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THE POST OFFICE
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A Transistor Hearing Aid

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The need to reduce the size and weight of hearing aids has been emphasized by the increasing use of these aids by young children. The advent of reliable transistors suitable for large-scale production has enabled the Post Office, in collaboration with a manufacturer, to produce a National Health Service hearing aid in which the microphone, amplifier and single-cell battery are contained in one case, the total weight, including the earphone, being 3½ oz.

INTRODUCTION

BEFORE describing the new transistor hearing aid issued to children under the National Health Service, it is of interest to review briefly the progress which has been made in Medresco* hearing aids since the publication in this Journal¹ of the previous article on the subject.

Throughout the history of the Medresco valve-type hearing aids supplied under the National Health Service, the need for reducing size and weight has been an important design consideration. The last version of the aid, made available in 1955, is the Mark IIIA, in which the size and weight of the batteries was considerably reduced by using valves of lower filament current consumption and a more efficient earphone, which made possible a reduction in the h.t. current. It is unlikely that any new version of the valve-type aid will be introduced.

Both l.t. and h.t. batteries are now approximately half the size and weight of those used in the Mark IIA design and probably represent the minimum economic size. The batteries normally issued to a patient consist of one h.t. and five l.t. batteries and these are sufficient to last 3 months when the aid is used for 15 hours per day. The complete aid weighs 1 lb 2 oz, of which 13 oz is accounted for by the batteries and their pouch.

The overall effect of the changes on the acoustic performance was to increase the efficiency in the middle-frequency range at the expense of a lower cut-off frequency, because of the use of the new earphone.

Approximately 300,000 Mark IIIA aids are now in use and large numbers continue to be issued to new patients. It is evident, therefore, that this type of valve

aid will remain in use and continue to give good service for as long as it is possible to carry out economic repairs.

There is, however, a growing tendency to prescribe a hearing aid for children at a much earlier age than previously—even down to 12 months—for whom a heavy and bulky aid is an added handicap. It was for this reason that a new valve aid, the Mark IV, was produced in 1955 for issue exclusively to children. It was of the "monopack" type, having miniature h.t. and l.t. batteries accommodated inside the amplifier case, there being no separate battery pack. The case was slightly larger than that for the amplifier of previous aids, although several components had been redesigned to provide extra space for the batteries. The total weight of 5¼ oz was achieved at the expense of a running cost three to four times that of a Mark IIIA aid. A free-issue set of small batteries, i.e. one h.t. and 10 l.t., lasted only 3½ weeks when used for 15 hours per day. A small quantity of the Mark IV aid was produced and sent for trial at selected schools in mid-1955. It was the intention of the Ministry of Health to issue the aid to all deaf children if it proved satisfactory.

The prospect of using transistors for this sort of hearing aid, where lightness and small size are particularly important, had not been encouraging up to this time. There was no British production capacity capable of supplying transistors in such quantities as would be required for Medresco needs, and they were relatively expensive. Most of the manufacturers interested in transistor production were still at the experimental stage and only one was known to be planning large-scale production.

It was not until towards the end of 1955 that sufficiently encouraging results were obtained from accelerated life tests conducted at the Post Office Research Station on sample junction transistors to justify embarking on a large-scale trial. Prices and facilities for quantity production also appeared to be favourable. Accordingly, at the request of the Ministry of Health, the development of a transistor hearing aid was undertaken by the Post Office in collaboration with a manufacturer.

In considering the various Medresco aids then in existence from which to choose a suitable type for converting to a transistor design, the monopack Mark IV model offered savings and obvious advantages. It was decided therefore not to proceed with this particular valve model but to introduce it as a transistor design to be issued first to children.

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* Medical Research Council.

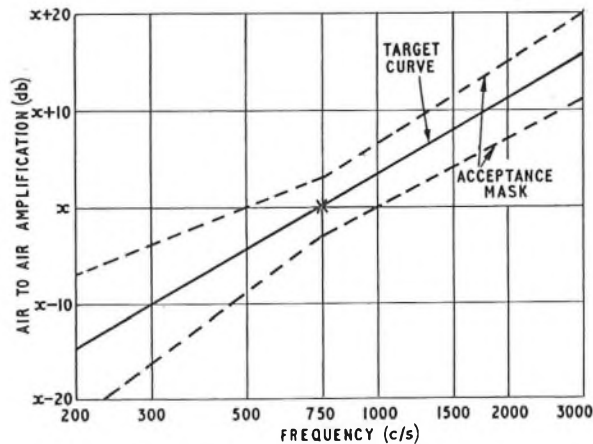
¹CAMERON, C. J., and AYERS, E. W. The Medresco Hearing Aid. *P.O.E.E.J.*, Vol. 44, p. 153, Apr. 1952.

DESIGN OBJECTIVES

Following the publication of the special report by the Medical Research Council on hearing aids,² experience with Medresco aids led the committee concerned to revise some of the recommendations. Additionally, the committee took into account the modifications required when the recommendations were applied to the design of hearing aids with insert earphones.

These recommendations resulted in a requirement for a single air-to-air amplification/frequency curve rising at about 8 db per octave over a frequency range of from 300 c/s to at least 3,000 c/s. The minimum air-to-air amplification[†] at 750 c/s was required to be 52 db.

The amplification/frequency response which was derived and used for specification purposes is shown in Fig. 1, which also indicates the defined tolerance limits.



The characteristic shall fit within the limits shown by the Acceptance Mask, where x is not less than + 52 db

FIG. 1.—SPECIFIED FREQUENCY RESPONSE FOR HEARING AIDS

In addition to the maximum output sound pressure of 200 dynes/cm² which was to be provided, the committee also required an alternative maximum output of approximately 60 dynes/cm² which could be selected and preset by the clinic.

Physical design of the aid as a whole was to be based on experience gained during use of the valve monopack aid, which had served to emphasize desirable features to be included and weaknesses to be avoided; but ease of production, use of readily available components and, above all, the maximum permissible cost of the aid, were also important factors which had to be taken into account.

The individual performance limits of the microphone, amplifier and earphone were to be specified so that any combination of a set of these three items, each taken at random, would produce an air-to-air response within the defined limits. That is, correcting the performance by means of adjustment or selection of different components would be rendered unnecessary and thereby allow flow-line assembly methods to be used.

Investigation of the economics of different sizes and types of battery led to the design of an amplifier circuit powered by a single 1.5-volt Leclanché-type cell. It was, in fact, the physical dimensions of this battery which largely determined the shape and size of the hearing-aid case.

² Medical Research Council Special Series, Report No. 261 (H.M. Stationery Office, 1947).

[†] Air-to-air amplification is the ratio of the sound pressure developed by an earphone in an artificial ear to the free-field sound pressure in which the aid is placed.

DEVELOPMENT OF THE AMPLIFIER CIRCUIT

As the frequency range of a hearing aid should not extend beyond about 4 kc/s it was clear that it would be possible to make use of the grounded-emitter rather than the grounded-base or grounded-collector configuration because, potentially, a greater gain per stage, either power or current, could thereby be achieved. Not only would the use of grounded-emitter circuits tend to reduce the number of stages but there is also the incidental but important advantage that the standing direct currents in the driving stages of the amplifier would tend to be smaller than if one of the other configurations were used.

