BASIC AMPLIFIER CIRCUIT.

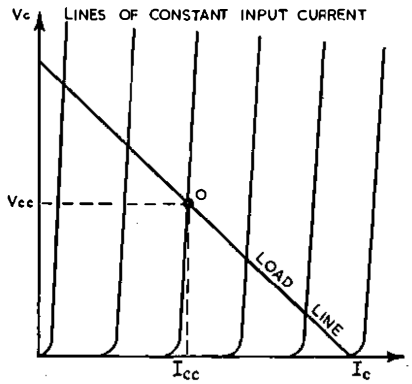


FIG. 25.—COLLECTOR CHARACTERISTICS AND OPERATING CONDITIONS OF BASIC AMPLIFIER CIRCUIT.

voltage, V_{cc}, at the collector, an operating point O is determined. When the input current is varied by the input signal generator, the operating point moves along a load line having a slope equal to the load resistance R_L seen at the primary of the output transformer. If the input signal is sufficiently increased, limiting takes place in the collector circuit either when the collector voltage falls to a low value and bottoming occurs, or when the collector current falls to I_{cbo}. Because of the low bottoming voltage, the Class A power efficiency of a transistor amplifier can approach 50 per cent. However, to obtain maximum output power, the load impedance R_L presented to the transistor must be approximately V_{cc}/I_{cc}; in power output stages rather low values of R_L are made necessary by the limitations on the collector voltages of present-day transistors. The low values of R_L often limit the stage gain obtainable when a large output power is desired.

POINT-CONTACT TRANSISTOR AS AMPLIFIER

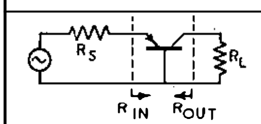
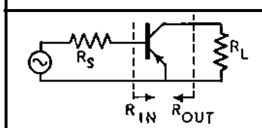
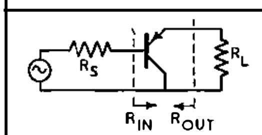
As mentioned in Part 5, the point-contact transistor, having $\alpha_{ce} > 1$, becomes unstable if sufficient impedance is added in the base circuit. For this reason, point-contact transistors used as amplifiers are generally operated with grounded base. Because the resulting input impedance is low and output impedance high, impedance transformation must be used between tandem-connected stages; otherwise the stage gain is limited to α^2_{ce} (typically 7 db.). The necessity for transformers makes wideband applications cumbersome, but several workers have described narrow-band I.F. amplifiers using point-contact transistors with grounded base. The point-contact transistor gives rise to considerable non-linear distortion in large-signal applications, because α_{ce} varies with emitter current (see Fig. 21 of Part 5). Point-contact units are also too noisy for some small signal applications, and at the present time the future of transistor amplifiers seems to lie with the junction transistor. Even at high frequencies, the junction transistor in n-p-i-n or p-n-i-p form, or the surface-barrier transistor, may well oust the point-contact unit.

JUNCTION TRANSISTOR AS AMPLIFIER

The junction transistor, having $\alpha_{ce} < 1$ (commonly 0·9 to 0·99), can be used with any electrode grounded, without fear of instability; each arrangement can give power gain for one direction of transmission but not for the opposite direction; their input and output impedances and gains are given in Fig. 26.

The grounded-base amplifier, having near-unity current gain, relies on its high output impedance and low input impedance to produce power gain. Typical values are, respectively, a few hundred thousand ohms and 10-100 ohms. Impedance transformation must be provided between stages connected in tandem to obtain power gain. Because the output impedance is so high, load impedances are typically much lower than the matching values; bandwidth is usually limited by $f_{\alpha cb}$ and not C_{cb}. The constancy of α_{ce} over the working region makes the relationship between emitter and collector currents much more linear than that between grid voltage and anode current in a thermionic valve, but distortion can arise because the emitter resistance, r_e, varies inversely with the emitter current.

It is common to make the source impedance, R_S, considerably greater than the matching value, in order to reduce distortion due to changes in r_e; the input circuit then behaves approximately as a constant-current generator. It must be emphasised that, in common with other transistor circuits, the input and output impedances are not independent of one another, as they often are in circuits using thermionic valves. For example, a typical junction transistor might have an output impedance of 0·5 MΩ

CIRCUIT CONFIGURATIONS	INPUT IMPEDANCE	OUTPUT IMPEDANCE	POWER GAIN * (db)
 (a) GROUNDED BASE	$R_{IN} = r_e + \frac{r_b(r_c - r_m + R_L)}{r_c + r_b + R_L}$	$R_{OUT} = r_c + \frac{r_b(r_e - r_m + R_S)}{r_e + r_b + R_S}$	$20 \log_{10}\left[\frac{2\sqrt{R_S R_L}(r_b + r_m)}{(R_S+r_e)(R_L+r_c)+r_b(R_S+r_e+R_L+r_c-r_m)}\right]$
 (b) GROUNDED EMITTER	$R_{IN} = r_b + \frac{r_e(r_c + R_L)}{r_e + r_c - r_m + R_L}$	$R_{OUT} = r_c + \frac{(r_e - r_m)(r_b + R_S)}{r_b + r_e + R_S}$	$20 \log_{10}\left[\frac{2\sqrt{R_S R_L}(r_m - r_e)}{(R_S+r_e+r_b)(R_L+r_c)+(r_e-r_m)(R_S+r_b)}\right]$
 (c) GROUNDED COLLECTOR	$R_{IN} = r_b + \frac{r_c(r_e + R_L)}{r_e + r_c - r_m + R_L}$	$R_{OUT} = r_e + \frac{(r_c - r_m)(r_b + R_S)}{r_b + r_c + R_S}$	$20 \log_{10}\left[\frac{2\sqrt{R_S R_L}(r_c)}{(R_S+r_b+r_c)(R_L+r_e+r_c-r_m)-r_c(r_c-r_m)}\right]$

* Power Gain is defined by comparison with an ideal transformer giving impedance match between R_S and R_L.
r_e = Emitter Resistance; r_b = Base Resistance; r_c = Collector Resistance; $r_m \simeq \alpha_{ce} r_c$ = Mutual Resistance.

FIG. 26.—CIRCUITS USING JUNCTION TRANSISTORS.

when its emitter faces a high impedance, but only 30,000 ohms when its emitter faces a short-circuit. Feedback is not readily applied to the grounded-base amplifier, because there is no phase reversal and because of the near-unity current gain.

The necessity for impedance transformation between stages can be obviated by using the grounded-emitter circuit, shown in Fig. **26**(*b*); the circuit has many useful properties and is perhaps more widely used than the grounded-base circuit. Because the input current flowing in the base circuit is the difference between the emitter and collector currents, there is a large current gain between the base and collector. If the load impedance is small compared with the output impedance of the transistor, the current gain between base and collector is $\alpha_{ce}/(1 - \alpha_{ce})$, a quantity designated α_{cb}. Because typical load impedances are often of the same order as the output impedance of the stage (e.g., a few tens of thousands of ohms), the *effective* current gain in working circuits is often considerably less than α_{cb}. When stages are directly coupled in tandem, without impedance transformation between them, the power gain per stage is equal to the square of the *effective* current gain; in typical circuits the gain per stage can be 25-35 db. The input impedance of the circuit is higher than that of the grounded-base amplifier; in typical circuits it ranges from about 500 to 3,000 ohms. Because the circuit produces a phase reversal and a large current gain, negative feedback is readily applied; an experimental audio-frequency line amplifier described later uses the circuit with mixed feedback. Because of the phase reversal between base and collector the large current gain does not give rise to instability if there is common impedance in the emitter circuit; on the other hand, the power gain of the stage is reduced. The desirable properties of the grounded-emitter circuit are obtained at a cost in the cut-off frequency of current gain, $f_{\alpha cb}$, and hence in bandwidth, as shown in Part 5; typical transistors have values of $f_{\alpha cb}$ of the order of 10 kc/s. Though the operating bandwidth, which depends on the impedance conditions at the base and collector of the transistor, is not necessarily equal to $f_{\alpha cb}$, the circuit is at present limited to applications covering little more than the audio-frequency range. With the availability of high-frequency transistors such as the n-p-i-n and p-n-i-p units, however, the range will be extended at least to cover the carrier-frequency spectrum.

The grounded-collector circuit (Fig. **26**(*c*)) has the useful property that its input impedance is, by transistor standards, very high. Values of 100,000 ohms can be obtained with matched conditions at the output. Because the potential difference between base and emitter is small, the output voltage is closely equal to the input voltage, and the circuit has analogies with the thermionic-valve cathode-follower. The circuit is useful as a power output stage when it is desired to operate from low-voltage supplies; higher power gain can then be obtained from the stage than when the collector is used as the output electrode.

Application of Negative Feedback to Junction Transistors

Line amplifiers have exacting requirements for linearity, constancy of gain and constancy of input and output impedances which have hitherto been met by using negative feedback. With the exception of α_{ce}, the parameters of junction transistors vary considerably from one unit to another, and a study of feedback applied to transistors is therefore necessary in the design of line amplifiers using them. When negative feedback is applied to a voltage-operated device (such as a thermionic valve) a *voltage* derived from the output circuit is added to the input voltage in such a way that the overall gain is reduced. Similarly, to apply feedback to a current-operated device (such as a transistor) it is necessary to add to the input current a *current* derived from the output circuit. Fig. **27** compares the two circuits. If the feedback current is to be

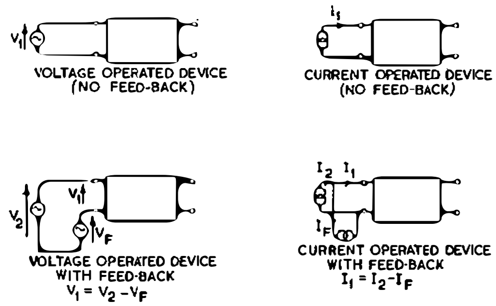


FIG. **27**.—COMPARISON OF VOLTAGE- AND CURRENT-OPERATED DEVICES WITH FEEDBACK.

derived from the output circuit without the use of a transformer, and if the use of transformers within the feedback path is to be avoided, the transistors must be used in such a way that the forward path gives a large current gain and provides a phase reversal. The grounded-emitter and grounded-collector circuits both produce large current gains, but only the grounded-emitter circuit produces a phase reversal; it therefore lends itself to the design of single-stage amplifiers with feedback. Fig. **28**, which forms the basis of the amplifier described in the next section, shows how mixed feedback can be applied to

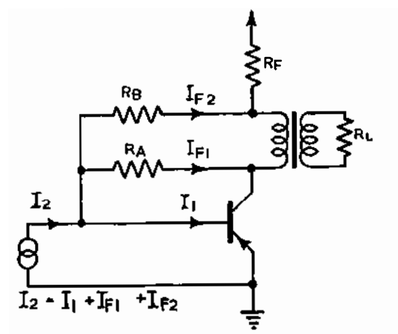


FIG. **28**.—MIXED FEEDBACK APPLIED TO A GROUNDED-EMITTER CIRCUIT.

a grounded-emitter circuit. By a suitable choice of values of R_F, R_B and R_A the two feedback currents I_{F1} and I_{F2}, respectively, can be made approximately proportional to the output voltage and output current in the external load R_L. This use of mixed feedback stabilises the output impedance of the amplifier in addition to stabilising the gain and reducing the harmonic distortion. Due to the generally low value of $f_{\alpha cb}$, the circuit just described is at present limited to audio-frequency applications.

Experimental Audio-frequency Line Amplifier using Junction Transistors

Fig. **29** shows an experimental audio-frequency line amplifier using junction transistors. Two transistors of the same type, operating in Class A push-pull, are used; the output power obtainable is then nearly equal to the no-signal dissipation of one transistor, about 40 mW for the type used. Because the transistors operate at maximum output, the load impedance presented at the collector of each transistor must be V_{co}/I_{cc}, as shown previously; this load impedance therefore increases as the supply voltage is increased, and it is desirable to use transistors having a high working voltage if high gains are required. The operating point of the amplifier must be well-stabilised, because the maximum output power is otherwise rapidly lowered. Thus 10 per cent. change in the no-signal

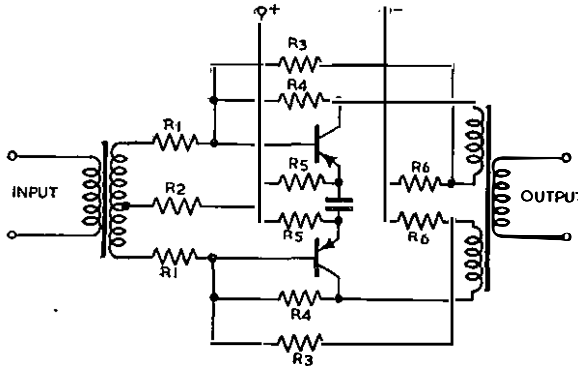


FIG. 29.—EXPERIMENTAL AUDIO-FREQUENCY LINE AMPLIFIER USING JUNCTION TRANSISTORS.

collector current could cause 20 per cent. reduction of maximum output power. To obtain sufficient stability, it is not satisfactory merely to supply a fixed-base current because changes of I_{ceo}, occurring due to changes of ambient temperature, would cause prohibitively large variations of emitter current. In the amplifier, the bases of the transistors are connected to potentiometers (R6, R3, R1 and R2) which determine their potential, while the resistors R5 are connected in series with the emitters. Because the potential difference between base and emitter is small, the emitter currents are closely determined independently of I_{ceo}. Mixed feedback is provided by the circuit comprising the resistors R3, R4 and R6; the spread of characteristics of the transistors at present available make it necessary to provide individual adjustment of R4 and R6 in each amplifier in order to obtain the correct output impedance, the reduction of gain by feedback being only about 5 db. Other details of the performance of the amplifier are given in Table 1.

TABLE 1

Performance of Experimental Audio-frequency Line Amplifier

Power consumption		4·8 mA at 50V
Overload point at 20°C ambient		+ 14 dbm.
Overload point at 50°C ambient		+ 10·5 dbm.
Bandwidth (for 3 db. fall of gain)		100 c/s—15 kc/s
Harmonic distortion at an output level of + 10 dbm. at 1 kc/s,		0·7%
Noise at output (C.C.I.F. Telephone weighting)		0·08 mV
Input impedance (return loss against 600Ω at 1 kc/s)		25 db.
Output impedance (return loss against 600Ω at 1 kc/s)	at 20°C ambient	29 db.
	at 50°C ambient	19 db.
Gain	at 20°C ambient	27·3 db.
	at 50°C ambient	27·7 db.
Loss from output to input terminals		approx. 51 db.

EXPERIMENTAL 3-STAGE LINE AMPLIFIER

Because the amplifier described in the last section does not give sufficient gain to replace existing line amplifiers, it is necessary to consider other circuits giving larger gain without feedback. An amplifier with three grounded-emitter stages in tandem is attractive because, like a single stage, it produces a phase reversal. An experimental amplifier with mixed feedback applied across three stages has been constructed and its circuit is shown in Fig. **30** in simplified form (power supplies and stabilising circuits have been omitted). Shunt feedback is provided by the resistor R4, and series feedback by the resistors R3 and R6. More feedback is applied than in the amplifier described in the last section; it reduces the gain from 77 db. to 52 db. Problems of stability were encountered during the development of the amplifier; they were overcome by the use of an inductance in series with the emitter of the input transistor, and a small capacitance in parallel with R4. Details of the performance of the amplifier are given in Table 2.

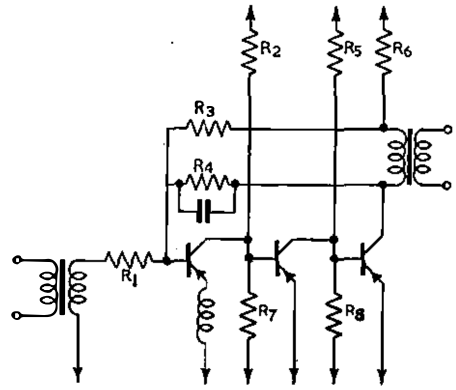


FIG. 30.—EXPERIMENTAL THREE-STAGE LINE AMPLIFIER USING JUNCTION TRANSISTORS.

TABLE 2

Performance of Experimental 3-stage Line Amplifier

Power consumption	10 mA at 30V
Gain	52 db.
Overload point	+ 11·5 dbm.
Bandwidth (for 3 db. fall of gain)	40 c/s to 25 kc/s.
Harmonic distortion at 1 kc/s and an output of + 10 dbm.	1·0% (40 db. signal/harmonics)
Noise at output (C.C.I.F. Broadcast weighting)	1 mV.

JUNCTION TETRODES AND THEIR POSSIBLE APPLICATIONS

The description "junction tetrode" may be applied to two quite different forms of junction transistor, but it is most commonly used for an n-p-n grown-junction triode having two similar ohmic connections made to opposite sides of the p-layer, a construction which presents considerable technological difficulties. One of these connections forms the normal base lead, while the other is biased negatively to such an extent that only a small part of the emitter junction near the normal base lead is operative. The base resistance, which tends to be high in simple grown-junction triodes owing to the length of the path of the base current through the base layer, is thus reduced in the tetrode. Because the base resistance produces feedback which limits the frequency response with emitter input to a figure below that associated with minority-carrier diffusion through the base, the tetrode has an improved high-frequency performance for a given thickness of base layer. The cross-section, and hence the capacitance, of the collector junction is, in practice, also reduced below that typical of junction triodes, thereby further increasing the maximum usable frequency of the unit as an amplifier. The low-frequency current gain of such junction tetrodes is generally lower than that of triodes, and the high-frequency performance can be at least equalled by thin-based grown and alloy junction triodes, and considerably improved upon by surface-barrier triodes and p-n-i-p or n-p-i-n units. Nevertheless, a line amplifier has been constructed in the U.S.A. to show how the tetrode might, some day, have a use in coaxial systems; it gives a gain of 22 db. over a bandwidth of 10 Mc/s.

A second (uncommon) use of the expression "junction tetrode" is for a grown unit having four alternate layers, either as n-p-n-p or p-n-p-n. The first layer is the emitter region, the second forms the base region, while the third and fourth together are referred to as an n-p or p-n "hook," the fourth region being connected to the load and suitably biased. The third layer may be left floating or it may be connected to the fourth by way of an ohmic or non-ohmic impedance to produce a variety of characteristics for the unit as a whole. The arrangement is best analysed by regarding the single n-p-n-p or p-n-p-n unit as made up of two physically separate n-p-n or p-n-p units having two

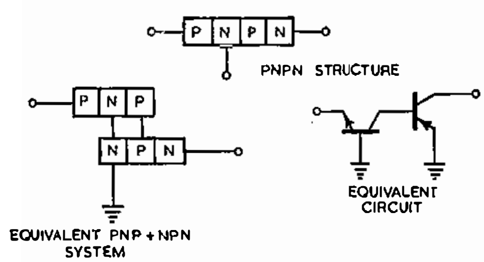


FIG 31.—EQUIVALENTS OF P-N-P-N GROWN UNIT.

interconnections, n to n and p to p, as shown in Fig. **31**. It is seen that the tetrode is equivalent to a grounded-base junction triode directly coupled to a grounded-emitter junction triode, and hence that, if the third layer is left floating, the unit has a current gain large compared with unity together with a low cut-off frequency and low output impedance relative to the corresponding parameters for a grounded-base triode.

COMPLEMENTARY SYMMETRY USING JUNCTION TRANSISTORS

The n-p-n transistor operates with its collector biased positively and with a negative emitter current, whereas the p-n-p transistor operates with its collector biased negatively and with a positive emitter current. If a positive-going signal is applied to their emitters, both types of transistor produce positive-going signals at their collectors, although the n-p-n unit is being driven towards current cut-off and the p-n-p unit turned on more fully. Thus, a pair consisting of an n-p-n and a p-n-p unit joined in parallel (with suitable arrangements for D.C. supplies) operates in push-pull when a signal is applied to them, as shown in Fig. **32**, and the

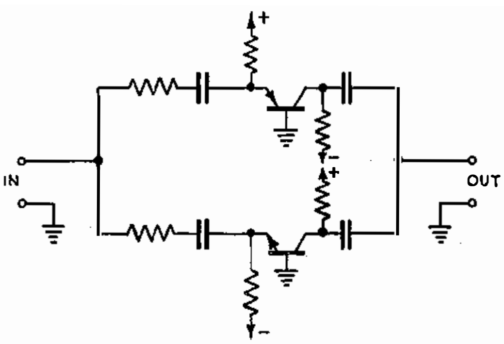


FIG. 32.—A PUSH-PULL AMPLIFIER USING COMPLEMENTARY SYMMETRY.

advantages of push-pull operation (either Class A or Class B) can be obtained without the phase-reversal necessary in valve amplifiers. The use of pairs of complementary transistors together is known as complementary symmetry; it is an example of the way in which transistors are opening up new possibilities in circuit design. By using n-p-n and p-n-p transistors alternately in a direct-coupled amplifier, the need for a multiplicity of power supplies is avoided. A two-stage push-pull amplifier has been described which has no coupling components and operates a loudspeaker without using an output transformer. Applications of complementary symmetry in this country must, however, await the availability of complementary pairs of transistors.