Paramount in the design of a transistor-amplifier stage is the consideration of the variation with temperature of the operating point, i.e. variation of the collector current and collector-emitter potential for a grounded-emitter stage, with consequential variations in stage gain and output. The point arises as follows. For the usable region of the transistor characteristics, i.e. where they are substantially linear, the following relationship very nearly applies:

$$I_c = I_{ceo} + \alpha_{cb} I_b$$

where I_c = total collector current,

I_{ceo} = collector current for zero base current,

α_{cb} = current gain from base to collector,

I_b = base current.

The current I_{ceo} is fundamentally temperature-dependent to such an extent that it is approximately doubled for each 7°C rise; it is thus possible that for low-power stages I_c can vary by quite a large factor. When it is considered also that irrespective of the type of coupling used between stages there will always be some d.c. resistance (R_c) in the collector feed, it follows that the collector-emitter potential of the operating point is also liable to vary considerably because of the $R_c I_c$ drop in potential from the (constant) battery voltage.

Apart from the obvious method of specifying the transistors to have an appropriately small upper limit for I_{ceo} , with a corresponding decrease in yield in manufacture and so an increase in cost, there are in principle two simple ways of mitigating the effects of temperature on the operating point. Firstly, the circuit can be arranged so that I_c is so large that the contribution made by I_{ceo} is small at the highest temperature of use of the stage; this method places a correspondingly small upper limit on the value of the collector feed resistance R_c . Secondly, the value of I_c can be stabilized against changes in I_{ceo} (by, for example, compensating the changes in I_{ceo} by opposite changes in I_b). The first method is used to some extent in the output stage of the hearing aid, where relatively high values of I_c are required in order to obtain sufficient a.c. power output, and in the interests of economy in battery current the second method is used in the driving stages.

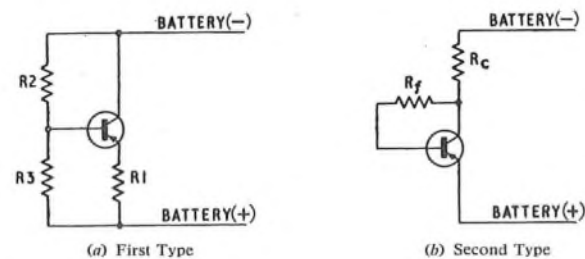


FIG. 2.—STABILIZATION CIRCUITS

There are two commonly used stabilization circuits when one battery supply is available. In the first circuit (Fig. 2(a)), the stabilization action can be understood by looking upon resistors R2 and R3 as a low-resistance potential divider to fix the potential of the base of the transistor independently of the base current, and at the same time regarding R1 as a high-resistance feed to the emitter of the transistor, thereby fixing the emitter current independently of the transistor potentials. As the collector current is very nearly equal to the emitter current the transistor currents and potentials can be substantially determined or stabilized by this sort of external circuit. The degree of stabilization is, in fact, increased the greater the ratio R_1/R_p is made, where R_p is the resistance of R2 and R3 in parallel. Thus, either R_1 must be relatively large, leading to a large voltage drop across it and so leaving too small a portion of the battery-supply voltage available between the collector and emitter of the transistor, or R_p must be relatively small, causing a large current drain from the battery as well as introducing in the a.c. transmission path a shunt loss across the input to the stage in grounded-emitter configuration. This first type of circuit is not suitable for a hearing aid with single-cell battery supply.

The second type of stabilization circuit is shown in Fig. 2(b). When the collector current tends to increase, the collector potential tends to decrease due to the voltage drop in resistor R_c and so the current through R_f tends to decrease, i.e. the base current tends to decrease and this in turn tends to decrease the collector current. There is therefore a regulating action. In fact, the degree of stabilization increases as the ratio $R_c/(R_f + R_c)$ increases. Although this second type of circuit does not enable such high degrees of stabilization to be achieved as does the first type (Fig. 2(a)) it does, nevertheless, enable a most useful improvement in stabilization to be made without increasing the current drain from the battery and without using extra components.

Output Stage

The design objective in terms of sound-pressure output from the earphone of the hearing aid was 200 dynes/cm². From a knowledge of the sensitivity of the earphone that could reasonably be expected it was estimated that an electrical drive for the earphone of about 2 mVA was required. With a single-cell battery supply of 1.5 volts to an ideal Class A stage the optimum a.c. load impedance to achieve this output is 506 ohms, and the d.c. operating current for this optimum load is 3.75 mA. Such values made it possible to have the earphone itself as the electrical load of the output stage, without placing unacceptable restrictions on the earphone's impedance or d.c. resistance or ability to carry the collector d.c. current of the output stage.

As this value of collector current is high compared with the values of I_{ceo} considered as acceptable upper limits for transistor manufacturers, there is no great need for stabilization of collector current in the output stage against temperature variations. Accordingly, the simple conventional means of providing base bias by an appropriate resistor (22,000 ohms) from the battery line to the base is used.

The alternative (lower) power output is provided by inserting a series resistor in the collector circuit.

Driving Stages

From the design objective of air-to-air amplification and

the estimated achievable sensitivities of microphone and earphone it was readily seen that the necessary amplifier gain could be achieved either by using transformer coupling in a 3-stage circuit or by using resistance-capacitance coupling in a 4-stage circuit. Consideration of the requirements of the transformer with particular reference to the impedance and d.c. resistance of the primary winding led to the conclusion that either the physical size of the transformer would be out of proportion to the rest of the amplifier or the gauge of the wire would be unduly fine, with attendant high fault liability; furthermore, it was doubtful whether the initial cost of the components in a 3-stage transformer-coupled circuit would be less than that of a 4-stage resistance-capacitance coupled circuit. It was therefore decided to concentrate on the latter type of circuit.

Penultimate Stage

To ensure adequate current drive to the base input of the output stage a suitable value of collector load resistance (R_c in Fig. 2(b)) is 1,200 ohms, and a suitable value of bias resistor (R_f) from the collector to the base is 47,000 ohms. With this circuit the current gain of the stage, i.e. the ratio

$$\frac{\text{current output to the succeeding stage}}{\text{current input to the junction of } R_f \text{ and the base}}$$

only varies by about 1 db for temperature changes from about 18°C to about 40°C. Over the same temperature range the collector current changes from about 650 μ A to about 900 μ A. (It may be noted here that an unstabilized stage operating over this same temperature range might well have a variation of current gain as much as 6 db and a variation in I_c from 250 μ A to 800 μ A.)

Other Driving Stages

Even if a manual gain control need not be provided, the lower output requirements of the other two driving stages have such a small effect on the choice of the collector load resistor (R_c) and bias resistor (R_f) that it is most convenient to have these other two stages the same as the penultimate stage. Furthermore, the provision of a manual gain control with a range of at least 30 db between the second and third of the four stages requires that the output of the second stage should be large enough to drive the third (penultimate) stage even when the gain control is at the minimum gain position.

The 4-stage circuit, neglecting the effects of battery-impedance feedback, would be as shown in Fig. 3. The

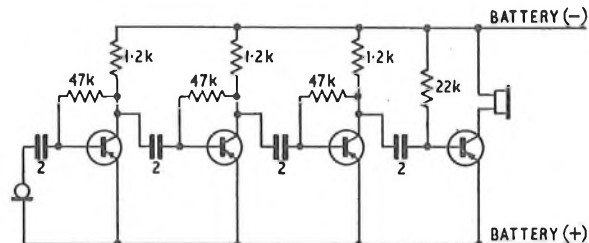


FIG. 3—BASIC 4-STAGE AMPLIFIER CIRCUIT

coupling capacitors all have sufficiently high capacitance to produce negligible effect on the frequency characteristic of the amplifier. This is dictated by the fact that miniature electrolytic capacitors must, for economic manufacture, be allowed such a large tolerance range that use cannot be made in any way of the capacitances for controlling the shape of the gain/frequency characteristic.

Effect of Battery Impedance

It is readily seen that impedance in the battery supply produces feedback currents to the bases of the second-, third- and fourth-stage transistors via the collector feed resistances of the first-, second- and third-stage transistors, respectively; the feedback to the base of the first stage is via the high-resistance base-bias resistor from collector to base, and although the feedback component is amplified in the first stage it produces an output current into the base of the second stage which is negligible compared with the feedback current obtained directly from the collector feed resistor of the first stage. It is also seen that the feedback current to the bases of the second and fourth stages are "negative" whereas that to the base of the third stage is "positive."

The feedback current to the base of the second stage can be reduced to insignificance by rearranging the first

Final Circuit

The final circuit incorporating the modified first stage, gain control and alternative power output arrangement is shown in Fig. 5.

DESCRIPTION OF THE TRANSISTOR HEARING AID

The aid, which is shown in Fig. 6, consists of microphone, transistor amplifier and battery contained within a single case, together with a separate insert-type earphone connected to the aid by means of a plug-ended flexible lead. The total weight, including the earphone, is $3\frac{1}{4}$ oz.

The Case

The case of the aid is a thermoplastic moulding of methyl methacrylate (Diakon), which has a permanent high-gloss finish, is durable and has a pleasing appear-

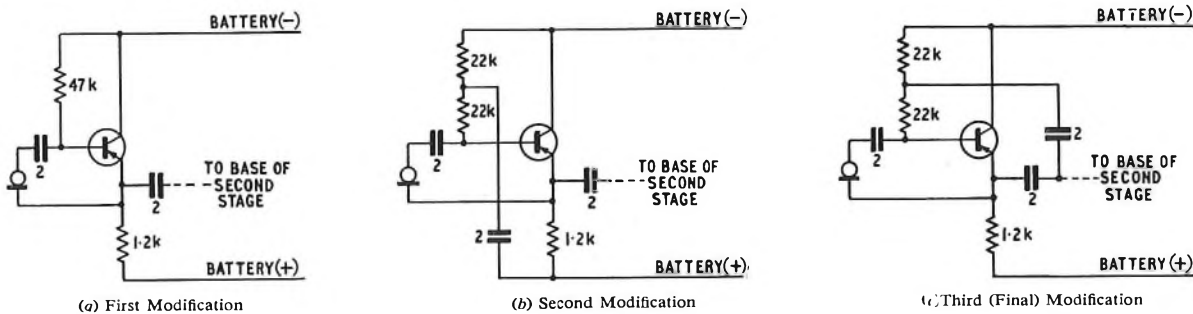


FIG. 4—INPUT STAGE

stage as shown in Fig. 4 (a). The circuit is identical to the first stage of Fig. 3 with regard to d.c. operating potentials and currents, and stage gain. It has the advantage that the feedback current to the base of the second stage now has to pass through the high impedance of the collector circuit of the first stage and so is reduced to a negligible amount. Such a rearrangement does, however, introduce a significant feedback-current path to the base of the first stage via the base-bias resistor. This feedback is substantially eliminated by splitting the base-bias resistor into two parts and using one part for decoupling in conjunction with an additional large capacitor, as shown in Fig. 4 (b).

The effect of this modified first stage on the amplifier as a whole is, however, to leave outstanding the small amount of positive feedback to the base of the third stage; this can be compensated sufficiently without extra components by connecting the decoupling capacitor (of Fig. 4 (b)) to the base of the second stage instead of to positive battery, thus deliberately re-introducing a small amount of negative feedback, as shown in Fig. 4 (c).

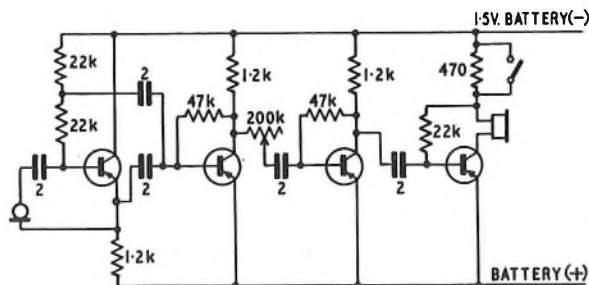


FIG. 5—FINAL CIRCUIT OF THE AMPLIFIER



FIG. 6—COMPLETE TRANSISTOR AID

ance. A plastic was chosen in preference to metal principally for reasons of cost. The colour is a neutral shade registered with the British Colour Council as String Beige.

Special care was exercised during design to produce a smooth overall contour to reduce the noise produced by clothing rubbing over the surface, which would be accentuated by the high gain and steeply rising amplification/frequency characteristic of the aid. For the same reason the sound-entry grille was slightly recessed. Difficulty inherent in moulding two separate halves of a

case to give correct alignment on assembly without any overlapping edges was avoided by using a one-piece tapered moulding, with a detachable base cover. The whole amplifier assembly, complete with microphone, is inserted through the base and locked in position by the fixing of the clothes clip. The battery is placed between contact springs at the base of the amplifier and firmly held in position by the gripping action of the moulded base cover over the shaped ends of the springs; the base cover is itself secured by the same action.

Amplifier Assembly

The complete amplifier assembly, consisting of the 4-stage transistor amplifier, combined volume control and ON-OFF switch, microphone, socket for earphone connector lead, battery contact springs and output-power selector switch, is carried on a chassis of moulded polystyrene. The microphone is freely suspended in the chassis.

The amplifier is divided into two halves for ease of production and maintenance. Each half-circuit is made up into a separate sub-assembly mounted on a printed-wiring board of synthetic resin-bonded paper placed each side of the main chassis (see Fig. 7) and held

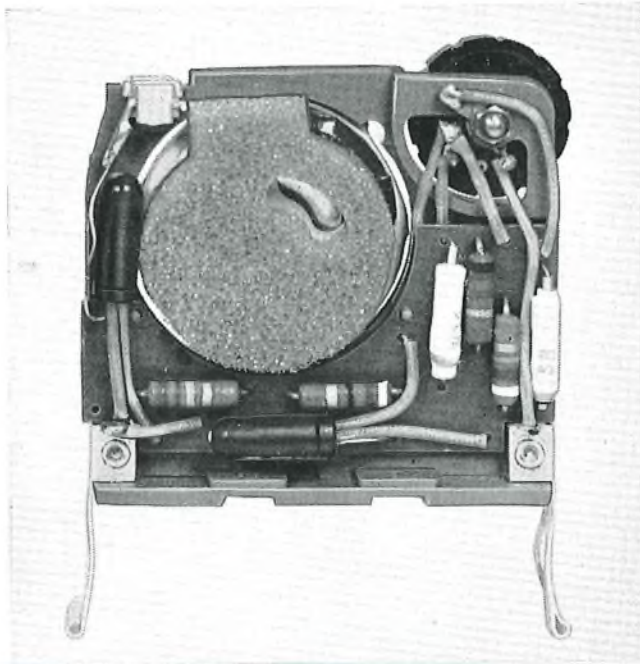


FIG. 7.—AMPLIFIER CHASSIS

in position on locating pins. The only external wiring to be added is from the printed-wiring sub-assemblies to the earphone socket, battery springs and volume control.

Selecting the required output power is achieved simply by means of a screw arranged to introduce or to short-circuit the resistance in series with the earphone in the output stage. It is accessible from the battery compartment and is normally preset by the clinic on the advice of the otologist when the aid is first issued to the patient.