POINT-CONTACT TRANSISTOR AS AN OSCILLATOR

Because the point-contact transistor (with $\alpha_{ce} > 1$) can exhibit a negative resistance when connected in a suitable circuit, oscillators using point-contact transistors are generally two-terminal.

Thus, the oscillator in Fig. **33** has a series-tuned circuit driven by the negative resistance which is produced at the emitter of a point-contact transistor when a resistance is connected in series with its base. At negative emitter currents the emitter is biased in the reverse direction, and its impedance is high (AB in Fig. **33**). When emitter current, I_e, flows in the forward direction, however, the collector current, I_c, flowing into the base exceeds the emitter current, I_e, flowing out of it, and the base potential falls. If R_b is large enough, the emitter potential, V_e, falls with increasing emitter current, giving the negative resistance region BC. At C, the collector-base potential has fallen to such a low value that the current gain has become less than unity, and the emitter input resistance again becomes positive, giving the region CD. If the emitter is biased to a point on BC, and a series-tuned circuit added to the emitter, oscillation will result if the series resistance of the circuit is less than the slope of BC. At high frequencies the current gain, α_{ce}, of the transistor becomes complex, and the maximum frequency of oscillation obtainable cannot exceed that at which the real part of α_{ce} has fallen to unity. By using a suitable complex impedance in the base circuit, a somewhat higher maximum frequency is obtainable, not exceeding that at which the modulus of α_{ce} has fallen to unity. To obtain oscillation above these frequencies it is necessary to use a feedback circuit, as described in the following section. The maximum obtainable frequency of oscillation is then, in principle, that at which the *power* gain of the transistor has fallen to unity.

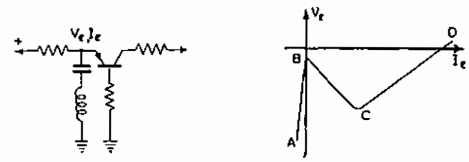


FIG. 33.—A TWO-TERMINAL OSCILLATOR USING A POINT-CONTACT TRANSISTOR.

JUNCTION TRANSISTOR OSCILLATOR

It is not possible to make the junction transistor exhibit negative resistance merely by the addition of resistance in series with its electrodes, and oscillators using junction transistors are usually of the feedback type, using the transistor as an amplifier in one of the ways described in a previous section. Of the three circuits of Fig. **26**, the grounded base is best suited to high-frequency operation. Fig. **34** shows an experimental oscillator suitable for use as

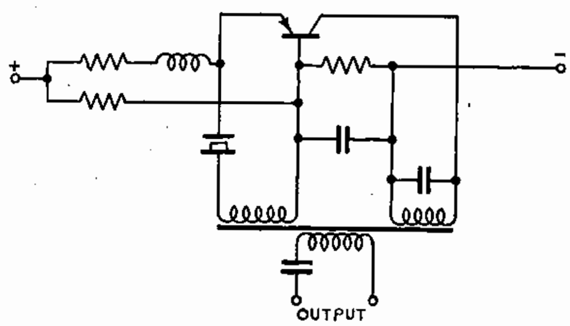


FIG. 34.—A QUARTZ-CRYSTAL CONTROLLED OSCILLATOR USING A JUNCTION TRANSISTOR.

a portable frequency standard or as a carrier frequency source; with the junction transistors at present available in this country the maximum frequency attainable without undue dependence on the transistor parameters is of the order of 300 kc/s. The experimental oscillator uses a CT-cut quartz crystal oscillating in its series mode, connected in series with the emitter. The transformer gives a sufficient step-up of current from the collector to the emitter to ensure oscillation when the output terminals of the oscillator are closed with their designed load impedance. The amplitude of oscillation is determined by limiting in the collector circuit; the abruptness of the limiting in a junction transistor makes the output level closely proportional to the supply voltage. The transformer is tuned to the frequency of oscillation, thereby reducing the harmonic content of the output signal. The load impedance presented to the collector of the transistor is determined by the supply voltage and the output power required, and is small compared with r_c. The series impedance of the crystal is large compared with the input impedance of the transistor, so that the only parameter of the transistor of any importance is α_{ce}, whose variation is small from one unit to another; thus, the choice of transistor is not critical. However, the design of the oscillator calls for a close tolerance on the series resistance of the crystal, and, because the loop gain is sensitive to the value of the external load, the latter must not vary too widely from the nominal value.

The performance of the oscillator is summarised in Table 3.

TABLE 3

Performance of Experimental Quartz-crystal-controlled Oscillator

Frequency	245·90 kc/s
Power output	8 mW
Power consumption	6·1 mA at 6V
Harmonic content of output signal	3%

Recent work in the U.S.A. has shown that oscillation at the maximum possible frequency with junction transistors requires low values of collector capacitance and base resistance as well as a high value of $f_{\alpha ce}$. For both surface barrier and p-n-i-p transistors, upper frequency limits between 100 and 200 Mc/s have been reported.

The Transistor as a Switching Device

As a switching device, the transistor has both advantages and disadvantages compared with the thermionic valve. The advantages are its small size and low power consumption, which are particularly important in the engineering of electronic computors. The main disadvantage is the lower speed of operation of transistors, for whereas the thermionic valve can readily perform 10^6, or more, switching operations per second, the transistor in the forms now commercially available is generally limited to some 10^5 operations per second. In respect of speed and power consumption, the present-day transistor is more comparable with the cold-cathode tube; but surface-barrier, p-n-i-p and n-p-i-n transistors should enable switching speeds of 10^6 per second to be reached.

The negative-resistance properties of the point-contact transistor can be utilised to produce a bi-stable circuit using only one transistor, instead of the two valves necessary in thermionic circuits. Thus, if in Fig. **35** the emitter is joined

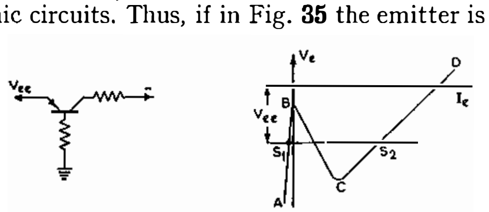


Fig. **35**.—A Bi-stable Circuit using a Point-Contact Transistor.

to a constant voltage supply intermediate between the emitter voltages at points B and C, the circuit is stable with the transistor turned off (point S_1) and also with the collector in a bottomed condition (point S_2). A negative pulse applied to the emitter can cause transition from S_2 to S_1, and a positive pulse can cause transition from S_1 to S_2. Despite the simplicity of the circuit, it is of limited use because of the variability of the parameters of present-day point-contact transistors, and additional components must be added to stabilise the operation of this and similar circuits.

The junction transistor, though it cannot be used to produce a bi-stable circuit with only one transistor, nevertheless has potential applications in switching circuits. A novel feature of the junction transistor is that, when it is turned on by applying a base current, considerably larger currents can be drawn between emitter and collector in either direction, with a voltage drop $V_{ce} < 0{\cdot}1$V; in fact, the roles of emitter and collector can be interchanged. The current which can pass between emitter and collector with low voltage drop is limited to $\alpha_{cb} I_b$; when the transistor is conducting in the reverse direction the corresponding current gain, α_{eb}, with emitter acting as collector and vice versa is greatly reduced, perhaps to a value of 2 or less in normal transistors. To make a bi-directional switch a symmetrical junction transistor has been proposed, having equal-sized emitter and collector junctions. Moderately high values of α_{cb} and α_{eb} are then obtainable for conduction in either direction. The device opens up new possibilities in switching applications; for example, modulators using it have been described, and also a simple and highly efficient television line-scanning circuit.

Concluding Remarks on the Series

Since Part 1 of the series was written, several important laboratory advances have been made. Thus, the p-n-i-p unit (described briefly in Part 5) has been more fully explored, though no production had been announced at the time of writing. Techniques for the production of surface-barrier transistors of consistent high-frequency performance, using germanium or silicon as base material, are being steadily refined. In addition, further types of transistor hitherto made only on a laboratory scale have been produced in the U.S.A. Silicon material has been much improved and at least one American company is offering n-p-n grown-junction silicon transistors for sale. A large-area p-n junction diode, produced by the diffusion of boron into one face of a wafer of n-type silicon, has been demonstrated as a generator of electrical power, using the photo-voltaic effect with sunlight as the source of energy.

The need for reliability of transistors has been increasingly recognised; hermetically-sealed, all-glass, metal and glass, or metal and ceramic, envelopes have almost entirely displaced plastic encapsulation. It appears, however, that freedom from contamination immediately prior to sealing is not always achieved in production.

Compared with thermionic valves, the present types of transistor involve fewer factors in their design, fewer steps in their manufacture and no more intrinsic cost in the raw materials. Ultimately, therefore, their cost in mass-production should compare favourably with that of valves of similar power ratings.

Applications—beyond that in hearing aids, where, already in the U.S.A. the transistor seems to have largely, if not entirely, displaced the thermionic valve—will grow in number as the suitability and reliability of mass-produced transistors are proved, e.g., by laboratory tests (including life tests) and by field trials of equipments such as those described in Part 6. The newer designs offer scope for wider applications in domestic radio and in television, in radio and line communications and in high-speed switching.

Detailed references have not generally been given in the text of the series. The following references for further reading are recommended:—

"Holes and Electrons in Semi-conductors," W. Shockley, published by D. van Nostrand.

Proc. Inst. Radio Eng. (New York). November, 1952.

"Principles of Transistor Circuits," R. F. Shea, published by Chapman & Hall Ltd.

Meeting of C.C.I.R. Study Group IX, Geneva, September 1954

U.D.C. 061.3:621.396

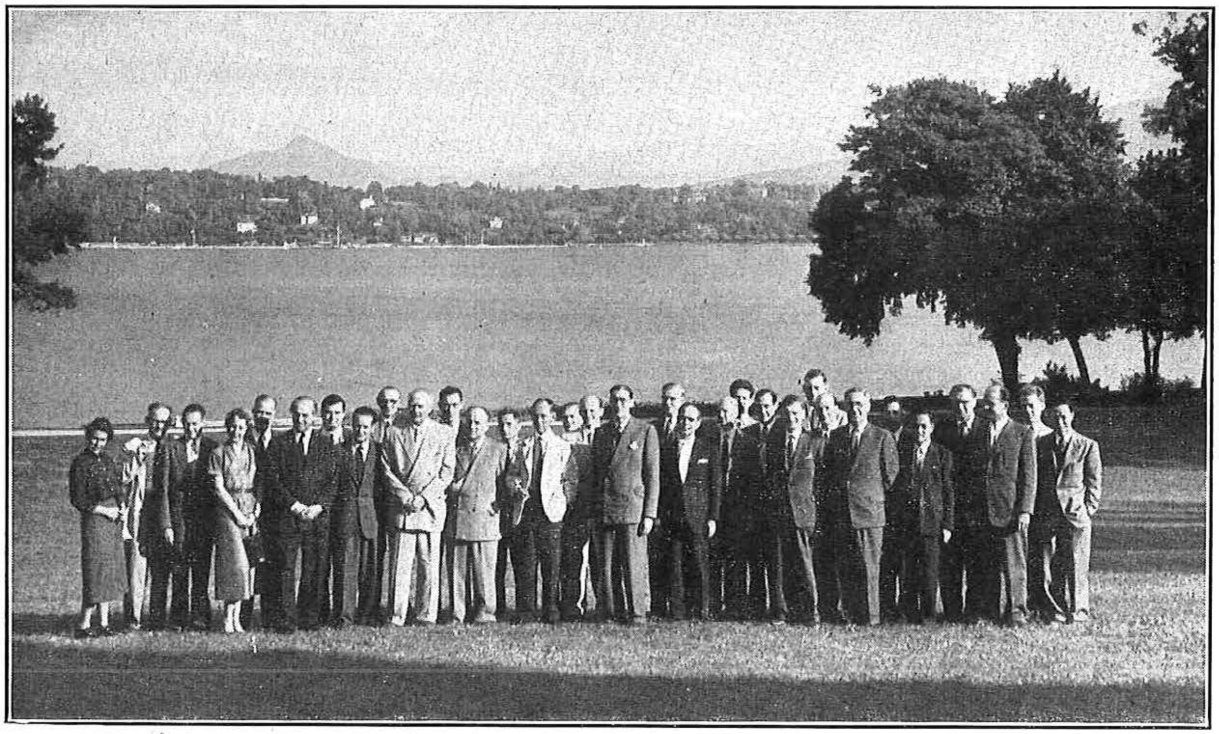
A note on the recent meeting of C.C.I.R. Study Group IX held in Geneva to discuss the characteristics of international radio-relay systems for multi-channel telephony and television.

Introduction

THE last Plenary Assembly of the C.C.I.R. was held in London in 1953, the next will be held in Warsaw in 1956, and in view of the rapidity with which radio-relay systems for television and multi-channel telephony are being developed in various countries an interim meeting of the C.C.I.R. study group concerned with such systems, Study Group IX, was held in Geneva from 10th to 22nd September, 1954.

The Conference, which was held in the Villa Bartholini, the headquarters of the C.C.I.R., was concerned with the following questions:

QUESTION NO. 90: *"International Wide-Band Radio-Relay Systems Operating on Frequencies Above About 30 Mc/s: Interconnection of Multiplex Systems."*
(Concerned with the relative advantages and disadvantages of time-division multiplex and frequency-division multiplex and associated interconnection problems.)



STUDY GROUP IN GROUNDS OF VILLA BARTHOLINI—LAKE GENEVA AND ALPS IN BACKGROUND.

Some 40 delegates, representatives and experts participated, from the following Administrations, private operating agencies, and scientific and manufacturing organizations:

- Australia
- Ceylon
- Czechoslovakia
- Denmark
- Federal German Republic
- France
- Italy
- Japan
- Norway
- Netherlands
- Switzerland
- United Kingdom
- U.S.A.
- U.S.S.R.
- Yugoslavia
- Compagnie Générale de T.S.F.
- International Marine Radio Co., Ltd.
- Marconi International Marine Communication Co., Ltd.
- Nippon Telegraph and Telephone Public Corporation
- Siemens & Halske
- Telefonaktiebolaget L.M. Ericsson.

The United Kingdom was represented by Messrs. Stanesby and Bray (G.P.O.), and Mr. Bryden (nominated by the Radio Industry Council) attended as an expert.

QUESTION NO. 91: *"International Wide-Band Radio-Relay Systems Operating Above About 30 Mc/s: Transmission of Telephony and Television in the Same System."*
(Concerned with the advantages of systems capable of transmitting television and telephony simultaneously or alternatively over the same broad-band channel, and with their characteristics.)

QUESTION NO. 92: *"Standardisation of Multi-Channel Radio-Telephone Systems Using Time-Division Multiplex and Operating at Frequencies Above About 30 Mc/s."*

QUESTION NO. 93: *"Standardisation of Multi-Channel Radio Systems Using Frequency-Division Multiplex and Operating at Frequencies Above About 30 Mc/s."*

QUESTION NO. 96: *"Maintenance Procedure for Wide-Band Radio Systems."*

QUESTION NO. 97: *"Hypothetical Reference Circuit for Wide-Band Radio Systems."*
(Concerned with formulating a hypothetical reference circuit so that designers of radio-relay systems for international use may be able to apportion the permissible noise contributions among various parts of the systems.)

The Study Group was also concerned with formulating its views on 23 questions and draft recommendations of the C.C.I.F.

Work of Conference

The Conference was opened by Mr. L. W. Hayes, Vice-Director of the C.C.I.R., who welcomed the delegates in the temporary absence of the Director, Professor Dr. van der Pol, after which Mr. Stanesby took the Chair.

Some 36 documents had been submitted before the Conference opened, including a report by the Chairman on those documents that had been in his hands a few weeks earlier, so that there was plenty of material upon which to base discussions. To expedite the work the study group divided into two parts: Sub-Group IXA, Chairman, Mr. Stanesby (U.K.), concerned with Questions Nos. 91, 93 and 97; and Sub-Group IXB, Chairman, Mr. Klein (Switzerland), concerned with Questions Nos. 90, 92 and 96. The C.C.I.F. Questions and Draft Recommendations were considered by the study group as a whole.

Within the compass of this brief article it is possible only to summarise the work done at Geneva. Four Draft Recommendations, 10 Draft Reports and three Draft Questions were formulated covering virtually all aspects of international radio-relay systems, and these, subject to any alterations or amendments that may be decided upon by the study group in 1956, at Warsaw, will be submitted to the Plenary Assembly for its approval. The contents of these documents are summarised very briefly below, the questions to which they refer being indicated:

Question No. 90:

Draft Recommendation: Procedures relating to the international interconnection of time-division and frequency-division-multiplex radio-relay systems are recommended and a general preference is expressed for frequency-division multiplex where new systems are concerned.

Draft Report: Discusses the economic, technical and maintenance problems arising if both time-division and frequency-division multiplex are used in international radio-relay networks.

New Question: This question asks whether in international connections between different types of radio-relay systems each Administration should accept on the receive side the conditions of transmission normal to the incoming system.

Question No. 91:

Draft Report: The advantages arising from the alternative or the simultaneous transmission of multi-channel telephony and television on the same radio-frequency carrier of a radio-relay system are discussed. It is felt that the alternative transmission of telephony or television is practicable and advantageous, but that it would be premature to comment on their simultaneous transmission without further studies, which are outlined.

Question No. 92:

Draft Recommendation: The relevant C.C.I.F. rules for international connections at audio-frequencies and for international signalling on metallic circuits are recommended for time-division multiplex radio-relay systems.

Draft Report: This lists the technical characteristics that need to be specified to facilitate the interconnection of time-division-multiplex radio-relay systems.

Draft Report: Considerations governing the choice of the fundamental characteristics of time-division-multiplex channelling equipment for radio-relay systems are outlined. The advantages of so choosing the characteristics of a 12-channel system that the pulses of two such systems could be interlaced to form a 24-channel system, are indicated.

Draft Report: The preferred baseband characteristics for time-division-multiplex pulse-position-modulation radio-relay systems are stated.

Question No. 93:

Draft Recommendation: It is recommended that C.C.I.F. rules on the method of making connections at audio frequencies, the method of signalling and the characteristics of the frequency-division-multiplex terminal equipment on international metallic circuits be adopted for radio-relay systems.

Draft Report: The report outlines the preferred arrangement in the frequency spectrum of broad-band channels in international radio-relay systems carrying frequency-division-multiplex telephony and/or television. It also deals with the broad-band channelling arrangements to be adopted for blocks of 240 and 600 telephone channels and one or more television transmissions, handled on the same radio-relay system.

Draft Report: The choice of the frequency deviation to be used on frequency-modulated frequency-division-multiplex radio-relay systems is discussed.

Draft Report: Reasons are given why various characteristics of frequency-division-multiplex radio-relay systems should be standardised to facilitate interconnection, and the characteristics themselves are listed.

Draft Report: Preferred values are given for certain characteristics relating to international interconnections between radio-relay systems at baseband, intermediate-frequency and radio-frequency. The preferred values for baseband interconnections apply to systems carrying 24, 60, 120, 240 and 600 telephone channels per broad-band channel and cover the nominal impedances and the levels at the points of interconnection. Other data are given for intermediate- and radio-frequency interconnections.

Draft Report: Certain characteristics relating to the intermediate-frequency and radio-frequency interconnection of radio-relay systems transmitting television are discussed, notably the frequency deviation and the frequency stabilisation of the carrier.

Question No. 96:

It was considered premature to consider this question, hence no work was done on it.

Question No. 97:

Draft Recommendation: The general form of a hypothetical reference circuit for frequency-division-multiplex radio-relay systems transmitting 60 telephone channels or more is formulated. The permissible noise overall should, it is stated, receive further study.

New Question: Attention is directed to the need for evolving a method of computing the intermodulation noise in radio-relay systems handling multi-channel telephony.

New Question: This question asks what frequency tolerances should be adopted for wide-band radio-relay systems.

It does not necessarily follow that the value of a technical conference is proportional to the amount of paper consumed; nevertheless, the fact that 86 separate documents were prepared and issued before or during the conference shows that a great deal of work was done. It was found possible to reach agreement extending over a very wide field, and to adopt, albeit tentatively, preferred values for many of the parameters affecting international connections between radio-relay systems. The meeting also drew attention to those matters specially in need of further study. It is believed that as a result Administrations will be far less likely to commit themselves firmly to various incompatible standards for radio-relay systems, and that the way has been paved towards a large measure of agreement at Warsaw in 1956.