The current gain of the amplifier is substantially independent of frequency over the major portion of its response and has a value of 100–108 db. At the extremities of the frequency band the amplification is less by

about 0.5 db at 3,000 c/s, due to transistor characteristics, and up to 0.4 db at 300 c/s, due to coupling capacitors. The top frequency cut increases to 2 db at the end of the useful life of the battery (which is taken to be when the terminal p.d. is 1 volt). Change in battery voltage during the life of the battery also decreases the overall gain by 6 db and causes a fall in power output of 3 db.

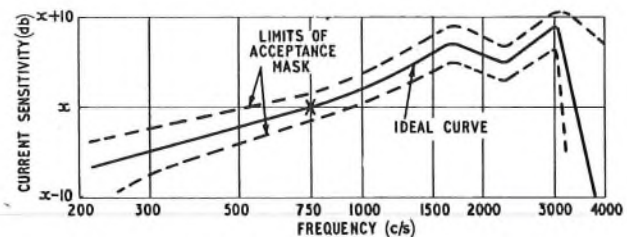
The performance of the amplifier is only slightly affected by temperature variations. The gain increases typically by about 6 db for a temperature change from 0°C to 34°C, while the output-sound pressure level, using an earphone of average sensitivity, lies within +1.5 and -3 db of 200 dynes/cm² for a temperature change from 20°C to 34°C.

Measurement of electrical gain is made in the factory on each amplifier before it is assembled in the aid.

Earphone

The earphone is an insert polarized type with a monopolar magnetic circuit and an unclamped magnetic diaphragm. The whole assembly, complete with spring connectors, is contained within a single outer moulded shell of flesh-coloured Diakon. Previous earphones of this type, which are currently in use with valve aids, employ double-shell construction, i.e. the motor unit is partitioned off from the connecting springs and plug-entry holes to reduce acoustic feedback. In practice, however, provided the plug is a satisfactory fit in the earphone socket and effectively blocks the entry holes, acoustic feedback can be reduced to negligible proportions without the need for a separate sealing chamber inside the earphone. Tests have also shown that acoustic interference through the back of the case is insignificant. Thus it was possible to employ single-shell construction for the earphone and thereby achieve a slimmer and more attractive appearance. It weighs slightly less than $\frac{1}{4}$ oz.

The earphone has maximum sensitivity over a frequency range extending up to 3,000 c/s and the response is reasonably smooth for this type of device. It is designed to handle output-sound pressures of at least 250 dynes/cm² with little or no distortion.



The response curve fits within the mask limits shown when the x -value of the curve so fitted is not less than +36 db relative to 1 dyne/cm²/mA measured in a 1.5 cc artificial ear

FIG. 8.—EARPHONE SENSITIVITY/FREQUENCY CHARACTERISTIC SHOWING LIMITS OF ACCEPTANCE

Fig. 8 shows the ideal curve of sensitivity/frequency characteristic and the limits within which production items are accepted.

The impedance of the earphone was determined almost entirely from considerations of the efficiency of the transistor-amplifier circuit. Other factors which had to be taken into account were physical limitations of the size of the coil, variations of output characteristics of transistors likely to be encountered, power-output

requirements, possible spread of transistor collector currents and temperature effects.

For acceptance purposes the sensitivity/frequency characteristic is measured on a sampling basis; every earphone, however, is subjected to a factory check of average sensitivity over three selected frequency bands, and of impedance.

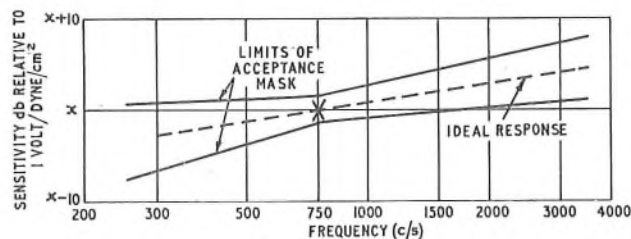
Microphone

While the crystal-type microphone is eminently suitable for working into the high input-impedance of valve circuits and has been in common use in valve aids, the electromagnetic-type microphone was preferred for direct working into the low input-impedances of transistors. The microphone used in the transistor aid uses the same magnetic system as the earphone, except for the material of the magnetic diaphragm. In addition, it has an outer diaphragm, of re-entrant shape, to increase the effective area and hence sensitivity.

A Thuras tube for base resonance is included as part of the rear-cover moulding and increases the sensitivity at low frequencies. Connexion leads from the coil are led out through the tube, and due allowance is made in fixing the diameter of the tube to cater for the effect of the thickness of the leads.

The coil is wound in synthetic-enamelled copper wire of gauge not finer than 48 S.W.G. for ease of handling and reliability.

The response of a microphone may be seriously mutilated by the effects of shape, structure and material of a case and the method by which the microphone is mounted in it. During the design, therefore, the effect of the case and mounting arrangements were taken into account so that the working response of the microphone combined with the amplifier and earphone responses would produce the desired air-to-air characteristic for the aid. As in the case of the earphone, the limits of acceptance of the microphone were, of necessity, as narrow as practically possible. Fig. 9 shows the ideal



The free-field microphone response shall fit between the mask limits shown; x shall not be less than -78 db relative to 1 volt/dyne/cm².

FIG. 9—MICROPHONE SENSITIVITY/FREQUENCY CHARACTERISTIC SHOWING LIMITS OF ACCEPTANCE

curve and permitted tolerances for the free-field response, determined as the potential difference across a non-inductive load of 2,000 ohms.

Every microphone is checked in the factory for sensitivity and smoothness of response, and full measurements are made in the laboratory on a sampling basis.

The microphone is suspended resiliently in the aid by means of a rubber tyre which is fitted round the periphery of the microphone and fixed to three locating pins moulded in the amplifier chassis. The microphone aperture is directly in line with the sound-entry grille and acoustically sealed to it by means of a soft pad of polyurethane. A second, small, pad of polyurethane

is stuck to the back of the microphone to protect it from violent physical shock.

Transistors

Within the limitations imposed by an uncomplicated circuit, including minimum number of components, low operating voltage and a simple assembly process—all contributing towards an economic article, it was necessary to specify accurately the spread in transistor characteristics which could be tolerated in order to achieve this purpose. No special methods, however, are employed in the manufacture of the transistors for Medresco hearing aids, the transistors being substantially the same as the Mullard commercial types OC 70 and OC 71.

Although ideally it would be preferable to specify the same transistor for all stages of the circuit, the need to secure an economic yield by normal production methods made it necessary to select transistors on the basis of performance to suit the requirements of one or other stage in the circuit.

Broadly, therefore, there are two types, suitable either for the output stage or for any of the driving stages, and specified on a functional basis in terms of the performance under working conditions in the hearing aid. Common tests are also specified to ensure high quality of capsule seal, cleanliness of element, low noise factor and mechanical robustness, etc.

To improve the yield even further, a manufacturer may also supply, for up to 25 per cent of the total quantity, transistors having reduced gain, provided they are satisfactory in all other respects. So far, however, this has not been found necessary.

The maximum permissible dimensions of the transistors used are 5.5 mm in diameter and 16 mm in length of body.

Battery

The battery used is a Leclanché dry-type 1.5-volt cell with dimensions to British Standard 966 (Type D14). The performance is defined in a Post Office specification in which particular attention is paid to the maximum acceptable impedance. The battery has a minimum life of approximately 3 weeks when used in the aid for 8 hours each day. Free issues of batteries are made by clinics. Batteries similar to those used in commercial aids may be purchased from retailers.

Connector

The only external connecting cord is that to the earphone. It is twin-twisted to suit the slimmer appearance of the new earphone and covered with flesh-coloured p.v.c. Each conductor consists of four tinsel strands laid up on terylene or nylon centres to facilitate terminating on the plugs. The plugs fitted at each end of the connecting cord are to British Standard and are polarized.

PERFORMANCE OF PRODUCTION AIDS

Typical maximum-gain/frequency air-to-air characteristics of production aids are shown in Fig. 10. Experience of the first large-quantity production proved that very few aids were rejected for failure to reach the minimum-gain requirement, the majority being well above. It is not possible in practice, however, to make use of the highest gains available, which are sometimes as high as 75 db at 2–3 kc/s, owing to the oscillation

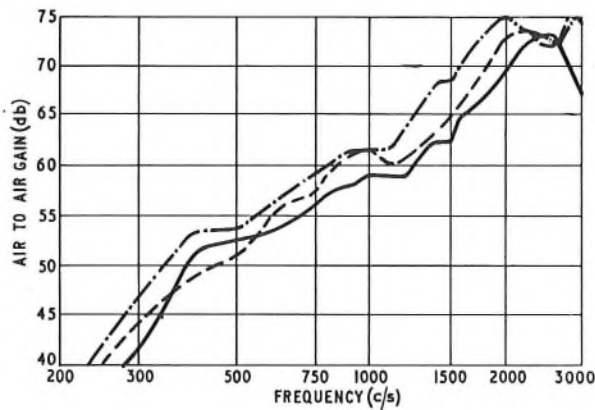


FIG. 10—TYPICAL MAXIMUM-GAIN/FREQUENCY AIR-TO-AIR CHARACTERISTICS OF PRODUCTION AIDS

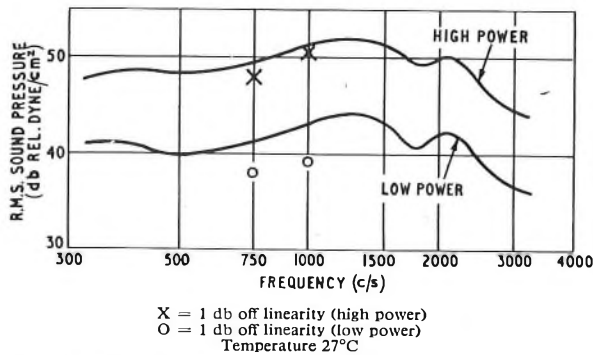


FIG. 11—POWER-OUTPUT/FREQUENCY CHARACTERISTIC OF TYPICAL AID AS MEASURED IN A 1.5 C.C. ARTIFICIAL EAR

which occurs. This is particularly marked when the aid is worn by children where rapid growth of the child makes it difficult to ensure, without regular replacement, that the earmould is always a close fit.

Fig. 11 shows the power-output/frequency characteristic of a typical aid in terms of maximum r.m.s. output-sound pressure at both full-power and half-power, as measured in a 1.5 c.c. artificial ear. The level at which the input/output relationship departs from linearity by 1 db (i.e. at approximately 10 per cent distortion) at 750 and 1,000 c/s is also given.

INDUCTIVE PICK-UP AID

A modified version of the standard transistor model includes a pick-up coil and switch for use with the inductive-loop systems now being installed in increasing numbers in schools. The 3-position switch connects either the microphone or the coil, or both microphone (muted by some 20 db) and coil, to the amplifier input. The latter facility was included to give a child some slight sensation of immediate-surroundings air-borne sound and thereby overcome the feeling of isolation which might be experienced when using the aid with only the coil connected in circuit.

Using the inductive-loop system the teacher addresses the class through a noise-cancelling microphone the

output of which is amplified and fed into a loop permanently wired round the class-room. The system is particularly useful for class instruction, being free from interference from normal airborne room noise.

FUTURE TRENDS

The cost of Medresco hearing aids is of paramount importance. Although at the outset of development the cost of the transistors was a major portion of the total cost of the aid, there has since been a considerable reduction and, with savings in maintenance expenditure, transistor aids should become as economical as valve aids.

Now that the major requirement of providing aids for children is being met, transistor aids are being produced for issue to adults. Since, however, there are now over half a million valve aids of all types in use, it will be realized that it may be some years before they are completely withdrawn from service as being uneconomic to repair and replaced by transistor aids. As it is, valve aids continue to be issued to new users at the rate of 4,000 per month.

It is also intended to produce transistor versions of the current external-earphone and bone-conduction-receiver types of valve aids as soon as possible. A new miniature rocking-armature capsule receiver has been adapted for use as an external earphone and its high sensitivity makes it ideal for use with the new transistor amplifier. For a bone-conduction aid a much greater output is required from the amplifier; a minimum of 3 volts must be used for the drive and it is extremely doubtful whether the existing bone-conduction receiver, as used with the current valve aid, will be entirely suitable. Thus, a complete electrical and physical design is being undertaken for this type.

Such aids as have been mentioned in this article should satisfy the requirements of the majority of the deaf population, but there remains the problem of the minority groups of patients suffering from types of deafness for which the characteristics of these aids are not suitable. The first and probably the most important group in this category is that of profoundly deaf children who find that they require a greater output than the Medresco aid will give. This raises the question of the protection of a child's hearing against unnecessarily high sound levels, and the matter is under consideration by the Medical Research Council.

There are also those patients suffering from nerve or perceptive deafness, where background noise or unduly loud sounds cause distress, and for whom some form of protection is desirable. Whether automatic gain control offers advantages over peak limitation in these cases is not yet clear and further evidence is needed.

ACKNOWLEDGEMENTS

Much of the work on the transistor hearing aid has been done in collaboration with Kolster-Brandes, Ltd., and Standard Telephones & Cables, Ltd., to whom acknowledgements are due.

An Introduction to Printed Circuits and their Application to Telecommunications*

J. W. WILLMOT, A.M.Brit.I.R.E.†

U.D.C. 621.3.049.75:621.39

The past ten years have witnessed a number of innovations in the design and construction of electronic equipment. Whilst the transistor has revolutionized circuit design, constructional methods have been transformed by the introduction of printed circuits. This article explains how printed circuits are made and used.

INTRODUCTION

ALTHOUGH exploratory work in the production of printed circuits started as early as 1927, the foundations are generally considered to have been laid in London in 1941 when Dr. Eisler, sponsored by a well-established printing firm, patented a method of etched-foil printing known as the Technograph System. In 1947 John A. Sargrove demonstrated an Electronic Circuit Making Equipment, and produced the first printed-circuit radio receiver, in which wiring, resistors, capacitors and inductors were all printed.

Subsequently an increasing number of manufacturers found that printed-circuit equipment could be produced more economically and provide a more reliable product than existing methods. It is commendable that these new methods, which employ a large degree of automation, eliminate the monotonous repetition work previously unavoidable on circuit-assembly production-lines.

Manufacturers have found printed circuits particularly attractive when used for transistorized portable radio receivers; they have also been used for a miniature radio-gramophone and for television receivers. A printed-circuit television receiver is shown in Fig. 1.