H. S.

Notes and Comments

New Year Honours

The Board of Editors offers congratulations to the following members of the Engineering Department honoured by Her Majesty The Queen in the New Year Honours List:

Cardiff Telephone Area	Skinner, C. L.	Technical Officer	British Empire Medal
Engineering Department	Daly, G., M.B.E.	Staff Controller	Officer of the Order of the British Empire
Home Counties Region	Owles, F. H.	Senior Draughtsman	Member of the Order of the British Empire
London Telecommunications Region	Jeffery, J. P., M.M.	Technician Class I	British Empire Medal
London Telecommunications Region	Whittaker, A. W.	Senior Executive Engineer	Member of the Order of the British Empire
Newcastle-on-Tyne Telephone Area	Rutherford, W.	Technician Class I	British Empire Medal

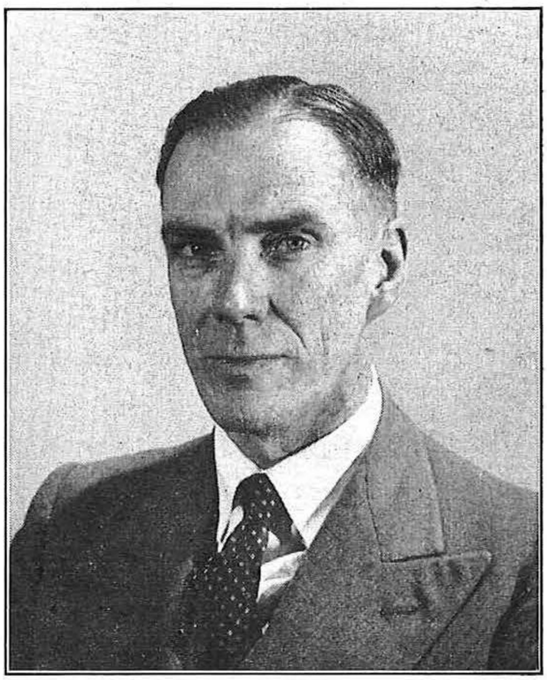
Commendation by the Postmaster-General

We note with pleasure that the Postmaster-General has commended Mr. C. Dawson, Technician IIB, Manchester Telephone Area, to whom the Royal Humane Society has awarded its Testimonial on Vellum for his gallantry in going to the help of a colleague who was overcome by gas in a manhole at Stockport on 27th April, 1954.

C. E. Calveley, O.B.E., E.R.D., B.Sc.(Eng.), M.I.E.E.

Mr. Calveley, promoted Staff Engineer in charge of the Telephone Branch of the Engineer-in-Chief's Office in December, 1954, is the son of the late Mr. W. H. Calveley who will be remembered by many as Sectional Engineer, Colchester, in the old South-Eastern District at his retirement in 1934.

He was educated at the Royal Grammar School, Colchester, and, after Matriculation, at King's College, London, where he obtained his Intermediate B.Sc. in Engineering. At the age of 19, he was successful in the



open competition for Probationary Inspectors (old style) and entered the Post Office Engineering Department on 25th January, 1928. Continuing his studies by attending evening classes at the Northampton Polytechnic Institute, London, he obtained honours B.Sc.(Engineering) in 1929 and passed the open competitive examination for old style Probationary Assistant Engineers in 1930. From then until 1938, when he was promoted to Executive Engineer, he obtained a wide experience in London and the Provinces on internal and external works covering repeater station maintenance, and the installation and maintenance of automatic exchanges and external plant including main underground cables.

As an Executive Engineer in the "O" Branch of the Engineer-in-Chief's Office, he was responsible for the general accommodation planning and engineering organisation of the new Telephone Areas.

In 1939, he was called for military service with the Royal Signals joining the British Expeditionary Force in France, firstly at Brest and then as liaison officer with the French P.T.T. in Paris. After the fall of France he was liaison officer with the Canadian Corps until October, 1942, when he joined the staff of the Supreme Allied Commander's Headquarters as Major. In May, 1943, he was given the command of No. 2 War Office Signals and, from his headquarters at Portsmouth, he played no small part in the preparation for the allied invasion of Europe. He accompanied the invading forces through France, Belgium, Holland and Western Germany, restoring telecommunications plant and providing telegraph and telephone communication by radio, landline and submarine cable.

Shortly after demobilisation he was appointed, in 1946, first Principal of the Engineering Department's Central Training School which was being established in Ministry of Supply Hostels near Stone, Staffordshire. This opened in October, 1946, with 121 students and reached a peak of 696 students in November, 1951, on a fully residential basis. In 1947, Mr. Calveley was awarded a Home Civil Service Commonwealth Fund Fellowship, tenable for one year in America. This he utilised to the best advantage of the School by studying Personnel Selection and Training with the American Telegraph and Telephone Company and their associates. He also attended the 12th Advanced Management Course at the Harvard Business School.

The undoubted success of the Central Training School is very largely due to Mr. Calveley's initiative, determination and tact. When it is remembered, that quite apart from arranging the actual instruction to be given at the School, the Principal is also responsible for the Hostel and about 150 official residences for married school staff, it will be realised that his duties are not only exacting and onerous but extend into fields not normally associated with those of an Assistant Staff Engineer. Mr. Calveley's wide experience in the Post Office and with the Armed Forces made him an obvious choice for this unique post.

He will be missed by his colleagues and the numerous friends he has made in Stone and District—he was president of the Stone Rotary Club in 1953/54—but all wish him well in his higher post.

H. R. H.

G. S. Berkeley, M.I.E.E.

Mr. Berkeley, promoted to Chief Regional Engineer in December 1954, served his apprenticeship as an engine fitter in Her Majesty's Dockyard, Chatham, gaining two Whitworth prizes and then, in 1924, entered the Department through the open competitive examination for Inspectors. Posted to the Testing Branch for 12 months, he was then transferred to the Telephone Development and Maintenance Branch of the Engineer-in-Chief's Office in

the old Manual Group which dealt with the accommodation and layout of Magneto, C.B.S., and C.B. 10A exchanges. In 1928, he was successful in the old-style Assistant Engineer competitive examination and soon afterwards he was transferred to the rapidly growing Auto Trunking Group under Mr. G. F. O'dell. During the following seven years, he dealt with all aspects of Trunking involving the maintenance of Grade of Service in automatic exchanges, re-arrangements of switching plant and extensions of public automatic exchanges and P.A.B.X.s, the trunking design of the Bypath, Common Control, and Siemens' No. 17 systems, as well as various trunking problems on probabilities. He summed up the results of this wide experience in his book, published in 1936, entitled "Traffic and Trunking Principles in Automatic Telephony" which was the first publication to be devoted entirely to this subject.

In 1936, he was promoted to Senior Executive Engineer and took charge of the "Circuits A" Group of the Telephone Branch, dealing with the development of 2000-type director, non-director, and U.A.X. circuits. Two years later, he took charge of the Comprehensive Circuits Group which dealt with investigations into new systems, dialling limits, and V.F. systems. In 1940, he was posted to the Telephone Branch Circuit Laboratory and, after a few months, transferred to the L.T.R. early in January, 1941, just after the extensive fire raids on London.

Joining the C.R.E's 24-hour Emergency Control in the L.T.R., he gave valuable and timely assistance in the restoration of emergency circuits until, later in the year, the weight of the air attack on London began to diminish. He then dealt with various internal maintenance problems until, in 1942, he was transferred to the City Area in charge of the Internal Maintenance Division. Three years later saw him back at Regional Headquarters again and, in October, 1945, he was promoted to Regional Engineer on Internal Maintenance.

His chief concern became the improvement of the standard of service given by the London automatic exchanges which had deteriorated sadly through the ravages resulting from enemy action. It was decided to embark upon the comprehensive overhaul of the whole of the automatic switching plant in London. This major operation began in 1947 and was completed in 1950.

In December, 1951, he became Deputy Chief Regional Engineer responsible for Staff and Service. Three years later, on the introduction of a second post in the L.T.R., he was appointed Chief Regional Engineer responsible for Planning and Works. In addition to his many other activities, he has been for some years an Examiner for the C. & G. examinations in Telephone Exchange Systems I, II, and III.

Mr. Berkeley brings to his new job a detailed knowledge of the requirements of the L.T.R. which will serve him well in the task of developing the communication network in London to meet the increasing demands for telephone service that are pouring in from all sides.

W. S. P.

Institution of Post Office Electrical Engineers

Additions to the Library

2239 *An Introduction to the Theory of Statistics.* G. U. Yule and M. G. Kendall (Brit. 1950).
A systematic introductory course on statistical methods suited to those possessing a limited knowledge of mathematics.

2240 *Automatic Digital Computing.* National Physical Laboratory (Brit. 1954).
Being the proceedings of a symposium held in 1953 at the N.P.L.

2241 *Modern Enlarging Technique.* F. Harris and G. L. Wakefield (Brit. 1954).
A complete and authoritative work on enlarging.

2242 *Electrical Who's Who.* Electrical Review (Brit. 1954).
Brief biographies of leading members of the professional and industrial branches of the industry.

2243 *Radio, Vol. II.* J. D. Tucker and D. F. Wilkinson (Brit. 1954).
Designed mainly to cover the requirements of the Radio II examination of the C. & G. of London Institute.

2244 *With the Watchmaker at the Bench.* D. de Carle (Brit. 1954).
Shows what is done, and how each operation is performed, in the watchmaker's workshop.

2245 *Telecommunications.* A. T. Starr (Brit. 1954).
Written to cover the syllabus of Telecommunications in the London University Degree and similar examinations; includes a short account of microwave technique and waveguide theory.

2246 *Fundamentals of Electrical Engineering.* E. Hughes (Brit. 1954).
A sequel to "Principles of Electricity in M.K.S. Units" by Morley and Hughes, and covers the electrical engineering syllabuses of the Third Year course for the O.N.C. in Electrical Engineering, the first year course for an Engineering Degree, and the Intermediate Examinations in "Electrical Engineering Practice" of the C. & G. of London Institute. The rationalised M.K.S. system of units has been used throughout.

W. D. Florence, *Librarian.*

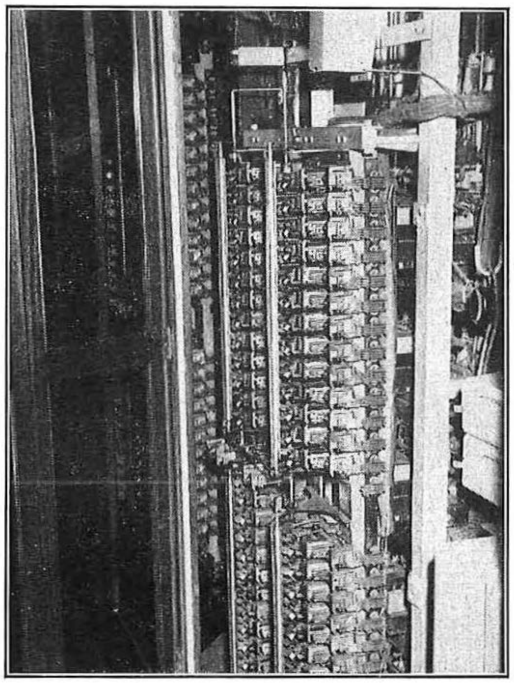
Regional Notes

Wales and Border Counties

REPLACEMENT OF EARLY STROWGER EXCHANGE AT CHEPSTOW

In July, 1915, an automatic telephone system was inaugurated at Chepstow. This was three years after the first public automatic exchange in Britain had been brought into service at Epsom. It is said that these towns were chosen in order to test the effect on the new system of large increases of telephone traffic resulting from horse-racing news.

It is about 25 years since the original automatic equipment at Epsom was replaced by a manual exchange, which in its turn has given place to modern automatic equipment, but the original Chepstow automatic exchange has remained in service, having been extended with equipment recovered from Epsom. Originally the Chepstow equipment provided a two-digit system and consisted of a single unit of Keith line switches and side-switch final selectors controlled by vertically mounted relays. The apparatus was manufactured in the United States and, together with the ringing and power equipment, was housed in a glass-panelled mahogany cabinet made by A.T.M. Co., of Liverpool. The line-switch side of this unit is illustrated. The local manual board was a wall-type magneto switchboard accommodated in the Post Office, which was in the same building. Access to this was obtained by dialling the digits "09," the ringing current from the final selector operating the indicator. Similarly, trunk calls were obtained by dialling either "01" or "02" for routing to Newport, and there was a dialling-out facility to the nearby town of Lydney by dialling the code "05." In the mid-1920s, a further unit, recovered from a P.A.B.X. at Gretna, together with group selectors, was added and remote manual-board facilities to Newport were given from level "●."



THE ORIGINAL KEITH LINE-SWITCH UNIT AT CHEPSTOW.

On 19th February, 1955, this equipment was taken out of service and replaced by a 2,000-type, remote non-director exchange with multi-metering, parented on Newport. A standard U.A.X.14 building has been used to house the new exchange, but this has been modified to give 12 ft. clear height in the apparatus room so that standard 10 ft. 6 in. racks can be accommodated.

No official ceremony marked the occasion, but the engineering staff felt some regret, as if at the passing of an old, if sometimes temperamental, friend.

S. E. N.

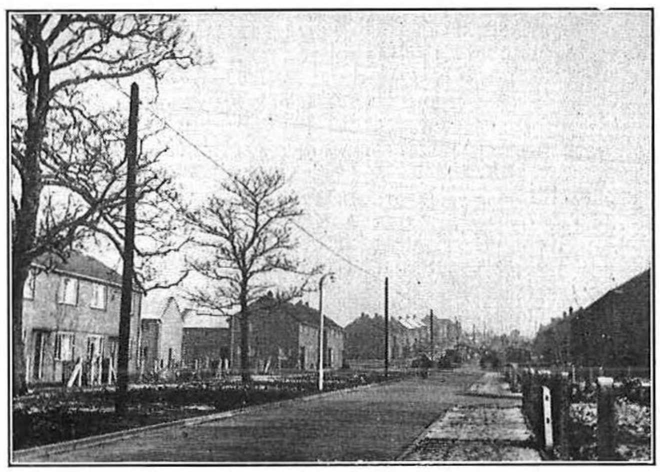
Midland Region

OVERHEAD DISTRIBUTION FOR HOUSING ESTATES

Since the war, rural and urban district councils have shown an increased reluctance to permit the erection of overhead plant on new housing estates. Where a low telephone penetration is expected, complete underground distribution cannot be justified because of its high cost. Experiments have therefore been carried out in the Peterborough Area in providing service by modifications of the normal methods of construction. By adopting these methods, the overhead plant has been made so much less conspicuous that many councils' objections have been overcome without incurring additional costs.

It appeared from discussions with the representatives of the councils that they objected not so much to the poles themselves as to the arms, insulators and open wires which made the poles so conspicuous. Arms, insulators and open wires are therefore eliminated in the forms of construction described below.

The first estate was served by a 10-pair polythene cable suspended in cable rings along a light pole route and terminated on a terminal block at a suitable point. Each subscriber was connected by a drop-wire held in drop-wire clamps supported from Brackets No. 22 on the pole and house. A subscriber along the line of route was served by feeding Cable, I.R.V., B & C back through the rings to the pole nearest to the house, and suspending the cable from drop-wire clamps held by Brackets No. 22 on the pole and house.



APPEARANCE OF TYPICAL AERIAL CABLE AND DROP-WIRE.

A second estate was served by a 15-pair polythene cable laid direct in the ground and terminated at a ring-type D.P. Two intermediate subscribers were served by direct underground lead-in, and the council provided assistance with the excavation work, which helped to reduce the cost to the Post Office, but it is the intention to erect a further ring-type D.P. Connections to the ring-type D.P. were made by drop-wire as on the first estate.

At a third estate a 15-pair polythene cable was erected along a pole route using the lashing method. A small loop was left in the cable at each pole. At poles where spurs to subscribers were required the loop was converted to a normal polythene cable joint and a two- or four-pair terminal block fitted. Service to subscribers was again provided by drop-wire supported from Brackets No. 22. Additional subscribers can be connected from any pole with a minimum of rearrangement, so ensuring good maintenance and low fault liability. The plant erected by this method can be made even less conspicuous by substituting for the I.R.V., B & C cable a figure-8 section cable with 20-lb. conductors and having a transparent insulant. This type of drop wire, which is at present undergoing field trial in the Midland Region, has been used on this estate with marked success and has obvious advantages. It is, however, capable of further development on the following lines. Polythene cable could be laid direct in the ground leaving cable loops at about every 100 yds. to allow the eventual opening of four-pair, ring-type D.P.s. The D.P.s would be erected only as applications for service matured, so keeping the number of poles to the minimum. It is hoped to carry out an experimental installation using this method.

Acknowledgment is made to Mr. D. K. G. D. Wright for the photograph illustrating this note.

R. W. P.

METHOD OF CHECKING CABLE PAIR AVAILABILITY

With a view to developing a satisfactory method of locating wrongly recorded or mis-routed local line cable pairs, trials similar to those previously described in the JOURNAL* have been carried out in the Midland Region. A two-man party has been employed, with extra assistance when required, and the equipment has been arranged to enable the work to be carried out as speedily and effectively as possible. The following facilities have been provided:—

V.H.F. radio is used to provide a speech link from the man in the field to either,

(a) the exchange M.D.F.,
(b) a cabinet or pillar (via an associated relay set), or
(c) exchange M.D.F. and an intermediate cabinet or pillar, concurrently.

A suitably wired panel enables an interrupted "ticker" tone from an Oscillator No. 23 to be applied at either high or low level to spare or working lines in automatic or manual exchanges. The panel enables lines to be tested if necessary, and makes it impossible to apply the tone to a line when a call is in progress.

The high-level tone allows cable pairs to be identified from outside the cable by means of a probe and amplifier, and can be used for checking pairs which feed premises by direct underground distribution, or for tracing "lost" pairs. The low-level tone is applied to pairs which are accessible (e.g., connected to a terminal block), and is picked up on test prods connected to a headgear receiver.

During the trials, experimental use was made of a 10 kc/s test signal modulated by a 400 c/s tone. This signal can be applied to lines when a call is in progress without causing interference to subscribers, and can be received by the testing party through a simple germanium demodulator. The audio-tone method has certain advantages and has been finally adopted.

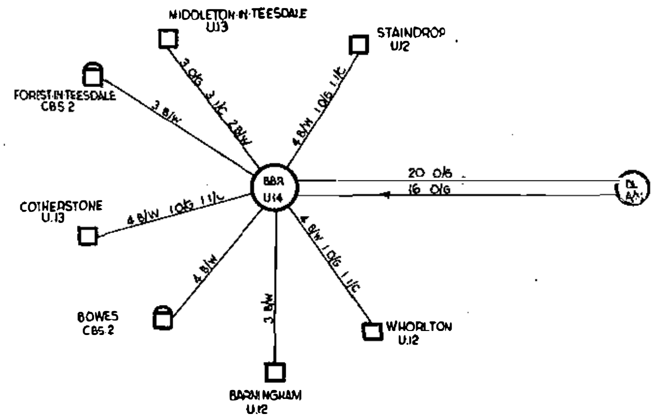
From the trials, a most satisfactory method of locating and identifying pairs has been evolved which should prove useful if it is necessary later in undertaking a large-scale check of records, or checking completed development schemes. R. G. T.

North-Eastern Region

BARNARD CASTLE CONVERSION FROM C.B.S. TO U.A.X. 14

A further step towards the automatisation of the towns and villages in Teesdale, in the Middlesbrough Telephone Area, took place on 11th January, 1955, when Lord Barnard of Raby Castle, Staindrop, performed the opening ceremony at the conversion of Barnard Castle exchange from C.B.S. 2 to U.A.X. 14. There is nothing unusual in the opening of a U.A.X. 14, generally speaking, but in this case the full conversion extended over approximately one week.

As will be seen from the two diagrams, showing conditions before and after transfer, Darlington auto-manual board handles the bulk of the operator traffic from the Dales, Middleton-in-Teesdale and Cotherstone U.A.X.s 13 being parented thereon to relieve load and congestion at Barnard Castle manual board. The limited number of cable pairs between the latter and Darlington, coupled with the fact that two groups of junctions and selector levels at Darlington were to be combined for U.A.X. 14 working, meant that comprehensive



JUNCTION NETWORK AFTER CONVERSION OF BARNARD CASTLE TO U.A.X.14.

change-over arrangements at Darlington exchange would be necessary. Proposals were accordingly made to the Traffic Section for the dependent U.A.X.s and two small manual exchanges to be connected to the new U.A.X. 14, one week earlier than the main transfer.