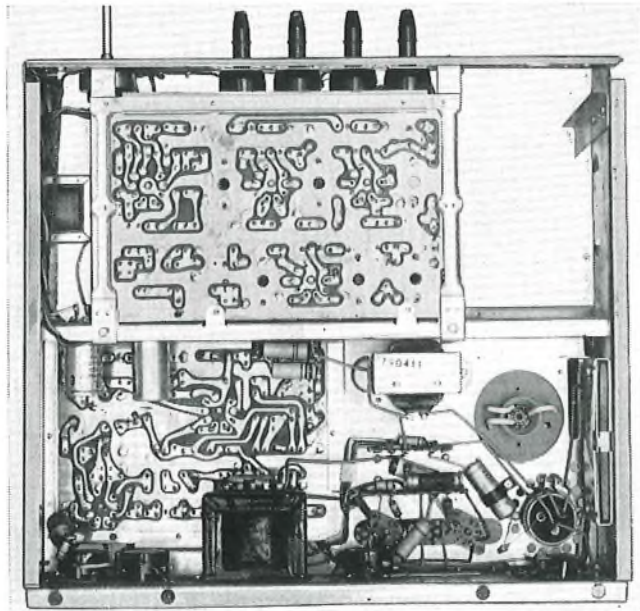


FIG. 1—PRINTED-CIRCUIT TELEVISION RECEIVER

* This article is based on a paper read by the author at a number of provincial centres of the Institution of Post Office Electrical Engineers during the 1956-57 and 1957-58 sessions.

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New processes offering more economical means of production are liable to abuse by less scrupulous manufacturers and in this respect some printed-circuit products are not above criticism. With reasonable care, however, the technique can reproduce circuits of extreme accuracy and uniformity.

The printed-circuit industry may be divided into three sections: the manufacturers of the copper-clad insulant base material, the circuit makers or printers, and the users. The manufacturers of the copper-clad baseboard generally confine their activities to this stage. The printers may also be the users, or they may print for independent users to the latter's specifications.

PRINTING METHODS

There are many methods of producing printed circuits on insulating bases, including the following:

(a) Spraying metal through a suitable stencil or mask on to the surface of the base.

(b) Embossed wiring, in which circuit parts of the copper foil are embossed and the remainder is removed by mechanical abrasion.

(c) Conventional silk-screen printing with conductive ink which may then be built up by subsequent electroplating.

(d) Stamped circuits in which adhesive-coated copper foil is sheared as it is pressed direct to a laminate base under a hot die. The unwanted sections are subsequently peeled off.

(e) A silver pattern may be pressed into a laminate base by a hot die. The silver may be in the form of foil or powder. Migration problems may arise in high humidity or high d.c. voltage applications.

(f) Composition die methods.

(g) Plated circuits in which both sides and interconnecting holes are plated by simultaneous sprays of a silver salt and a reducing agent such as formaldehyde.

(h) The etched-foil techniques. These are the commonest methods at present in use in this country and will therefore be described in some detail.

Etched-Foil Techniques

The etched-foil process commences with a phenolic board of synthetic resin-bonded paper (s.r.b.p.) completely covered with a foil of copper. Other base materials used include resin-bonded fabrics, epoxy-glass fabrics, silicone-glass fabrics, p.t.f.e., p.v.c., polystyrene and Terylene. S.R.B.P. is made in different electrical grades to suit the application, and in thicknesses ranging from 0.003 in. to 0.25 in.

Although copper is the usual foil, other metals such as brass, nickel, nickel-iron alloy, aluminium and constantan are available. Owing to its wide separation from copper in the atomic scale, aluminium is unsuitable for applications where both metals would exist together.

Copper foil is either deposited electrolytically or rolled into sheets of the required thickness. Rolled copper is preferable for u.h.f. work owing to the relatively rough

surface on the growth side of electrolytic sheet. This rougher surface is normally the side bonded to the phenolic paper base.

The copper-clad s.r.b.p. is built up of layers of partially cured resin-impregnated paper of good electrical characteristics, surmounted by the copper foil, which has a bonding agent such as epoxy resin between it and the top layer of paper. The boards are cured at a pressure of 1,500 lb/in². and a temperature of 350°F. Since the resins used are of a thermosetting variety the cycle is not reversible. A well-cured board with adequate resin content will not show the individual paper layers when sliced or split. A high resin content produces a board which has good electrical properties but is relatively brittle and difficult to punch. A compromise suitable to the work in hand is therefore chosen.

The adhesion of the foil to the board is important and a minimum force of 5 lb to remove a 1 in. strip of foil from its backing is considered satisfactory.

Copper foil, usually 0.0015 in. thick, is generally applied to one side only of the insulating base. A sandwich stock of foil-base-foil is, however, available and with this both sides may be suitably and differently etched for certain applications.

To form the required configurations the unwanted portions of copper are etched away by acids during the manufacture. There are several methods of removing the unwanted portions and protecting the required circuits, the three most common being:

- (i) silk-screen printing,
- (ii) offset lithographic printing, and
- (iii) photographic printing.

Silk-Screen Printing

A master drawing of the required configurations is photographed to produce a negative on a glass plate. From this negative a positive print in gelatine is taken on a plastic backing. The plastic-backed gelatine is pressed on to the silk screen and the assembly is dried. The plastic backing may now be peeled off leaving the necessary configurations in the silk in the form of dried gelatine. For long-production runs a screen of specially prepared metal is now generally used although the process may still be referred to as silk-screen printing.

The prepared screen of silk (or metal) is fixed slightly above a sheet of copper-clad s.r.b.p., which is often held secure and flat by a vacuum grille arrangement. A squeegee carrying bituminous or other etch-resisting ink is applied to the screen, pressing a pattern in ink through the untreated areas of the silk on to the copper foil. The copper-clad board is removed and dried. It is then etched in a tank of 10 per cent nitric acid, washed and neutralized by ammonia. Finally the etch-resisting ink is removed by a degreaser, such as trichlorethylene vapour, in a condensing tank. Holes are then punched to accept component wires.

Silk-screen printing is generally considered to be cheaper than off-set lithographic or photographic printing, and it generally produces a less accurate pattern. Pure silk screens are liable to alter in area with time and change of temperature and humidity; hence the preference for a metal screen. Furthermore, a metal screen will produce about 50,000 circuits whereas a silk screen is usable for about 1,500 only. The resolution is, however, ample for many applications and the process is used extensively for domestic receivers and television circuits.

Offset Lithographic Printing

Offset lithographic printing, which is illustrated in Fig. 2, is intermediate between silk-screen and photo-

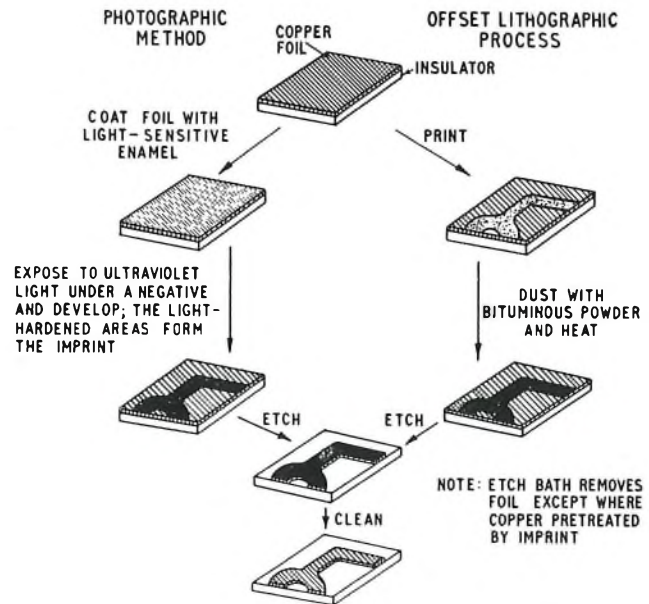


FIG. 2—OFFSET LITHOGRAPHIC AND PHOTOGRAPHIC PRINTING

graphic printing in cost and accuracy and follows very closely traditional printing methods. The copper-clad sheet is fitted horizontally in the lithograph printing machine adjacent to a zinc plate on which the pattern is printed in relief. A roller applies water to the zinc plate wetting the background, and a subsequent roller applies greasy ink which adheres only to the printed areas.

A blanket roller then picks up the pattern from the master plate and prints it on the copper foil. The ink is then dusted with bituminous powder and heated to form a hard resist.

Exceedingly good resolution is now being obtained by this process, sufficient, for example, for inductors and capacitors in television receivers and filters.

The printed copper surface is etched and finished in a manner similar to that described for silk-screen printing.

Photographic Printing

This process (Fig. 2) produces prints of an accuracy unattainable by any other method. The process commences with the production of a matt black and white drawing of the circuit in which the copper sections are shown black. The scale of this drawing is often 2 : 1, or 4 : 1 for exceptionally detailed circuits. From this drawing a photographic master negative is prepared, a special camera giving linear reproduction over the entire surface being necessary. From the master negative several working negatives on celluloid are prepared.

The copper-clad s.r.b.p. base is cleaned and coated with an even film of a special photo resist which is hardened by ultra-violet light but is relatively insensitive to light of longer wavelength.

The working negative is held in intimate contact with the sensitized sheet of copper clad by a vacuum-bed printer and exposed to ultra-violet light for about

2½ minutes. The unexposed areas of film may then be removed from the copper foil by trichlorethylene.

Immersion in a suitable dye enables the success of the process so far to be inspected. Satisfactory prints are sprayed for 2 or 3 minutes with a solution of ferric chloride which removes the copper from the unprotected area. The etch is applied in the form of a spray and the time is closely controlled, for if the etch is allowed to permeate the base its subsequent insulation may be seriously impaired. Nitric acid or chromic acid may also be used as etching liquids.

After etching, the resist is removed from the copper-foil areas by an abrasive such as pumice and the circuit is washed, dried and the holes punched.

PRINTED WIRING

The majority of printed circuits are confined to the reproduction of wired interconnexions in printed form using conventional components mounted on the side of the base opposite to the foil. These are held in position by wire ends or tags which protrude through holes in the base, at which point they are soldered to the copper foil. The minimum width of conductors and the minimum spacing between adjacent conductors varies with different processes, but values generally lie between 0.010 in. and 0.033 in.

Since the current-carrying capacity of a conductor is directly proportional to the surface area, it will be appreciated that a thin ribbon is one of the best possible formations. It is claimed that a printed copper circuit $\frac{1}{8}$ in. wide and 0.001 in. thick will safely carry at least 10 amp. The cross-sectional area of such a conductor is 0.000125 in². The nearest equivalent gauge of copper wire is 30 S.W.G. and at the somewhat conservative standard rating of 1,000 amp/in² the current carrying capacity is 120 mA. In practice the d.c. resistance is generally the limiting factor.

Insulation resistance is usually measured on a standard circular pattern which is also used for permittivity and power factor measurements.

Leakage is mainly surface leakage and phenolics, with a figure of 10⁶ megohms per square, compare favourably in this respect with non-phenolics such as glass-base silicone laminates, diallylphthalates, Epon-glass, Teflon glass and Epon-Orlon.

The design of the conductor layout is itself a fascinating subject but is too extensive to be described here. The question of "cross-overs" does not constitute so great a problem as might at first be imagined. Since at least one end of most conductors terminates on a resistor or capacitor, careful disposition of the components on the reverse side of the board enables them to effect the necessary cross-overs. Formulae have been evolved for determining optimum layouts of conductor patterns.

In circuits where relatively large areas of unwanted copper remain, various patterns are often removed to produce voids. The primary purpose of this is to secure uniform heating and allow volatile matter to escape during dip soldering.

Since the coefficient of expansion of base material relative to copper is approximately 2:1, differential expansion presents a problem and additional differences of expansion in different parts of a board due to varying copper/space ratios will accentuate the difficulty, hence the endeavour to produce a relatively even pattern density.

THREE-DIMENSIONAL PRINTED CIRCUITS

Circuits printed on rigid laminates are often as compact as their conventional three-dimensional counterparts. Where space is very restricted, however, a two-dimensional printed layout is at some disadvantage and various methods have been evolved to overcome this.

The foil circuit may be printed on a flexible base which may then be wrapped around and between the components which will support it. Alternatively, circuit elements may be printed on rigid bases which may be interlocked at right angles (Fig. 3), the foil connexions

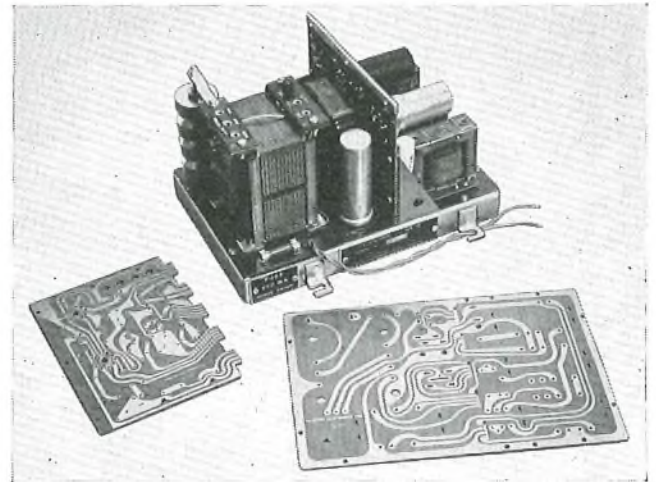


FIG. 3—POWER PACK USING INTERLOCKED PRINTED WIRING

registering one with the other being soldered in the normal manner. Small units of this type constituting inter-valve circuits are commonly known as couplets or pacs.

For valve circuits, extreme compactness is achieved by the modular system of printed circuits in which components are mounted on small ceramic wafers $\frac{7}{8}$ in. square, which are then stacked one above the other $\frac{1}{8}$ in. apart and interconnected by vertical wires. The top wafer carries the valve holder, and the stack of wafers, which is called the module, carries all the components associated with that valve. The bottom wafer is connected to a printed-circuit base common to all modules in the unit.

PRINTING COMPONENTS

Reactive Components

Small inductors of the order of 10 μ H per 1 in. diameter are conveniently printed as part of the general circuit. A conductor that is, in effect, a thin ribbon provides maximum ratio of surface area to cross-sectional area so that in printed inductors the skin effect is reduced to a minimum. D.C. resistance, however, tends to be somewhat higher than normal.

The efficiency of inductors at high frequencies is restricted by the loss in the base material, but by careful attention to design interpretation, coils having values of Q-factor up to 100 at 35 Mc/s have been produced. Fig. 4 shows a diplexer in which capacitors and inductors are printed in addition to the wiring.