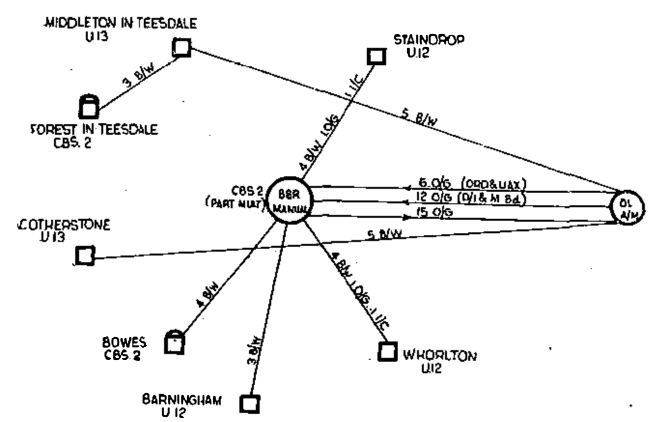
As Darlington auto-manual board handled the "0" level traffic from Middleton-in-Teesdale (including Forest-in-Teesdale) and Cotherstone, the junctions from these exchanges were split at Barnard Castle, one by one, and connected to the U.A.X. 14 equipment. This gave five outgoing and five incoming automatic junctions between Darlington and Barnard Castle with which to carry the "0" level traffic from Middleton, Forest and Cotherstone, but at this stage the subscribers on the two U.A.X.s 13 were not advised to dial each other directly. The U.A.X.s 12 at Barningham, Staindrop and Whorlton, plus the small manual exchange at Bowes, were then dealt with, their junctions being connected to the U.A.X. 14 equipment on a piecemeal basis, and the parent route to Darlington augmented gradually to a total of 11 outgoing and 11 incoming junctions.

By the third day of the advance transfer period all dependents were working satisfactorily under the new conditions, the parent exchange having been advised to differentiate between the junctions in the multiple at Darlington to either Barnard Castle automatic area or Barnard Castle manual (for Barnard Castle ordinary subscribers or C.C.B.s only). In addition, instructions were of course given to dialling-in exchanges to stop dialling code "88" (the original code for Barnard Castle at Darlington exchange) as from the 3rd January, 1955, and to dial "0" instead for all calls for Barnard Castle area. For main transfer day, this left only the comparatively simple change-over of the 520 subscribers and C.C.B.s plus the remaining parent junction route up to its full strength as shown in the diagram.

Simultaneously with the transfer, full "999" facilities were given to Barnard Castle and its dependents and, in addition, to a number of directly-connected U.A.X.s to Darlington Exchange. R. T.

PROVIDING A TELEPHONE CIRCUIT TO THE ROYAL TRAIN

When H.M. the Queen and H.R.H. the Duke of Edinburgh visited Sheffield on 27th October, 1954, the site chosen for the overnight stop for the royal train, in which they were travelling, was remotely situated. This presented a problem when trunk subscriber facilities had to be provided for the



JUNCTION NETWORK BEFORE CONVERSION OF BARNARD CASTLE TO U.A.X.14.

* P.O.E.E.J., Vol. 46, p. 144.

train, as the site was three-quarters of a mile, across fields, from the nearest local line plant on the Post Office network. To provide service a one-pair polythene cable was laid over the ground, suitably camouflaged in the bottom of hedges and buried where necessary, except for 120 yds. of its length near the site, where it was attached to galvanised wire and erected on extra-light poles.

In view of the importance of the circuit, the provision of a speaker circuit between the site and the local maintenance control seemed most desirable in case of a breakdown, particularly as the temporary cable was liable to damage. To meet this requirement economically, Post Office type mobile radio equipment was obtained. The master station was set up at the Rotherham maintenance control and two mobile stations were operated, one by the staff at the site and the other by a cable-jointing party who stood by at a suitable vantage point along the route. To conserve the batteries of the mobile stations, messages were exchanged at fixed time intervals.

By relaying messages via the maintenance control, the radio equipment was particularly helpful when co-operation was required between the staffs at the trunk exchange and the site for the final testing of the main circuit.

The occasion illustrated one of the many useful applications of the mobile radio equipment which is designed to be easily operated by inexperienced staff.

E. A. B.

London Telecommunications Region

TRUNK MECHANISATION—FARADAY STAGE 2

The completion of the second stage of the London Trunk Faraday non-director exchange contract and its opening on the 8th January, 1955, completes the London contribution to the trunk mechanisation programme. Stage I of this contract was completed in February 1954, and London Trunk Kingsway was opened in October 1954. The second stage of the Faraday installation provides for incoming trunk traffic to the London Group. The careful planning of the pre-opening and opening operations, in co-ordination with all other Regions, was based on the usual procedure, and was aimed at achieving an opening date in March 1955. In the course of this work the possibility of a national railway strike arose and on 1st January, 1955, a decision was taken to proceed with the opening forthwith, the work to be completed on Saturday, 8th January, 1955.

The additional equipment brought into service is located on the 2nd floor of Faraday Building South-East Block and includes 148 racks of motor uniselectors and 83 racks of relay sets for incoming A.C.1, D.C.1 and D.C.2 routes, and for dialling out to C.B., Auto-to-Auto with regenerators and without regenerators, and Assistance.

Thirteen routiners are provided for this equipment and the outgoing junctions, and are associated with automatic fault recorders. Assistance traffic is routed to Faraday Building North Block. It is interesting to note that the 2nd floor formerly accommodated the Toll A and B manual boards, the service on which was transferred to Faraday Building South Block to allow of their recovery, a major preliminary work for which time was restricted.

The call-through test, having been pressed forward, was completed on the 4th January, 1955 and final engineering tests on all junction and trunk circuits were compressed within the period up to 4 p.m., Friday, 7th January, by 24-hour staffing. The revised opening arrangements called for the transfer to commence at that time and be completed by 9 a.m. on the following morning. In this operation 1,543 junctions were made available for service at 4 p.m. on the Friday, after which trunk routes were taken into service as each was proved satisfactory by the engineering staff, 167 incoming and 57 bothway trunks being switched in by 9.30 p.m. Simultaneously, planned additions to London Trunk Faraday Stage 1 (outgoing section) and London Trunk Kingsway were completed, involving the testing and switching-in of a total of 117 trunk circuits. The efficient co-operation of the provincial centres was a big factor in the successful transfer.

The completion of this contract provides a second 5,000 trunk automatic unit in the L.T.R. Standard Telephones & Cables, Ltd., in co-operation with the L.T.R., engineered and installed the exchange utilising motor uniselectors of Siemens Bros. design, which, together with the A.C.1 relay sets and regenerators, were manufactured by the Automatic Telephone & Electric Co., Ltd. All stages of the work were executed under pressure and the final stage was accelerated for the reason given: in this, Standard Telephones & Cables, Ltd.'s full co-operation contributed considerably not only to the success of the main course of the work but also to that of the final high-pressure stage.

F. V. P.

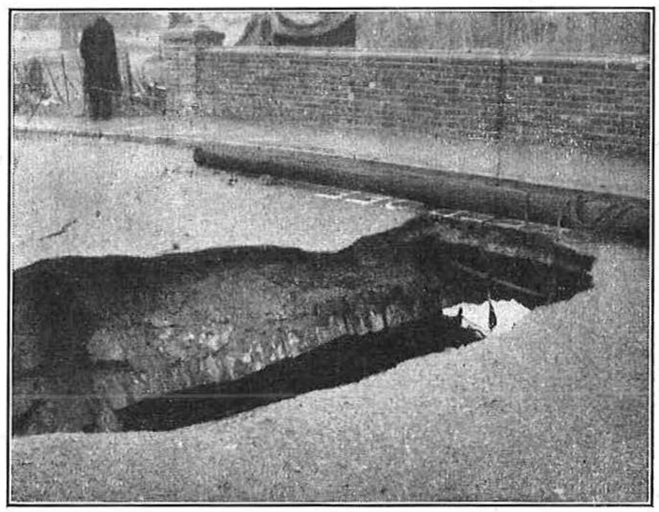
Home Counties Region

COLLAPSE OF ROAD BRIDGE AT HADLOW

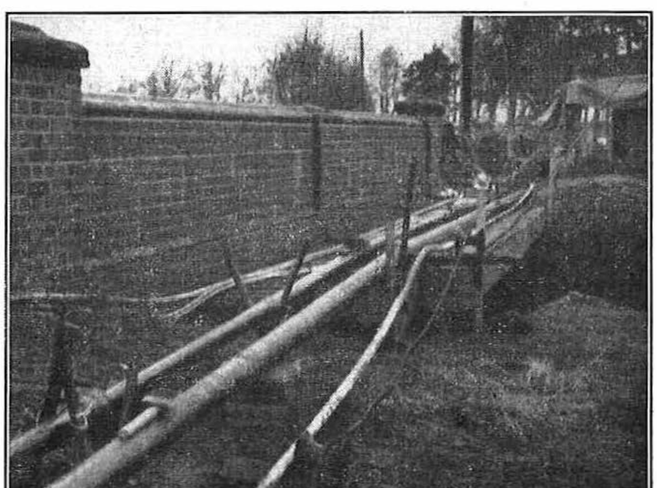
Local inhabitants of the village of Hadlow were surprised to find the main A.26 road from Tonbridge to Maidstone with a large hole in it in the latter part of January. Fortunately the occurrence took place at night and there were no road casualties. At this point the River Bourne, a small tributary of the Medway, crosses the A.26 road, and the flood waters of the thaw, following heavy snow, had apparently washed away the footing of the main arch which collapsed. It seems likely that the bridge, an old one, had been extended at some time to carry a wider road, but that the new brickwork had not been bonded to the old.

One P.O. cable which is in the carriageway had to be provided with a temporary support across the hole, but fortunately all other services, including another P.O. track, were in the footway, which was unaffected by the subsidence.

Water, gas, power and P.O. plant are all carried over the bridge and have been diverted over a temporary bridge and



HOLE IN BRIDGE AT HADLOW, SHOWING TEMPORARY SUPPORT FOR ONE POST OFFICE CABLE.



DIVERSION OF SERVICE CABLES AND PIPES OVER TEMPORARY BRIDGE AT HADLOW.

for some distance down the road. Fortunately the County Council had already made plans for road widening and had bought much of the land required, and road work could therefore be put in hand with a minimum of delay. It is the intention of the Council to build a new bridge a few yards farther up the road. This will be erected on dry land and the stream, which takes a bend at this point, will then be straightened out to run under the new bridge.

L. W. B.

OUT OF THE ORDINARY!

Many and varied are the causes of faults on subscribers' overhead circuits, but a most unusual occurrence caused a fault recently on the line serving Beachy Head Lighthouse. The last span from the cliff top to the lighthouse consists of about 500 yds. of single 300-lb. cadmium copper and the cause of the break in the middle of the span was a mystery until the maintenance staff were able to gain access, when it was learned that a helicopter "quizzing" the lighthouse had caused the trouble.

The crew of the lighthouse had tried to warn the pilot by waving him up, but he took it as a friendly gesture and waved back. They were also concerned for the safety of the line as they were expecting a call regarding their relief, which was almost due. The pilot was no doubt puzzled as to what had caused the impact, as he returned to investigate, but apparently without success.

Beachy Head is normally accessible by foot only for a short time at low tide and restoration was delayed by very high tides. The method adopted was to drop the wire to the bottom of the cliff on the mainland, weighting the end with a 5-gallon drum filled with stones and juggling to avoid ledges and boulders on the cliff side. A sash line was extended from the lighthouse to the foot of the cliff and joined to the wire, the weighting drum then being abandoned.

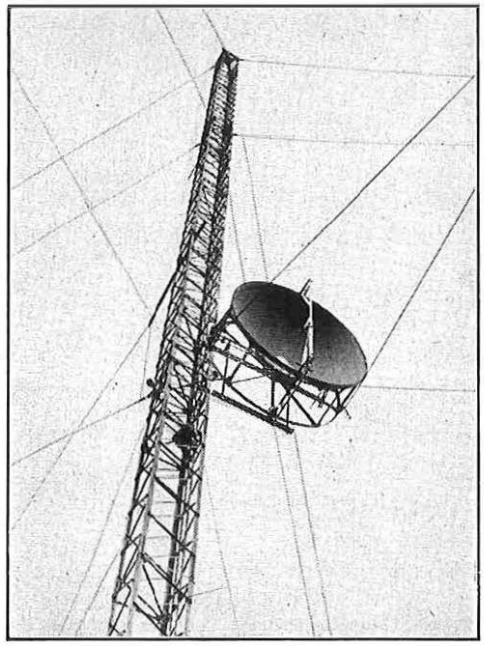
To be independent of tides on a future occasion, arrangements are being made for the lighthouse staff to shoot a line by rocket to the mainland, draw back the telephone wire and themselves terminate it at the lighthouse. Alternatively, a helicopter could be used!

W. J. B.

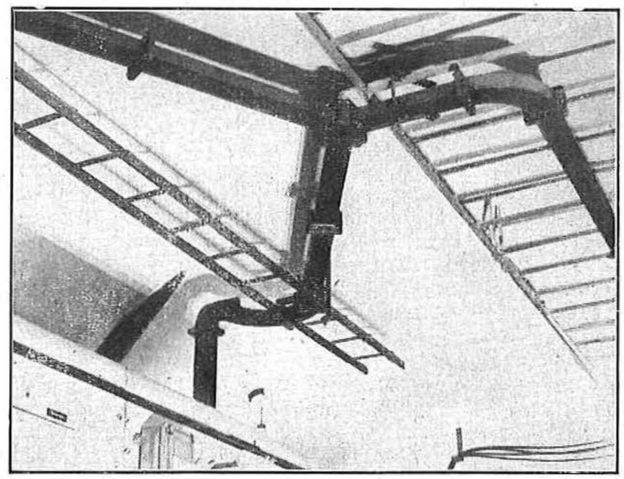
LONDON—ISLE OF WIGHT TELEVISION LINK

It was with considerable interest and anticipation of an enjoyable job that the Home Counties Region accepted the invitation of the Engineering Department to assist in the provision of Stage I of the first of the "Broad-Band" Radio Links in the Region, designed to provide television service to the Isle of Wight.* The help given was very varied and all staff who took part look forward to participating in Stage II and in further links as they become necessary.

It was clear from the outset that speed in the early stages was necessary if the target "Ready for Service" date was to be met, so the Ministry of Works rapidly negotiated the site clearances. The owners of the site selected for the pick-up point (known as "Golden Pot") were willing to sell, and access was obtained at an early stage of negotiations. Building requirements were co-ordinated on much the same lines as is usual for T.R.S. buildings and the building design—using adapted standard B1 timber buildings and a lavatory unit joined by a covered walk—and site layout, was by Ministry of Works Headquarters' Architect. Construction was by a local contractor under the direction of the M.O.W. Bournemouth District Office, but the setting of the bottom section of the mast (which is rigid) and the stay anchorages, were included as part of the site works. The mast, erected by a specialist contractor with the help of Guildford Area staff on the ground, carries red aircraft warning lights which were taken up with the mast during erection and fed from a portable generator. Daily progress was advised to the R.A.F. and the Ministry of Civil Aviation. Miscellaneous ironwork fittings for the mast, waveguide and internal equipment, were made in the Guildford workshop.



MICROWAVE DISH BEING HOISTED ON MAST AT "GOLDEN POT"



WAVEGUIDE Y-JUNCTION IN RADIO BUILDING AT "GOLDEN POT" SITE

Fresh water was taken from an asbestos cement pipe feed in a neighbouring field, normally used to supply cattle troughs. Separate earthing systems were necessary and had to be driven 36 ft. deep into the chalk subsoil. The Electricity Authority built a H.V. line, fitted with line-post type insulators to avoid interference, to bring a supply from a point 3 miles away, the last 100 yards into the station being by L.T. underground cable. All local farmers were approached and their tractors and other equipment fitted with suppressors as required.

The Rowridge end of the link on the Island was more simple in that the equipment was installed in a special room in the B.B.C. building. The temporary mast was, however, provided by the Post Office, the four mast footings being constructed under a Regional Contract and the mast itself by the specialist contractor who erected the "Golden Pot" mast. The Portsmouth Area provided staff for watching contracts and for general assistance on site. The radio equipment at both stations was installed and lined up by Engineering Department staff with the help of the Area officers who have since been trained in link maintenance and have now assumed responsibility for the installations. After a period of continuous attendance, visits to the stations are being steadily reduced with the object of putting them on an emergency basis as soon as possible.

* A technical description of the link equipment is given in the article on p. 36.

Associate Section Notes

Bishop's Stortford Centre

This year, the Centre got off to a very early start by making a well-attended coach visit to the National Radio Exhibition at Earls Court on 1st September. We were rather disappointed, however, to find that there was no P.O. stand this year.

On the evening of the 28th September, a further visit of radio interest was made to the G.P.O. Cable and Wireless station at Ongar. We were very enthusiastically received by the staff of the station, and nothing was too much trouble to explain or show to us.

We were very fortunate on the evening of the 27th October, in having Mr. E. Briscoe, of Dunmow Laboratories, to come along to our H.Q. and give a talk and demonstration on the use of modern plastics in telecommunications. We were left with the impression that there was plenty of scope for the application of these modern materials in telecommunications.

The following meeting of the section was on 7th December, when a film show of light entertainment was given.

The membership, as a whole, is very enthusiastic, but we should still like to see more of our external colleagues at our meetings.

Early in the new year, we are arranging a visit to the Non-director exchange at Epping, primarily for our external colleagues, in order to give them a better understanding of what happens in an automatic telephone exchange. J. P.

Bradford Centre

A General Meeting was held on the 3rd June, 1954, when the following officers were elected for the 1954/55 session:—

Chairman: Mr. E. Bauer; *Secretary:* Mr. A. R. Lawrie; *Treasurer:* Mr. T. Walmsley; *Liaison Officer:* Mr. L. Whiteley; *Librarian:* Mr. A. J. Procter-Blain; *Auditor:* Mr. D. McWalter.

Committee: Messrs. A. Annall, M. Blazzard, H. Cowgill, W. J. Hardie, B. Killeen, B. McCoubrie and J. Rowley.

The session opened with a visit to the docks and ship canal at Manchester, when a party of 27 members was conducted by motor launch on a very enjoyable and informative tour.

On 15th October, members visited the offices of the "Telegraph and Argus" newspaper. During the visit the main processes concerned in the production of a newspaper were ably demonstrated and explained. On the 16th November, an "Open Night" was held when no fewer than 222 friends and relations of the staff were shown round the telephone exchange and given light refreshments. Such a large party required detailed planning of guides and groups, and it is to the credit of those responsible for the arrangements that the visit was carried out smoothly and efficiently. Members of the day-operating staff acted as guides for the switchroom and assisted in the canteen.

On Tuesday, 30th November, Mr. A. J. Procter-Blain read a paper entitled "An Introduction to the Rationalised M.K.S. System of Units." This was followed, on 16th December, by a lecture given by Mr. E. Bauer on "The Detection of Atomic Radiation in Civil Defence." This talk was illustrated by slides and diagrams using an epidiascope, and was followed by a demonstration of radiation detecting, using up-to-date apparatus.

At a meeting held on 10th January, 1955, Mr. A. J. Procter-Blain was elected Joint-Secretary with Mr. A. R. Lawrie, preparatory to the latter taking up an appointment as Telecommunications Traffic Superintendent. Mr. B. Killeen was elected Librarian and Mr. R. Lightfoot was co-opted on to the committee. On 3rd February, Mr. Lawrie left Bradford to take up his new post in Leeds. The committee wish to record their thanks for his past services as Secretary and to wish him every success in his new position.

On 3rd February, a party of 20 visited the Blackburn works of Mullard, Ltd., where they were shown the intricate processes involved in valve manufacture.

The rest of the year's programme is as follows:—

26th April.—Visit to Shell Refinery at Stanlow.

9th May.—Visit to Northern Radio Show at Manchester.

2nd June.—Annual General Meeting, followed by a film show.

So far the Centre has had quite a successful season. Membership continues to be relatively high, but more papers by members would be appreciated. A local library has been formed and there is a circulation of periodicals. The Central Library continues to be popular with members. A. J. P. B.

Darlington Centre

Inclement weather and in consequence a disinclination to leave TV and radio to venture outdoors, affected the attendances at winter meetings, but it was noteworthy that our keen members from the out-stations turned up in their usual force! Nevertheless, the lack of numbers was compensated by the enthusiasm of the audience—this was particularly evident when Mr. J. G. C. Rowley, from the British Railways Staff Training College, gave his talk on "Railway Signalling." Those present were treated to a most interesting talk on the history and development of signalling from its early days to the present modern coloured electric automatic signalling. The speaker left no doubt that he knew the subject and all were impressed by the high standard of efficiency demanded; this left the conviction that there should be almost 100 per cent. safety in the operation of the railways. Both for the speaker and the Centre members this was a most enjoyable meeting and it is hoped that Mr. Rowley will come along in a future session to enlighten members on the "Auto Colour Light System."

Hearty congratulations are extended to Messrs. E. ●. M. Grimshaw and K. Hamilton in gaining National awards of the Institution. Teddy Grimshaw, until his transfer to Middlesbrough, was a popular member of our Centre and his versatility, which qualified him to give several talks at our Centre, has already been recorded in previous notes.

Youths-in-training should note that membership of the Centre is open to them at the half-price fee of 1s. annually. C. N. H.

Edinburgh Centre

The second half of the present session got off to a flying start on January 11th when Mr. W. F. Irvine gave an excellent talk on "Subjects for Colour Photography," illustrated by many professional-looking coloured slides. The talk held the interest of all fortunate enough to be present despite the terrible weather of that evening. On the Saturday of the same week a full complement of members visited Portobello Power Station and saw at first hand the many improvements and additions to that important cog in the country's power network.

A full and varied programme until the end of the session is offered to all old and new friends and, remember, a good attendance at the remaining meetings will encourage the committee to go ahead with even more ambitious plans for next session. Attendances at our various activities during the past few months have been quite good but it is hoped that those who do not take advantage of the Centre facilities will do so in the future. J. R. H.

Glasgow and Scotland West Centre

Mr. R. W. Palmer, Assistant Staff Engineer, gave the session a good start when he addressed a large section of our membership on his recent American visit. A keen interest was shown in all aspects of the visit and during question time he was kept busy answering questions on such varied topics as policy, routiners, advertisement, shared service, grade of service, etc. We also had the pleasure of the company of the C.R.E., Mr. Hines, who took the opportunity to present Mr. R. Grant with an Essay Certificate won by him in the last competition.

Messrs. G. and J. Weir, of Cathcart, were hosts to a party of 35 members on 21st October. The magnitude of the works and the diversity of operations proved so interesting that a return visit has been suggested for next year.

On 4th November, Mr. Jas. Adair, a former Procurator Fiscal of Glasgow, gave a fascinating talk on "Old Glasgow and its Street Characters" which was thoroughly enjoyed even to the extent of Mr. Adair being bombarded, during the break for tea, by a group of enthusiasts, who, like Oliver Twist, "wanted more"!

Events during December were a visit to the Engineering Laboratory of Glasgow University, a talk on "Metal Rectifiers" by Mr. J. Dixon, Area Engineer; a visit to a distillery, and the last talk of the year 1954, "The provision of P.O. buildings" by Mr. J. Revell, Deputy Telephone Manager. J. F.

(Continued on p. 64.)

Staff Changes

Promotions

Name	Region	Date
Asst. Staff. Engr. to Staff Engr.		
Calveley, C. E.	E.-in-C.O.	13.12.54
Depy. Chief Regl. Engr. to Chief Regl. Engr.		
Berkeley, G. S.	L.T. Reg.	20.12.54
Asst. Staff Engr. to Depy. Chief Regl. Engr.		
Salter, L. F.	E.-in-C.O. to L.T. Reg.	20.12.54
Snr. Exec. Engr. to Asst. Staff Engr.		
Styles, G. E.	E.-in-C.O.	17.1.55
Kilvington, T.	E.-in-C.O.	7.1.55
Exec. Engr. to Snr. Exec. Engr.		
Chappell, A. J.	L.T. Reg. to N.W. Reg.	6.12.54
Surman, W. L.	E.-in-C.O. to M. Reg.	17.1.55
Horsfield, B. R.	E.-in-C.O.	14.12.54
Billinghurst, F. M.	E.-in-C.O.	31.1.55
Exec. Engr. (Open Competition)		
Widdicks, J. A.	E.-in-C.O.	1.12.54
Hughes, C. J.	E.-in-C.O.	1.1.55
Gregory, A. R.	E.-in-C.O.	1.12.54
Asst. Engr. to Exec. Engr.		
Rutland, G. A.	S.W. Reg.	30.11.54
Head, C. E.	L.T. Reg.	10.12.54
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, B. 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.	M. 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
Cossins, W. B.	E.-in-C.O.	3.1.55
Inspector to Asst. Engr.		
Morley, B. L.	S.W. Reg.	19.6.54
Bayes, R. A.	N.E. Reg.	26.7.54
Pierson, G.	N.I. Reg.	10.8.54
Denny, F. H.	N.I. Reg.	13.12.54
Kirk, D.	N.I. Reg.	13.12.54
Rowell, G.	N.E. Reg.	15.11.54
Martland, A. R.	N.W. Reg.	9.11.54
Connoly, C. F.	N.W. Reg.	10.11.54
Fairey, F.	N.W. Reg.	19.11.54
Hodgkinson, N.	N.W. Reg.	25.11.54
Small, W. B.	N.W. Reg.	30.11.54
Wood, J. M.	N.W. Reg.	3.12.54
Prutton, O. G.	N.E. Reg.	3.12.54
Richardson, H.	N.E. Reg.	14.12.54
Trotter, E. R.	N.E. Reg.	28.10.54
Ford, E.	M. Reg.	4.12.54
Thornhill, E.	M. Reg.	6.12.54
Wild, F.	M. Reg.	3.1.55
Bryan, J. C.	S.W. Reg.	22.1.55
Rogers, D. J.	S.W. Reg.	18.12.54
Sutton, R.	S.W. Reg.	5.10.54
Etheridge, R. R.	S.W. Reg.	4.11.54
Blanthorn, W.	N.W. Reg.	14.1.55
Waller, H. E.	L.T. Reg.	25.11.54
Johnson, B. H.	L.T. Reg.	25.11.54
Brodie, D. A.	L.T. Reg.	25.11.54
Paul, N. A.	L.T. Reg.	25.11.54
Harris, W. J.	L.T. Reg.	25.11.54
Tech. Offr. to Asst. Engr.		
Green, H. J.	L.T. Reg.	8.7.54
Callan, E. R.	L.T. Reg.	23.8.54
McMullan, P. J.	Scot.	30.8.54
Spence, J. M.	Scot.	30.8.54
Tod, R. B.	Scot.	4.10.54
Rae, N. D.	Scot.	4.10.54
Tech. Offr. to Asst. Engr.—continued.		
Glennie, J. C.	Scot.	1.11.54
Patrick, G. R.	L.P. Reg.	6.9.54
Robinson, G. A.	L.P. Reg.	24.9.54
Holman, R. V.	L.P. Reg. to L.T. Reg.	14.11.54
Bee, W.	N.W. Reg.	9.11.54
Hart, S.	N.W. Reg.	11.11.54
Gregory, W.	N.W. Reg.	14.11.54
Flitcroft, F.	N.W. Reg.	19.11.54
Kirtlan, J.	N.W. Reg.	19.11.54
Barlow, A.	N.W. Reg.	19.11.54
Taylor, W. J.	N.W. Reg.	19.11.54
Dean, A. A.	N.W. Reg.	19.11.54
Barnaby, R. E.	M. Reg. to E.-in-C.O.	29.12.54
O'Hagan, V.	N.W. Reg. to E.-in-C.O.	29.12.54
Hacking, J. R.	N.W. Reg. to E.-in-C.O.	29.12.54
Davenport, D. K.	N.W. Reg. to E.-in-C.O.	29.12.54
Purdy, J. E.	N.W. Reg. to E.-in-C.O.	29.12.54
Robinson, J.	M. Reg. to E.-in-C.O.	29.12.54
Fulton, C.	N.W. Reg. to E.-in-C.O.	29.12.54
Forbes, W.	N.W. Reg. to E.-in-C.O.	29.12.54
Cree, J. M.	Scot. to E.-in-C.O.	1.1.55
Huddleston, J.	N.W. Reg. to E.-in-C.O.	29.12.54
Bradford, C. G.	L.T. Reg.	13.10.54
Bett, C.	N.E. Reg.	28.10.54
Sharp, J.	N.E. Reg.	28.10.54
Timmington, C. J.	M. Reg.	31.12.54
Brookes, W. R.	M. Reg.	31.12.54
Dennis, A. H.	M. Reg.	12.1.55
Webb, A. G.	Scot.	25.10.54
Simpson, A. P. R.	Scot.	1.12.54
Webley, D. B.	S.W. Reg.	5.10.54
Blackstaffe, J. A.	S.W. Reg.	29.12.54
Gabbutt, J. A.	N.W. Reg.	3.12.54
Belshaw, R.	N.W. Reg.	6.12.54
King, W.	H.C. Reg.	21.12.54
Little, J. H.	W.B.C.	1.1.55
Franklin, C. H.	W.B.C.	9.12.54
Burnham, L. S.	L.T. Reg.	25.11.54
Richards, T. J.	L.T. Reg.	25.11.54
Cottle, L. J.	L.T. Reg.	25.11.54
Griffiths, S. L.	L.T. Reg.	25.11.54
McEwan, J. C.	L.T. Reg.	25.11.54
Gannon, W. C.	L.T. Reg.	3.1.55
Lavender, J. F. O.	L.T. Reg.	25.11.54
Carr, G. W.	L.T. Reg.	25.11.54
Brand, R.	L.T. Reg.	25.11.54
Hayward, H. T.	L.T. Reg.	25.11.54
Rhodes, F.	L.T. Reg.	25.11.54
Wheeler, J. A.	L.T. Reg.	25.11.54
Rushby, F.	L.T. Reg.	25.11.54
McCarthy, E. T.	L.T. Reg.	25.11.54
Walther, W. F.	L.T. Reg.	6.9.54
Wright, A. C.	L.T. Reg.	25.11.54
Littlecott, G. H.	L.T. Reg.	13.9.54
Fisher, D.	L.T. Reg.	11.1.55
Ward, S. G. H.	L.T. Reg.	25.11.54
Pett, J. P. C.	L.T. Reg.	2.10.54
Whitehead, A. T.	L.T. Reg.	11.1.55
Pettitt, H. F.	L.T. Reg.	20.9.54
Irwin-Brown, H. J.	L.T. Reg.	2.10.54
Wynne, E. W. C.	L.T. Reg.	1.7.54
Margetts, W. E.	L.T. Reg.	23.8.54
Milne, D. D.	Scot.	5.1.55
Blance, J. B.	Scot.	31.1.55
Cowan, A.	Scot.	5.1.55
Claireaux, I. M.	Scot.	22.1.55
Lee, J. Y.	N.W. Reg. to E.-in-C.O.	8.1.55
Ainsworth, J. N.	N.W. Reg. to E.-in-C.O.	1.1.55
Stichbury, R. L.	N.W. Reg. to E.-in-C.O.	8.1.55
Matthew, J. D.	Scot. to E.-in-C.O.	29.1.55
Bridgwood, J. L.	M. Reg. to E.-in-C.O.	29.1.55
Rigby, D. F.	M. Reg. to E.-in-C.O.	29.1.55
Parrott, R.	M. Reg. to E.-in-C.O.	29.1.55
Powell, R.	M. Reg.	13.1.55
Haddrell, N.	M. Reg.	17.1.55
Davies, R. L.	W.B.C.	16.9.54
Willis, J.	N.E. Reg.	1.12.54
McDonnell, J. D.	N.I. Reg.	10.1.55
McDowell, E. H.	N.I. Reg.	24.1.55
Hartley, F.	N.W. Reg.	27.1.55

Promotions—*continued.*

Name	Region	Date	Name	Region	Date
Tech. Offr. to Inspector			*Tech. I to Inspector.—continued.*		
Beynon, B. J. A.	N.E. Reg.	15.6.54	Aiston, A. H.	N.E. Reg.	24.1.55
Mansell, R. J.	S.W. Reg.	13.9.54	Wallace, W. P.	N.W. Reg.	14.1.55
Darch, J. H. R.	S.W. Reg.	24.11.54	Evans, W. S.	N.W. Reg.	20.1.55
Cooper, F. E.	S.W. Reg.	24.11.54	Maxwell, J. W.	Scot.	29.1.55
Whittaker, A.	N.W. Reg.	20.1.55	Robson, R. A.	L.T. Reg.	11.11.54
			Houghton, A. S.	L.T. Reg.	19.6.54
Tech. I. to Inspector			Morgan, H. J.	L.T. Reg.	3.12.54
Thorne, I. E.	S.W. Reg.	25.9.54	Savage, B. A.	L.T. Reg.	24.1.55
Newbery, A. W. J.	S.W. Reg.	21.11.54	Wright, F. T.	L.T. Reg.	17.5.54
Marshall, T. H.	M. Reg.	5.10.54	Grievson, W. E.	L.T. Reg.	20.9.54
Purton, S. C.	M. Reg.	15.5.54	Clark, E.	L.T. Reg.	6.12.54
Skinner, H.	N.W. Reg.	11.11.54	Simpson, G.	L.T. Reg.	3.1.55
Moffat, A. W.	Scot.	14.8.54	O'Haulon, P. J.	L.T. Reg.	17.1.55
Hawksby, F.	N.E. Reg.	1.11.54			
Conway, J. H.	N.E. Reg.	2.11.54			
Harris, V. F.	M. Reg.	29.12.54	*Snr. Sc. Offr. to Prin. Sc. Offr.*		
Thomson, D. M.	M. Reg.	15.12.54	Rickard, E. F.	E.-in-C.O.	17.1.55
Newman, J.	E.T.E.	2.1.55			
Phillips, W. J.	L.P. Reg.	22.11.54			
Barrell, J.	N.E. Reg.	1.11.54	*Sc. Offr. to Snr. Sc. Offr.*		
Lee, J. A.	N.E. Reg.	3.12.54	Walters, R. E. S.	E.-in-C.O.	7.12.54

Retirements and Resignations

Name	Region	Date	Name	Region	Date
Exec. Engr.			*Asst. Engr.—continued.*		
Wilcox, A.	E.-in-C.O.	2.11.54	Jones, F. V.	N.W. Reg.	19.1.55
Elliott, F.	L.P. Reg.	20.12.54	Ryan, J. F.	L.T. Reg.	21.1.55
Reed, E. C.	N.E. Reg.	31.12.54	Gowland, J. E.	N.E. Reg.	31.1.55
Denyer, W. C.	E.-in-C.O.	13.1.55			
			Inspector		
			Chamberlain, R.	M. Reg.	15.11.54
Asst. Engr.			Haggart, J. M.	Scot.	30.11.54
Tether, C.	N.E. Reg.	2.12.54	Shaw, J. C.	L.T. Reg.	2.12.54
Trail, G. S.	W.B.C. (*Resigned*)	13.12.54	Dixon, R.	N.W. Reg.	11.12.54
Price, A. I.	M. Reg.	24.12.54	Harris, A. E.	S.W. Reg.	14.12.54
Smith, B. W.	S.W. Reg.	28.12.54	Harrod, J. T.	L.T. Reg.	22.12.54
McCann, E.	E.-in-C.O. (*Resigned*)	31.12.54	Keith, E.	Scot.	31.12.54
Howlett, W. J.	E.T.E.	31.12.54	Stringer, F.	W.B.C.	31.12.54
Kendrick, H. S.	M. Reg.	31.12.54	Fowler, L.	M. Reg.	28.1.55
Stevens, H. F.	M. Reg.	31.12.54	Copland, W.	Scot.	31.1.55
Pierce, L. J.	E.-in-C.O. (*Resigned*)	31.12.54	McCulloch, W.	Scot.	31.1.55
Duffield, H.	H.C. Reg.	9.1.55			
Jones, S. K.	L.T. Reg.	18.1.55	*Asst. (Sc.)*		
Brown, J.	Scot.	19.1.55	Wilkins, D. F.	E.-in-C.O.	14.1.55

Transfers

Name	Region	Date	Name	Region	Date
Area Engr.			*Asst. Engr.—continued.*		
Wilkinson, E. H.	N.I. Reg. to N.E. Reg.	21.9.54	Hussey, E. D. F.	E.-in-C.O. to Pakistan	4.12.54
			Watkins, A. H.	E.-in-C.O. to H.C. Reg.	12.12.54
			Gent, P. E.	E.-in-C.O. to N.E. Reg.	19.12.54
Exec. Engr.			Shore, A.	E.-in-C.O. to Ministry of Supply	20.12.54
Oakford, E. R.	E.-in-C.O. to L.T. Reg.	17.1.55			
Lamb, A. H.	E.-in-C.O. to N.E. Reg.	31.1.55	Bacon, F. P.	E.-in-C.O. to H.C. Reg	29.12.54
Faulkner, A. H.	E.-in-C.O. to P.M.G. Dept., Australia	20.3.52	Kelly, H. R. S.	E.-in-C.O. to N.I. Reg.	2.1.55
			Lippitt, D.	E.-in-C.O. to W.B.C.	2.1.55
			Johnson, D.	Scot. to E.-in-C.O.	9.1.55
Asst. Engr.			Spencer, D. C.	E.-in-C.O. to P.D.	10.1.55
Green, J.	P.M.G. Dept., Australia, to N.I. Reg.	14.6.54	Brown, K. N.	E.-in-C.O. to A.P.R.D.	10.1.55
			Spink, J. S.	S.W. Reg. to H.C. Reg.	18.1.55
Harvey, A. G.	M. Reg. to P.M.G. Dept., Australia	12.1.52	Cox, J. S.	E.-in-C.O. to H.C. Reg.	23.1.55
			Kitt, M. J.	E.-in-C.O. to H.C. Reg.	23.1.55

Deaths

Name	Region	Date	Name	Region	Date
Asst. Engr.			*Asst. Engr.—continued.*		
Broadbent, H. M.	N.E. Reg.	27.11.54	Clarke, W.	N.W. Reg.	5.1.55
Martin, W. H.	N.W. Reg.	20.12.54	Fegan, G. H. F.	S.W. Reg.	29.1.55
Faulks, G. H.	S.W. Reg.	22.12.54			

ASSOCIATE SECTION NOTES—*(continued from p. 61)*

Guildford Centre

At the time of writing the 1954/55 session of the Guildford Centre is in full swing. The programme to date has included a monthly film show of engineering and travel films, projected from the Centre's own 16-mm projector, together with various lectures and visits.

During September 1954, parties of members visited the A.J.S. motor-cycle factory at Plumstead, London, and the cable ship H.M.T.S. *Monarch* at Greenwich.

On 20th October, we were pleased to welcome Mr. P. A. Cummins, of the Radio Controlled Model Society. The members found his lecture and demonstration, "The Radio Control of Models," of great interest and were very impressed by the degree of control he was able to demonstrate on a battery-driven model of a DUKW.

On the 13th November, 1954, 20 members paid a morning visit to the National Physical Laboratories at Teddington, 10 members of this party also visiting Tower Bridge in the afternoon.

An interesting lecture entitled "Television Reception" was given on 6th December by Mr. L. G. Wallis, former secretary to this Centre. A visit, on 10th December 1954, to the factory of Vickers-Armstrongs, Ltd., at Weybridge, aroused much interest, the party seeing the manufacture of numerous components required in modern-aircraft construction.

A lively discussion followed the reading of a paper entitled "The Problem of Keeping Up to Date" by Mr. C. J. Search, Senior Section member, on 25th January. The speaker drew attention to some possible applications of present-day research to telecommunications practice of the future, and left members in no doubt that keeping up to date will become an ever-increasing problem.

With the approach of spring our programme will deviate from engineering and touch a subject which is a hobby to many of our members. On 8th February, we welcomed Mr. G. A. Pilcher, of the Chase Guild, who presented a lecture and film show on "Cloche Gardening."

Further film shows and visits are being arranged for the remainder of the season. E. N. H.

London Centre

The London Centre is now approaching the end of another successful session, the 17th since its formation. The most notable success has been the award, made by the Senior Section, to Mr. G. L. Sanderson for his paper, "Outside Television Broadcasts"; he received a cheque for 4 gns. and the Institution's Certificate of Merit. Another member, Mr. C. S. Wicken, received an award of 1 guinea for his paper, "An Experimental Observation Circuit." Mr. G. W. Bates, of the Test Section, was unfortunate in that his paper "Post-War Developments of Testing Dials Automatic" was disqualified on a technical point.

The last lecture of this session follows the Annual General Meeting on the 24th May, 1955, when Mr. E. F. H. Gould, E.-in-C.'s office, will lecture on "Testing and Inspection of Post Office Engineering Stores" in the Small Hall, I.E.E., Savoy Place, W.C.2.

The two lectures arranged this session that were a departure from the normal pattern of the London Centre programme—"Some Conception of Space and Space Travel" by W. A. W. Lankshear and "Power from Nuclear Reactors" by Dr. A. J. Salmon—were a great success. Mr. Lankshear has been approached to give another lecture during the coming session.

After six issues of a Newsletter, a single foolscap broadsheet, the London Centre decided to publish a Roneod Quarterly Journal. It contains articles by Associate Section Members and other authors on technical subjects, visits of interests, book reviews, details of additions to the I.P.O.E.E. Library, and miscellaneous items of interest. Anyone interested should contact Mr. P. Sayers, LD/EK 3, Wren House, 27 St. Paul's Churchyard, London, E.C.4, who will send a copy on request. P. S.

Sheffield Centre

During the past 18 months the Sheffield Centre has been dormant but once again we are a thriving community. At the time of going to press, a part of our winter programme has been successfully negotiated. Items included a most enlightening visit to the British Iron and Steel Research Association; a lecture, with demonstrations, given by Mr. E. A. Scholey, entitled "The Early Days of Electricity" which illustrated, in the main, the works of Faraday, and a visit to the English Steel Corporation.

In order to stimulate interest and at the same time create a social atmosphere at our meetings, we are providing light refreshments. So far the idea has proved quite successful.

The remainder of the session's programme holds many attractions and it is hoped that more of our members, especially the youths, will take advantage of them. J. R.

Communications

All communications should be addressed to the Managing Editor, *P.O.E.E. Journal*, Engineer-in-Chief's Office, Alder House, Aldersgate Street, London, E.C.1. Telephone: HEAdquarters 1234. Remittances should be made payable to "*The P.O.E.E. Journal*" and should be crossed "& Co."

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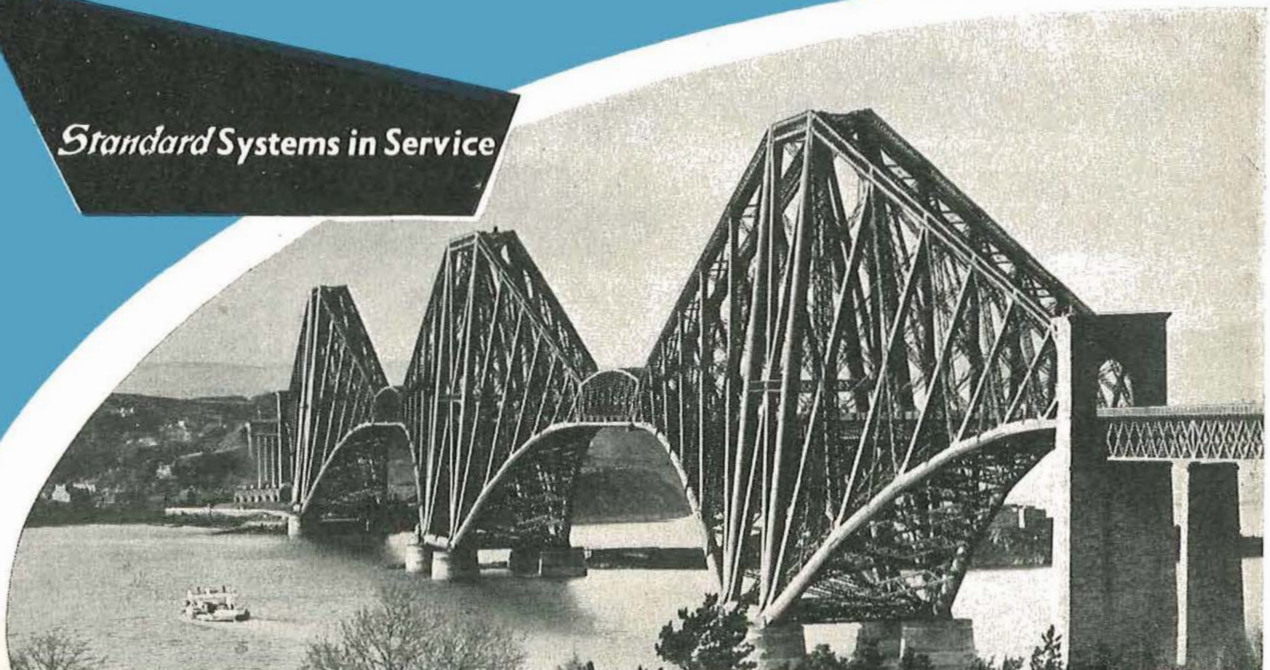

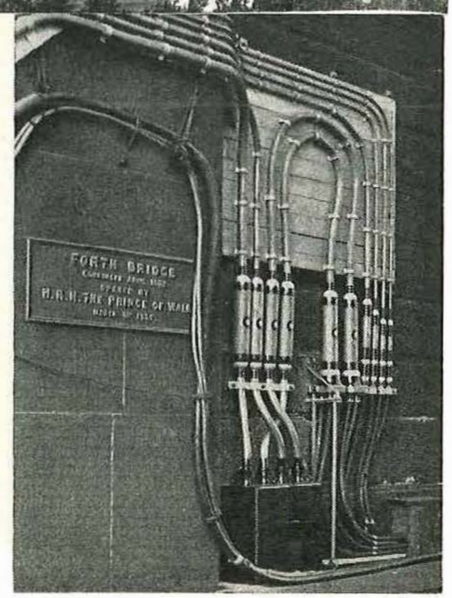

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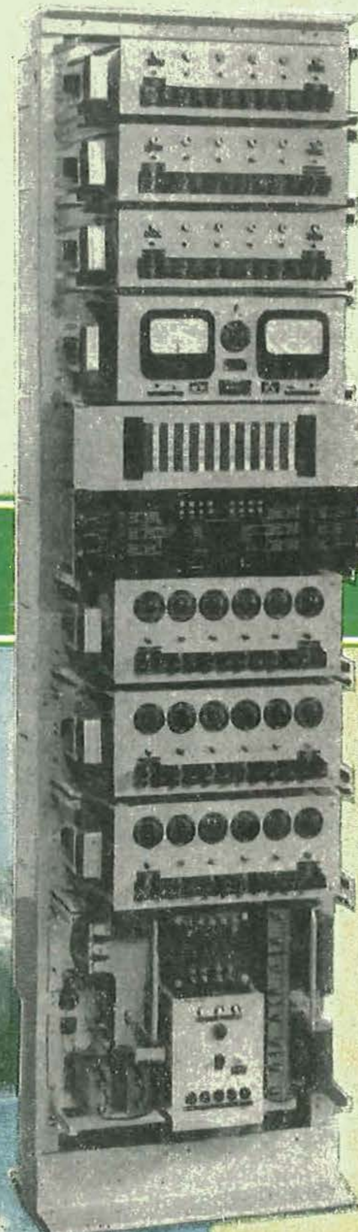

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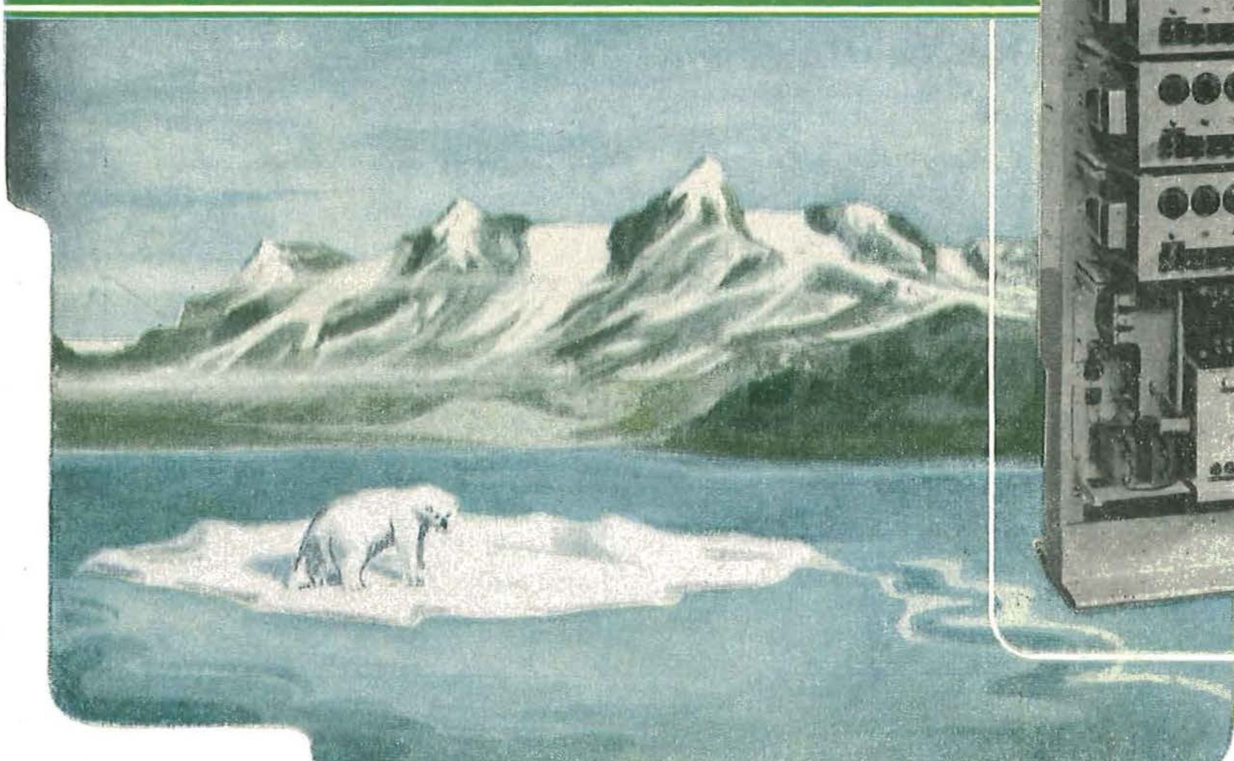

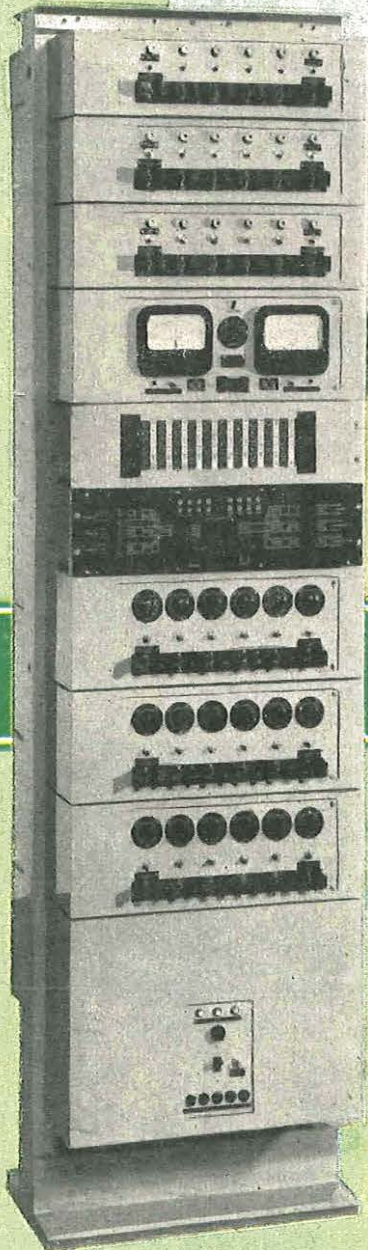

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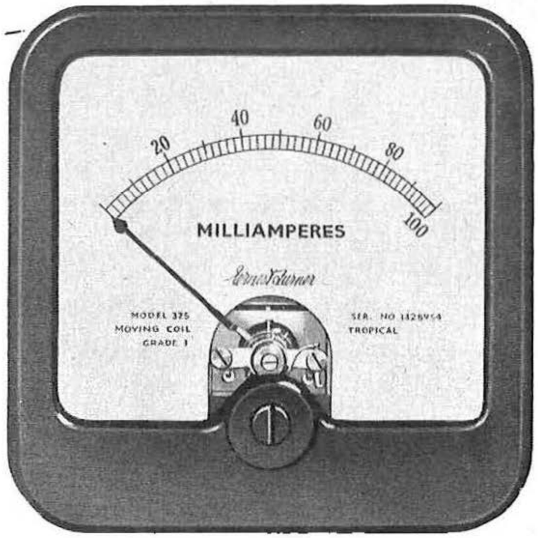

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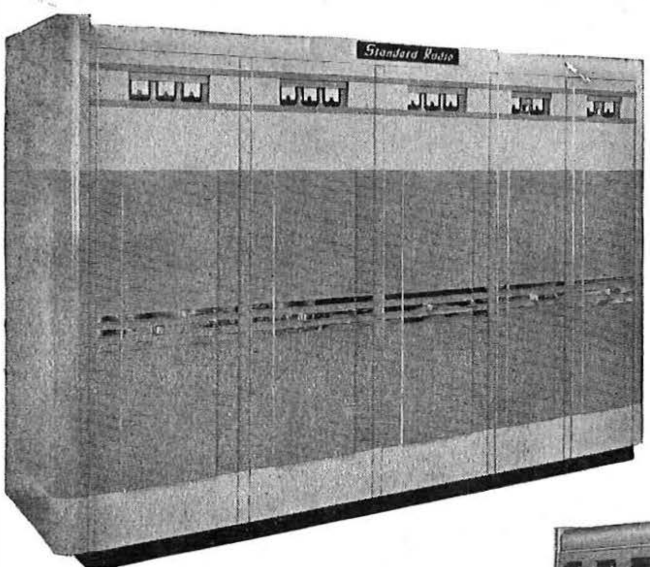

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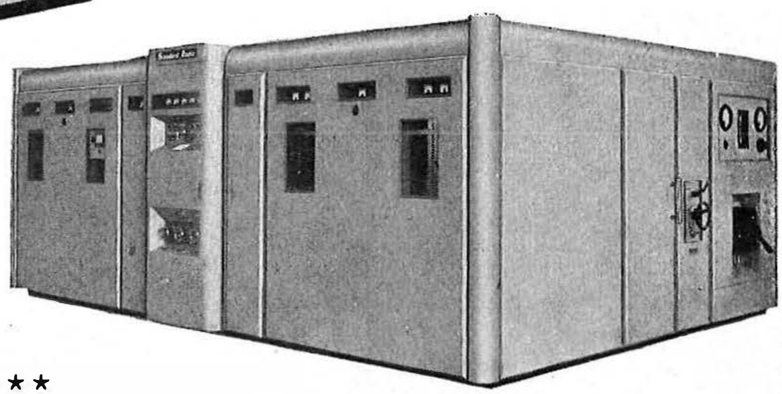

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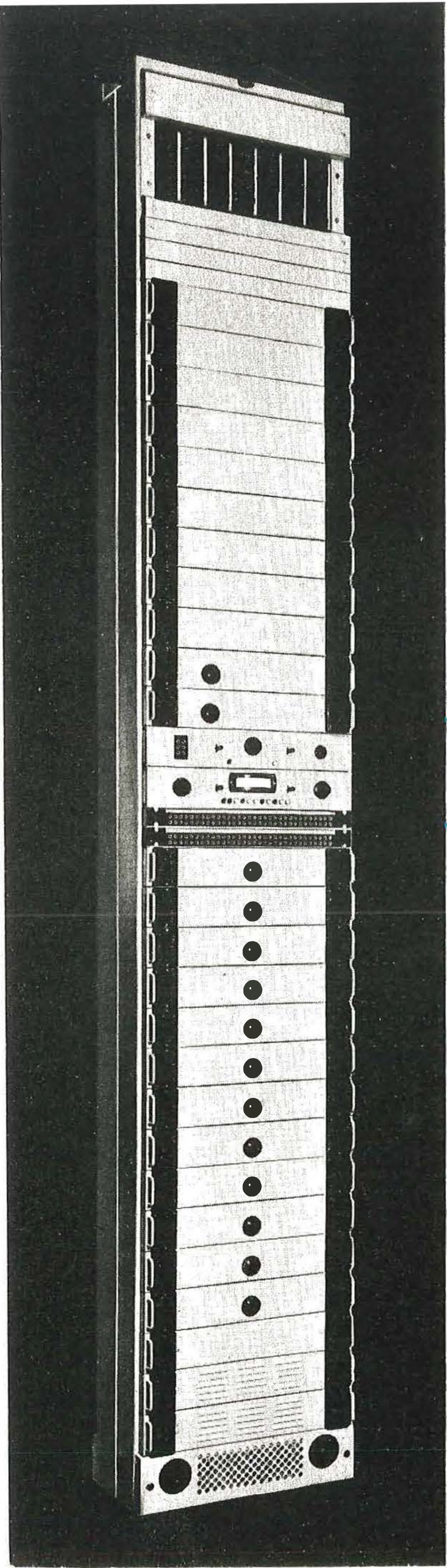

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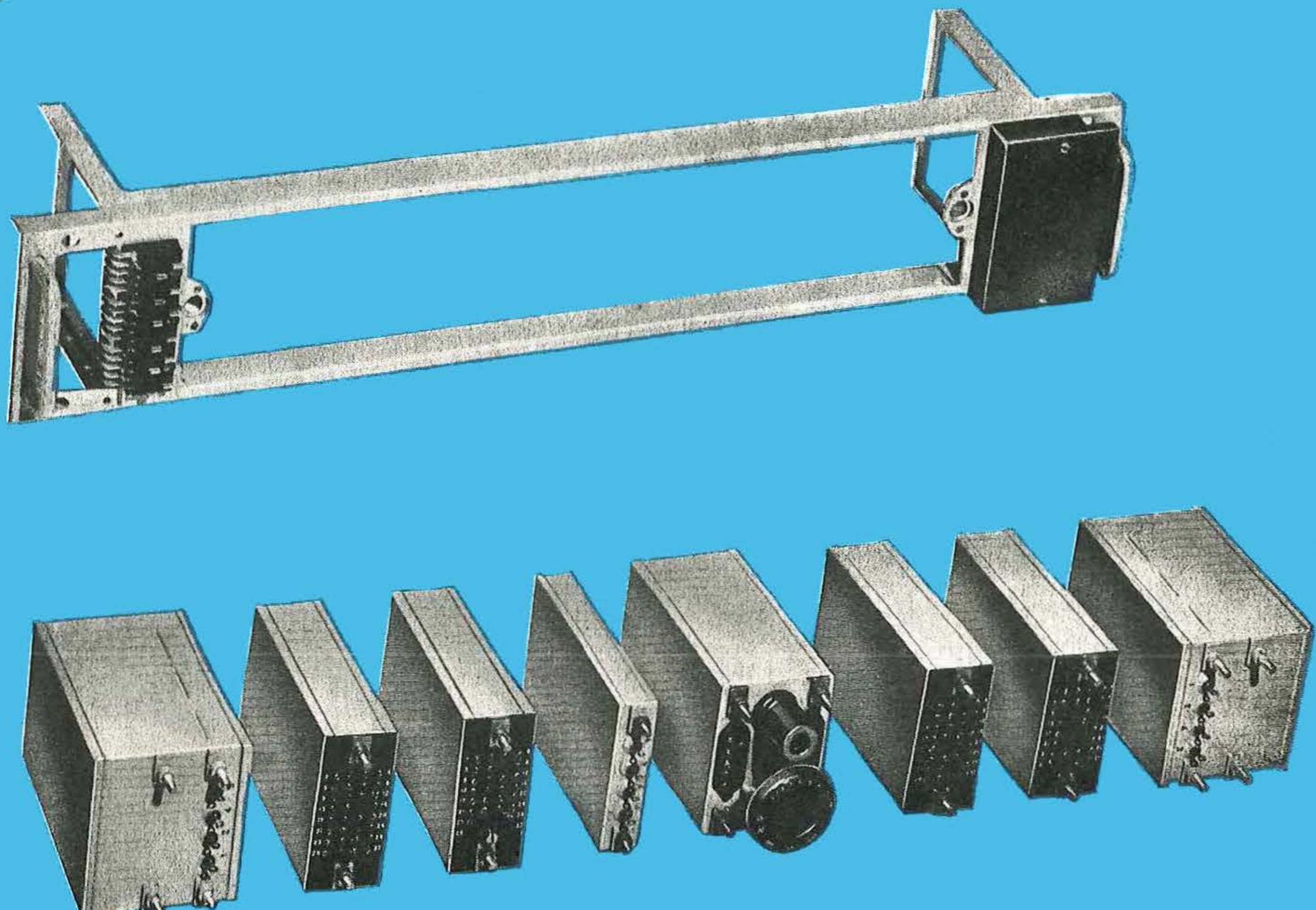

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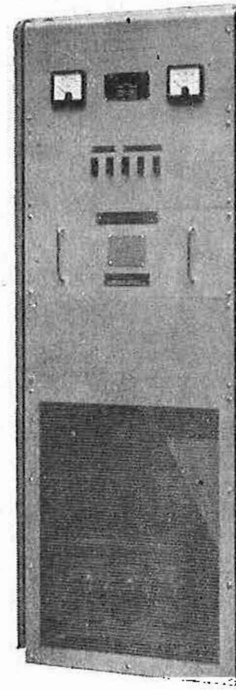

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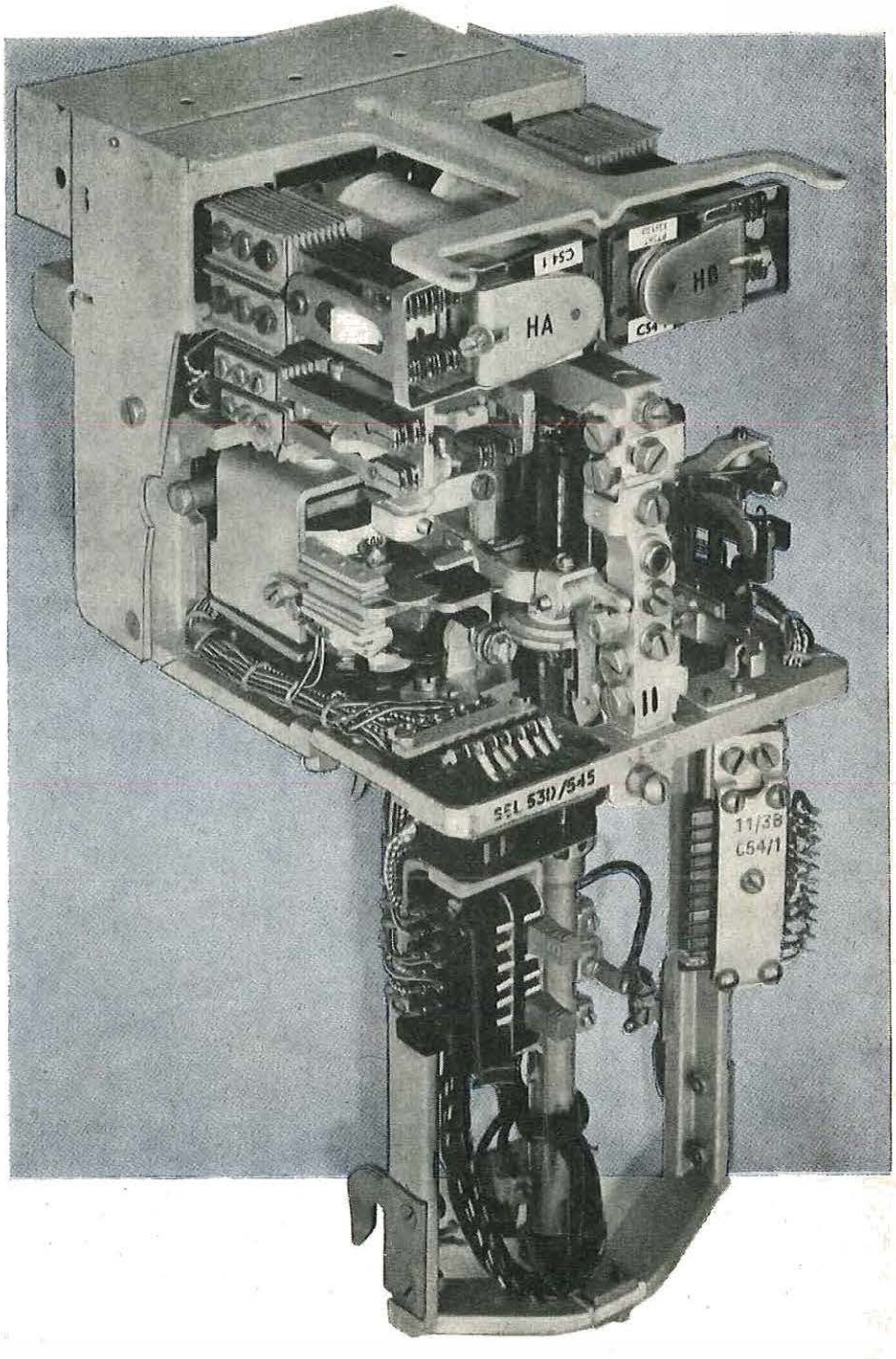

Nowhere in a telephone exchange is the reliability of Selector SE50 more fully proved than by its excellence in doing the exacting job of a linefinder.

Selector SE50 stays adjusted in this most arduous function—showing the soundness of its basic design, with the wear-reducing maximum of metal-to-metal contact area for all mechanical movement and the absence of bending adjustments.

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final selector

Discriminating selector repeater

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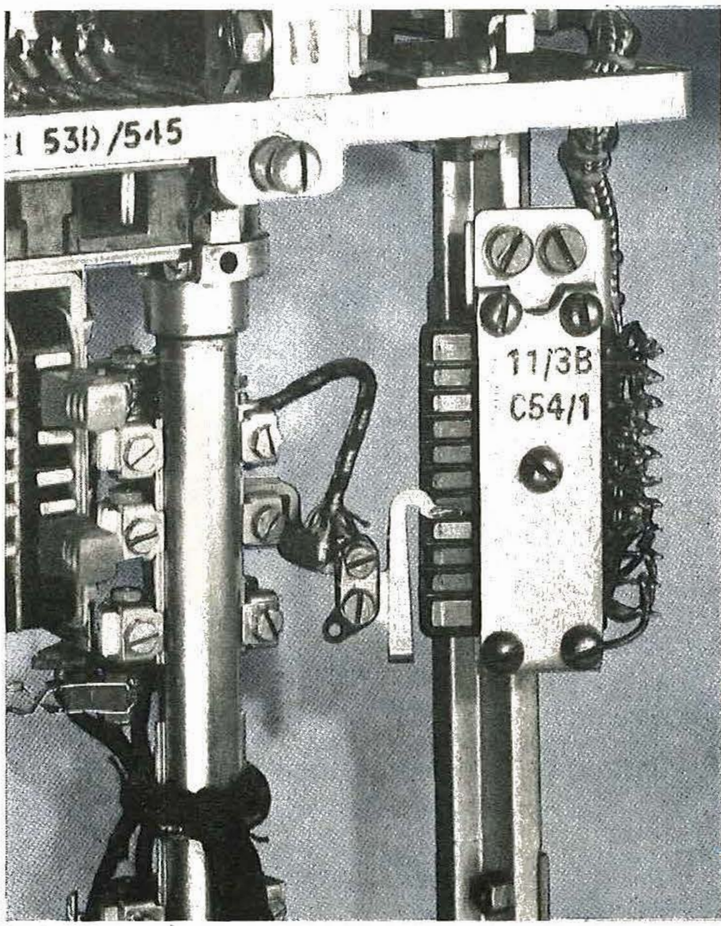

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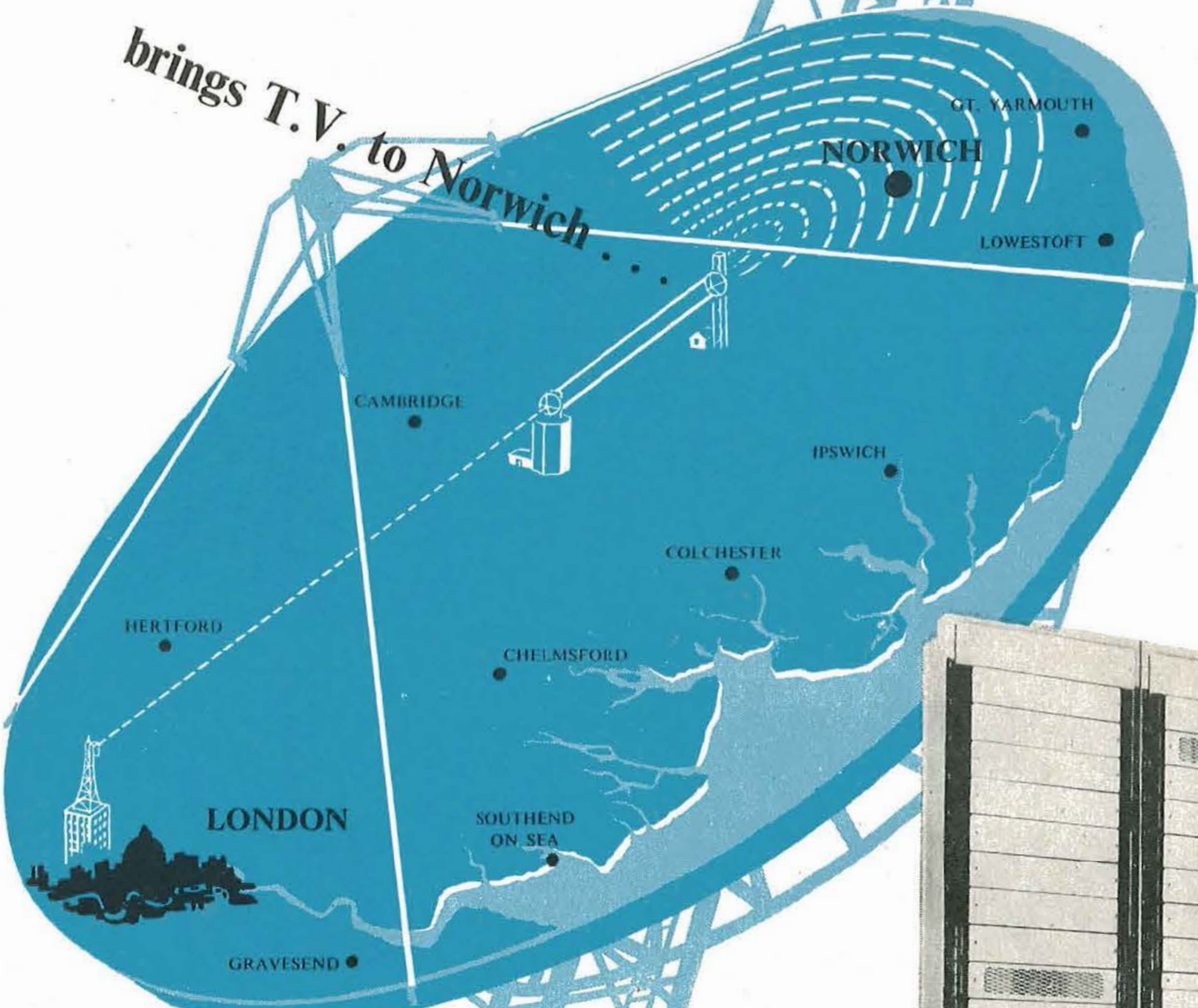
brings T.V. to Norwich . . .



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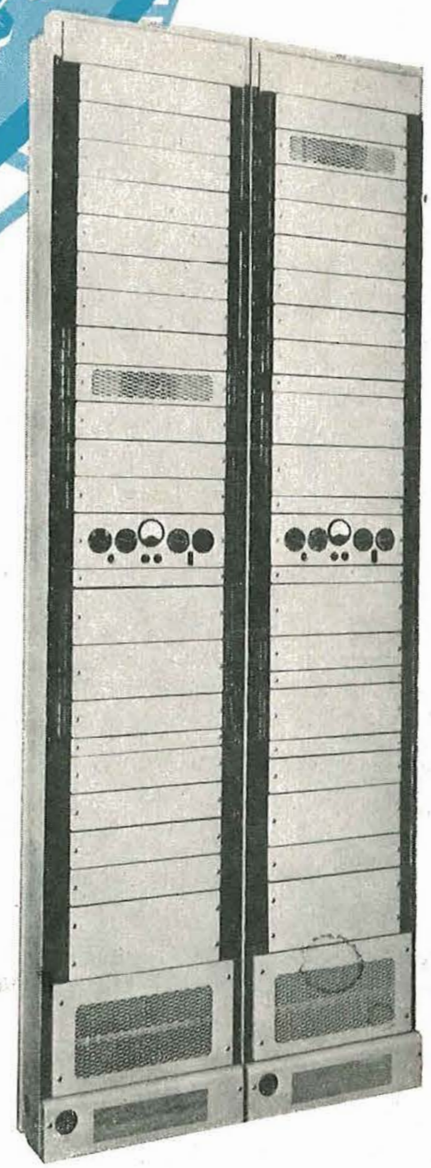

TWO G.E.C. *microwave* UHF *radio relay racks. Capable of transmitting 405-, 525- and 625-line pictures.*

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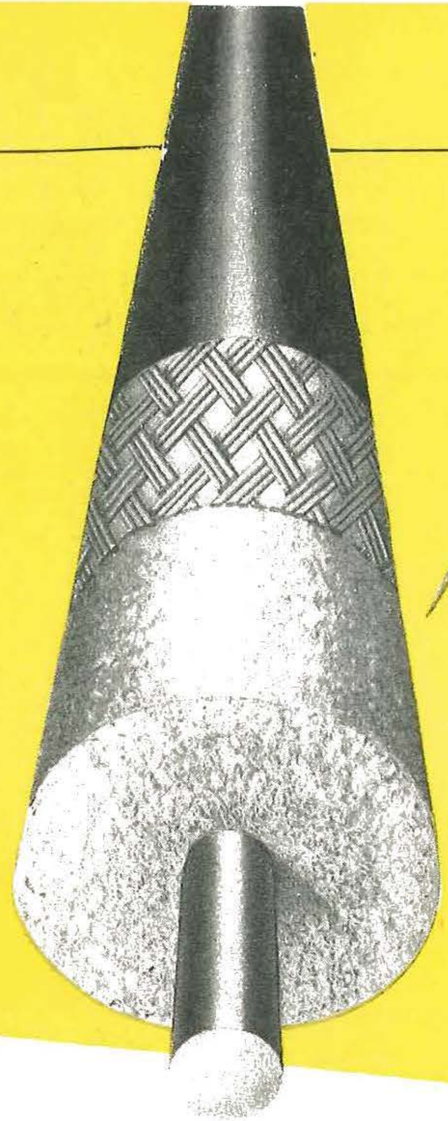

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30%

less attenuation with only small increase in size

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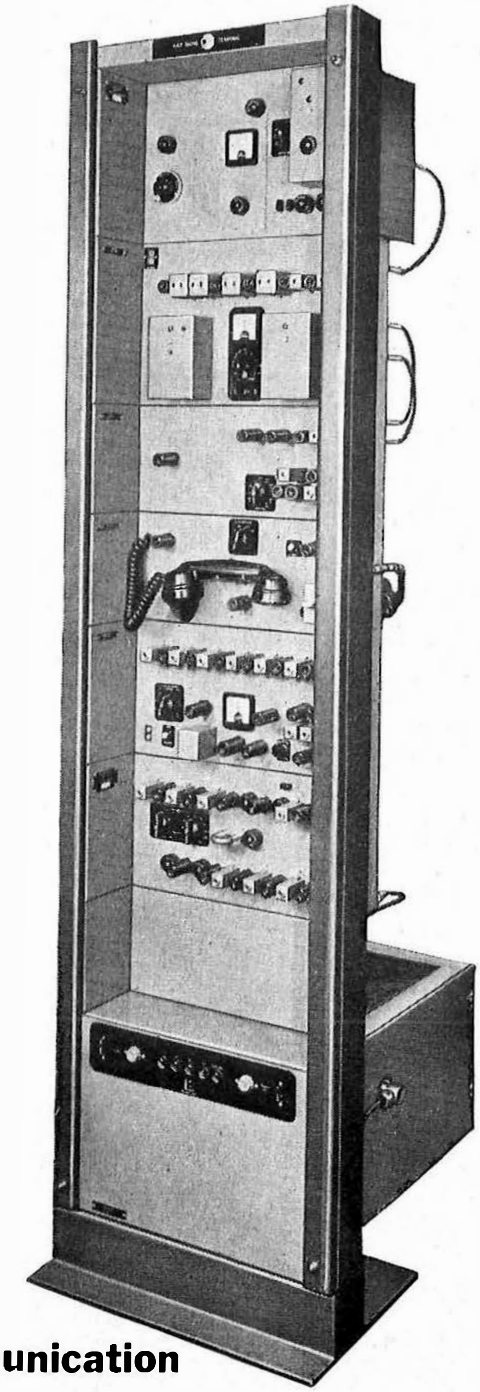

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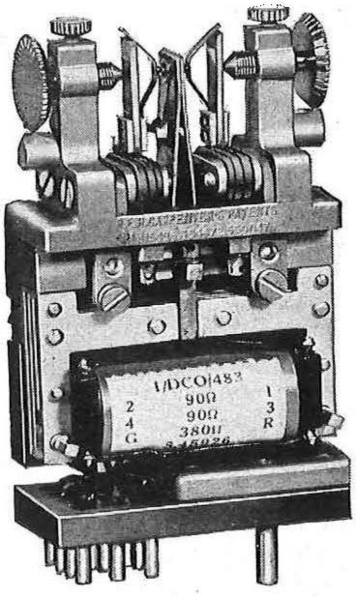
CARPENTER POLARIZED RELAYS



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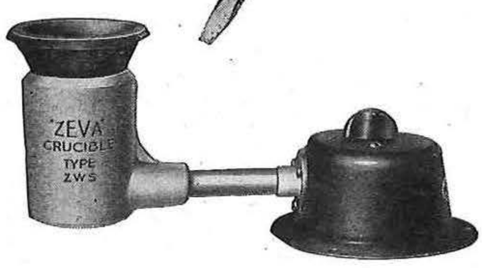

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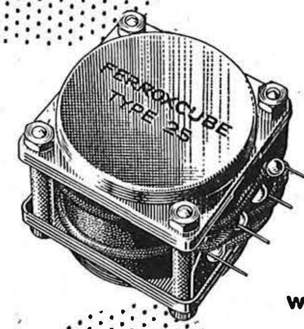

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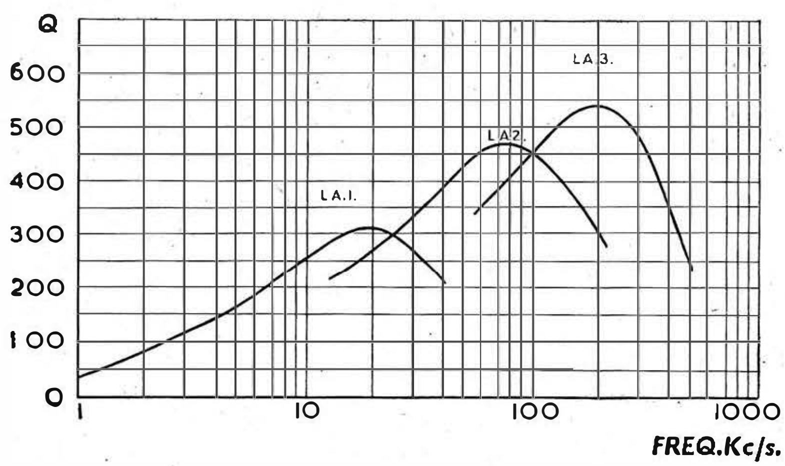

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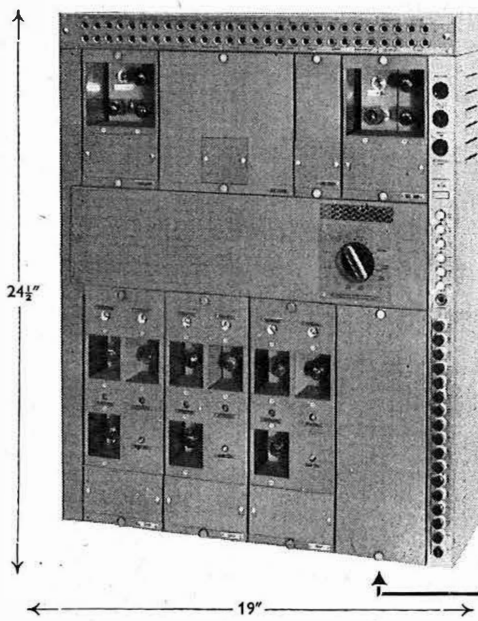

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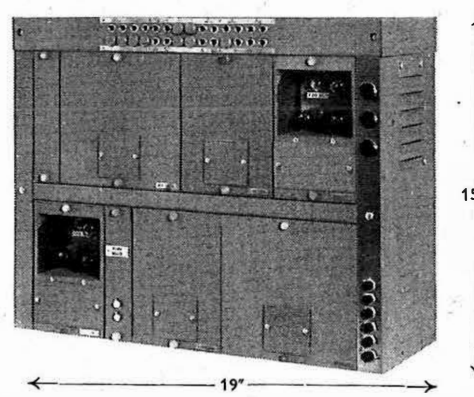

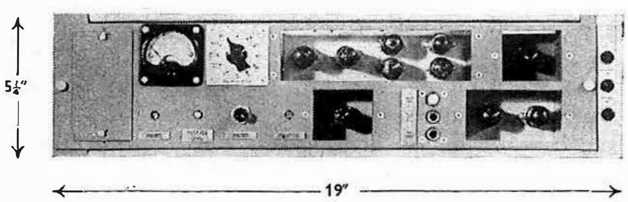

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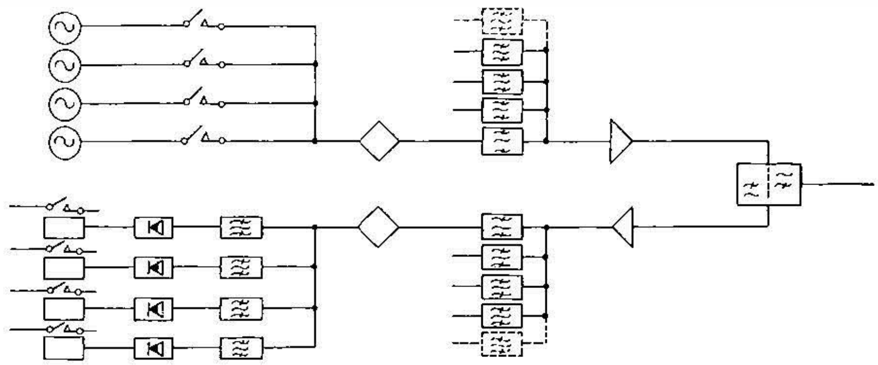

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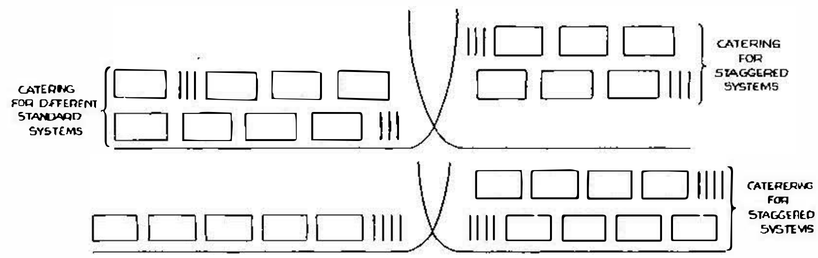
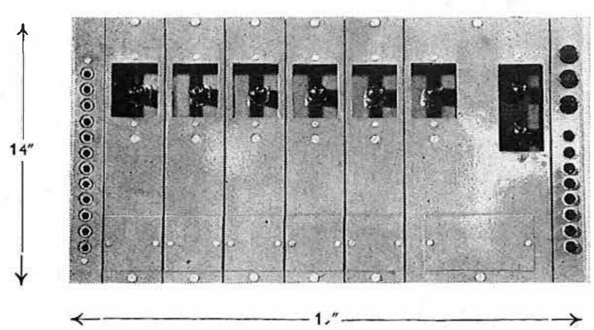
or Dialling
or An actual telegraph channel

The change is made by plug-in relay sets and for:—
Ring down, 3 relays are required
Full dialling and supervisory, 5 relays are needed
Telegraph only, normal telegraph relays or static modulators are used



The signalling channels placed in an otherwise wasted part of the frequency band, as illustrated.



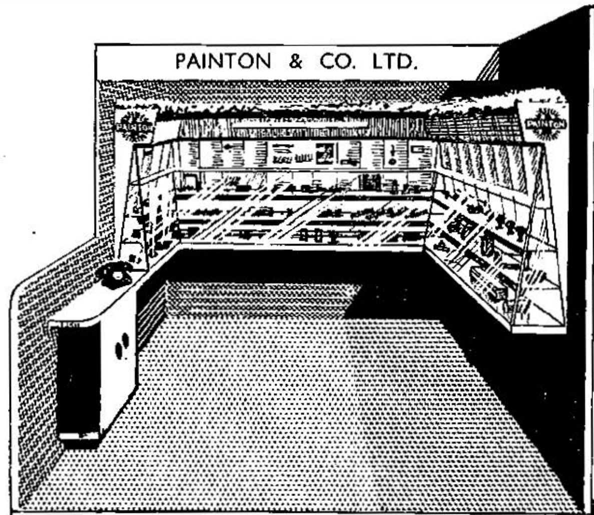
This Unit can be equipped on any of our 1+3 or 1+4 Systems, also on most other manufacturers' systems, WITHOUT CHANGING THE CROSS OVER POINT and therefore no interference problems are introduced on existing routes.

T. S. SKILLMAN & CO. LTD., Grove Park, Colindale, London, N.W.9
T. S. SKILLMAN & CO. PTY. LTD., Cammeray, Sydney, N.S.W.

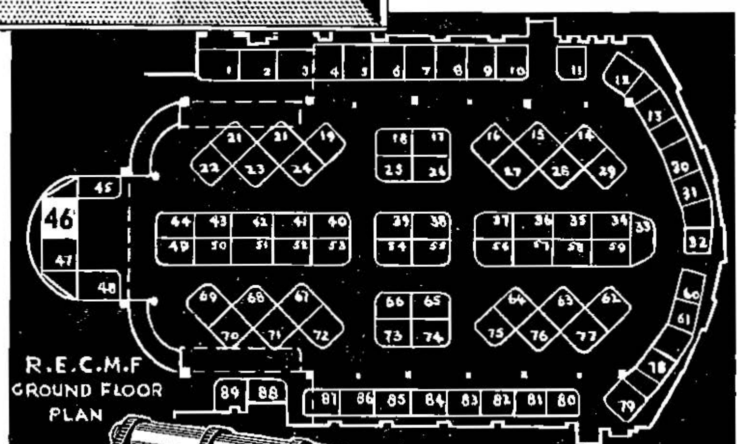

Designed to
meet G.P.O. specifications
TUNGSTONE Batteries have been designed to meet Post Office and British Standards specifications. They are being used in Telephone Exchanges and Power Stations, etc., all over the British Isles; in Australia, India, New Zealand, Egypt, South Africa, West Indies, etc.
The illustration is of a 50 cell Battery TUNGSTONE type BSSEW.43. giving 3150 A.H. at the 9 hour rate. Installed for G.P.O.

PAINTON

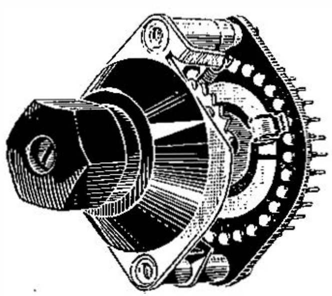
By Appointment to the Professional Engineer

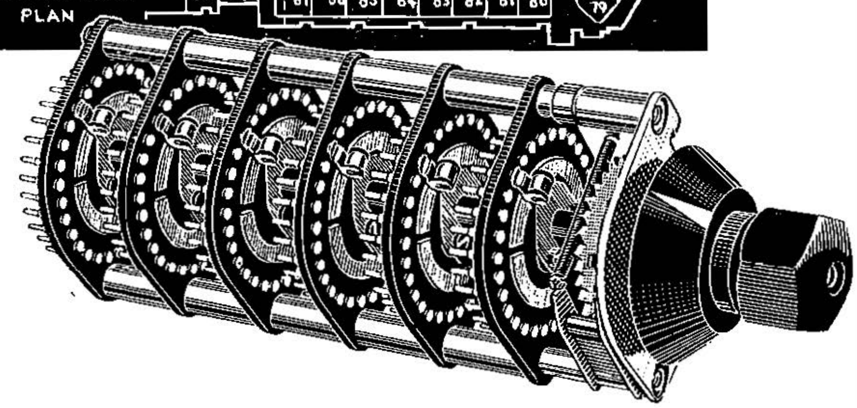


A cordial invitation is extended to you to visit our Stand No. 46 during your attendance at the 1955 R.E.C.M.F. Exhibition. The complete range of Painton Components will be displayed including . . .



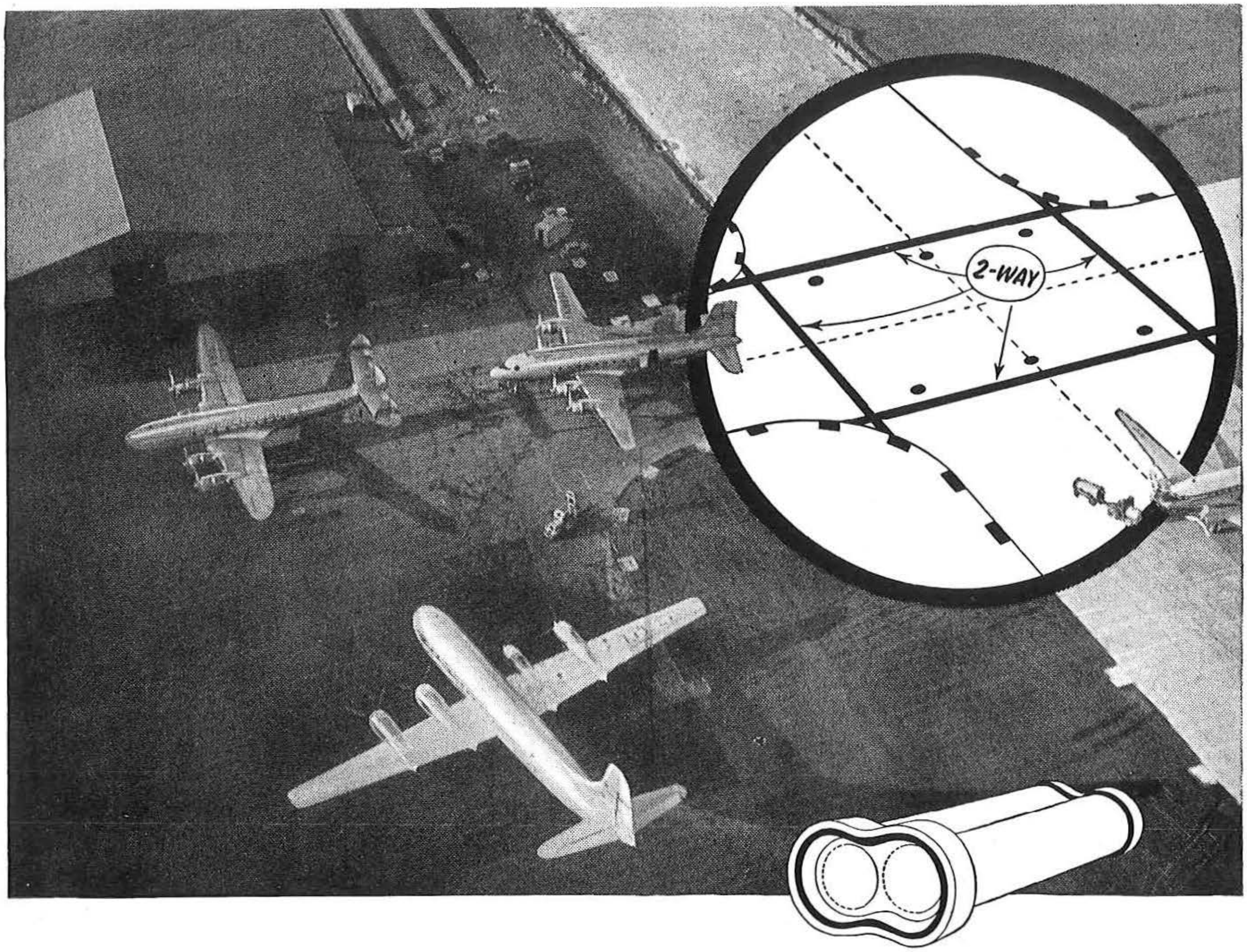
. . . the commercial version of the new PAINTON WINKLER SWITCHES, a selection of which are illustrated here.





PAINTON

Northampton England



Under an Airport Runway

If you never want to have to dig them up again put down

This is a typical runway intersection—it is a key point. Under it is a network of conduits, carrying the cables for the runway lights. If anything happens to those conduits, if they have to come up again—*two* runways will be out of action.

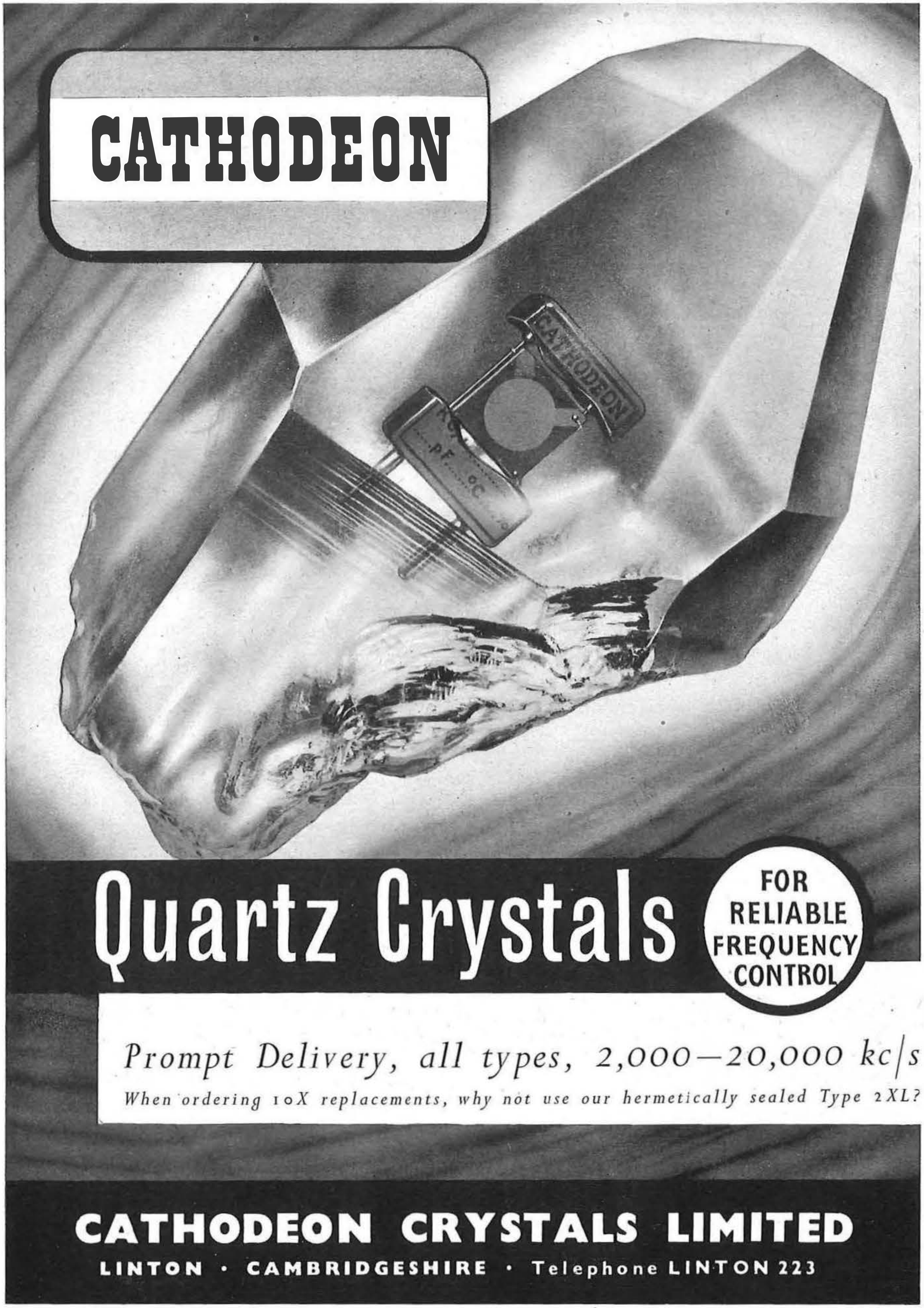
Think what that means to a big airport. Last year *in August alone* London Airport handled nearly 9,500 aircraft and 210,000 passengers. A lot depends on those conduits; they must be able to stay down there, doing their job—for good!

That's why they put down conduits of salt glazed vitrified clay.

Salt glazed conduits are glassy smooth and hard as nails. They are acid-resisting ; sulphates in the soil cannot corrode them. The same applies to the hundreds of salt glazed *drain-pipes* that are out there too. Safe and efficient, salt glazed conduits and pipes can —and do—stay down for centuries.

Salt Glazed* VITRIFIED CLAY *pipes and conduits

NATIONAL SALT GLAZED PIPE MANUFACTURERS' ASSOCIATION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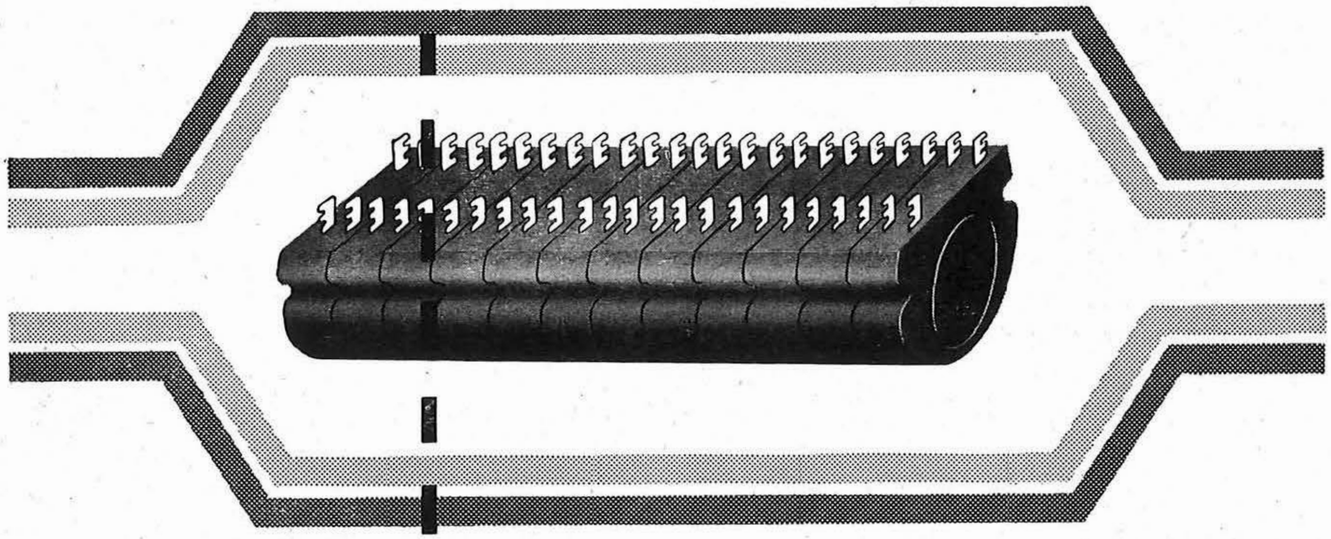
Loading coils inside the cable splice

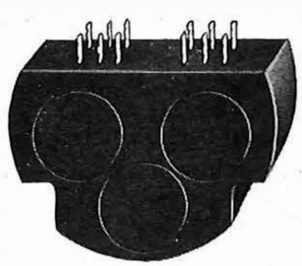


The advantages of the splice loading technique are particularly marked in the loading of small cables of up to 74 pairs. The coils can be included in a jointing sleeve or unit of only slightly larger diameter than would normally be used.

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.



TRIPLE COIL ASSEMBLY

Mullard

SPECIALISED ELECTRONIC EQUIPMENT

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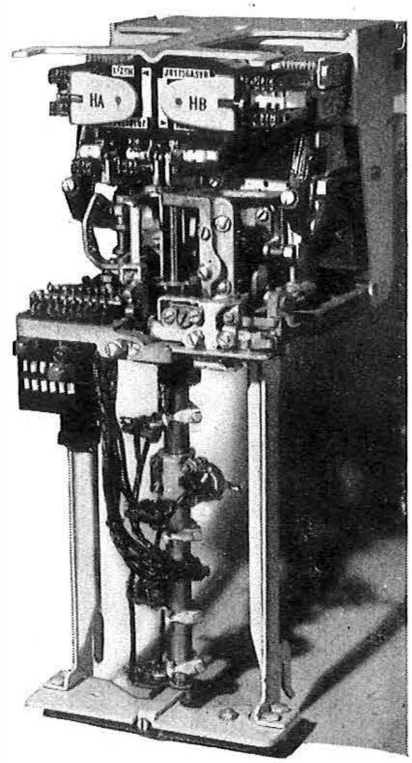

Carlton Exchange, operated by the Jamaica Telephone Co. Ltd., is a typical example of British enterprise in the Caribbean.

Carlton Exchange is of 3,000 lines capacity and is equipped at all selecting stages with the type 32A selector, the basic unit of the Strowger system, as manufactured by Automatic Telephone & Electric Co. Ltd. The simplicity and flexibility of the system are factors of considerable appeal to this and other administrations who are concerned with providing an economic and reliable service to their subscribers on an easily expandable basis.

This is only one of many exchanges supplied and installed by Automatic Telephone & Electric Co. Ltd., in the Caribbean area.

Another Strowger Exchange

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