Large inductances for use with iron cores may be achieved by folding printed circuits like a concertina, the coils being formed into a series winding by welding

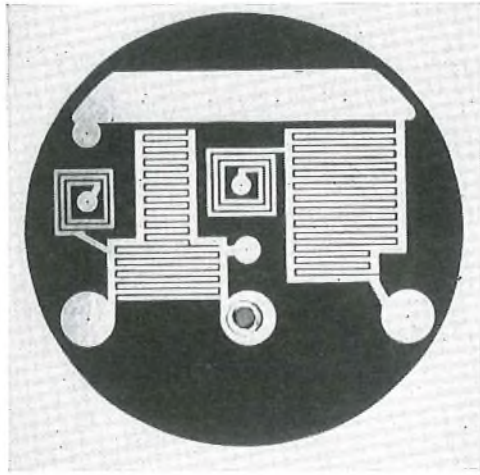


FIG. 4—DIPLEXER, SHOWING PRINTED INDUCTORS AND CAPACITORS

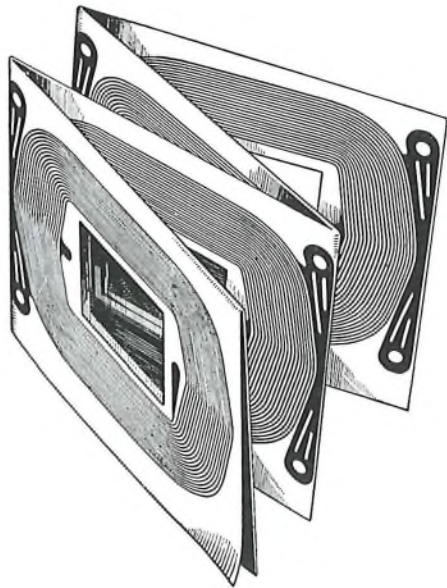


FIG. 5—PRINTED TRANSFORMER WINDING ON FLEXIBLE BASE

through the base after the first fold has been made (Fig. 5). The conductors of the inner turns may be made wider to produce a more equalized temperature gradient.

Small-value capacitors may be printed in a circuit using the interleaved fork configuration, the bulk of the electrostatic field being contained in the base insulant, which has a permittivity of between 3 and 6. Capacitances of the order of 35 pf/in² are obtained. As with inductors the base and bonding material are the power-absorbing materials, and with s.r.p.b. power factors are rarely below 0.01. With special bases such as polystyrene a figure as low as 0.001 may be achieved.

Non-Reactive Components

There are at present few manufacturers printing resistors as an integral part of a printed circuit, but the processes to be described are well known and it is to be expected that in the foreseeable future they will be developed for full-scale production.

(a) *Use of Three-Layer Material* (Fig. 6). In its simplest form the three-layer material consists of a s.r.p.b. base supporting a thin resistive layer of nickel-

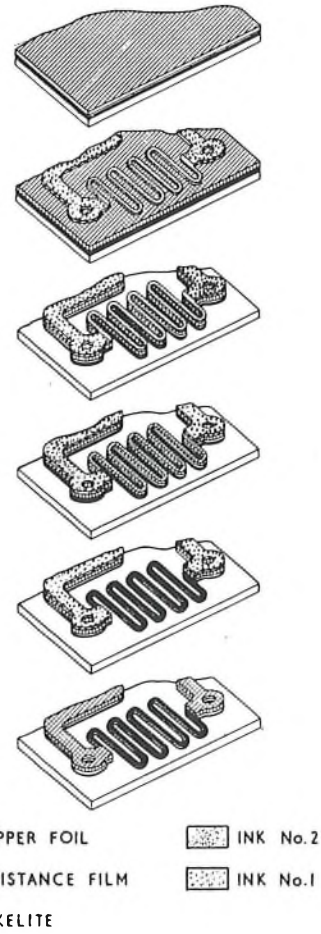


FIG. 6—PRINTING OF RESISTORS USING THREE-LAYER MATERIAL

chrome which in turn supports a layer of copper foil. The circuit is then lithographically printed in a similar manner to that previously described with the exception that those parts of the circuit required to become resistive are printed with a special ink.

Both inks are acid resistant so that the initial immersion in ferric chloride removes all the background metals leaving the complete circuit as yet undifferentiated. After rinsing, the circuit is immersed in a bath of aliphatic hydrocarbons which attack only the special ink covering the resistive configurations of the circuit. The copper covering these parts may now be removed by a suitable differential etching agent such as ammonium persulphate, leaving the nickel-chrome exposed but unharmed.

Other materials such as graphite in suspension may be used in a similar manner. Since the resistivity in this case is controlled by the mix, an average value is chosen and the various values of resistance are obtained by the aspect ratio of the patterns. Power ratings are of the order of 0.5 to 1 watt per square centimetre.

(b) *Use of Multi-Layer Materials*. The production of selective etching solutions becomes increasingly difficult with more than two layers, so the following method is employed.

The stock is similar to that used for the three-layer process, and may include the addition of a layer of carbon between the insulant base and the nickel-chrome layer.

The entire circuit is first printed with a common type of ink after which the unwanted metals of the background are etched away. The ink covering is removed and the different sections of the circuit are treated individually. The eventual carbon sections are marked off and the remainder covered with etch resist. A bath of ferric chloride then removes all metals from the exposed portions of the circuit leaving the required carbon patterns. A similar sequence then allows the nickel-chrome configurations to be exposed by ammonium persulphate.

SOLDERING

The number of soldered joints in a conventional circuit may be reduced by up to 50 per cent when the same circuit is redesigned in printed form, due mainly to the avoidance of connexion tags between wire-ended components and the wiring between tags.

The printed circuit is often treated with a solder-resist which allows the solder to adhere only at the necessary points and thus a saving in solder is obtained. The resultant work is neater and easier to inspect.

Before soldering, the components are inserted in the base which is then fitted in a carrier to prevent warping during soldering. If it has not been pre-tinned it passes over a flux spray immediately prior to the solder bath. Stearic acid, toluene and rosin alcohol are preferred as fluxes since they are free from residues which may subsequently impair the electrical properties of the s.r.b.p.

The base is next dipped in a bath of molten solder just sufficiently to immerse the copper foil. Entry into the bath is usually at an angle to avoid trapping air bubbles under the foil surface and the board may be vibrated. The circuit is immersed for only a very short period (3 to 6 seconds) as excessive heat causes blistering of the base and separation of the foil. The temperature of the solder is in the region of 240°C and a layer of molten wax is sometimes floated on the solder surface to prevent oxidation.

Another method of soldering is to run the base across the apex of a fountain of molten solder which is pumped vertically through a slit. This ensures a clean surface to the solder and minimum heating of the board.

After inspection, the completed circuit is often coated with a protective varnish or plastic acrylic spray to preserve it against moisture absorption and possible corrosion.

PRODUCTION

The material costs of printed circuits show little advantage over other methods, and any saving in overall cost must therefore arise from a saving in labour costs such as assembling, soldering, and testing. Assembly time is drastically reduced, it being not uncommon for 300 to 400 soldered joints to be made in one dip-soldering operation, and there is the certainty that wrong connexions cannot be made.

Changes in circuit design can be accommodated without difficulty, and subdivision of designs into small units aids flexibility, but if carried to excess the inter-connexions offset the advantages gained by printing.

Estimates vary as to the minimum number of circuits which can be printed economically. Assuming that a photographic method is being employed about 50 units may be regarded as a minimum.

Although at present most component assembly is performed manually, machines which will insert components automatically are being increasingly employed. Each machine inserts one component only into each panel, the panels passing on an assembly conveyor belt to as many machines as are necessary to completely equip the circuit with components.

APPLICATION TO TELECOMMUNICATIONS

A telecommunications system consists of permanently wired units such as telephones, amplifiers and relay-sets frequently interconnected by cabling and wiring of varying flexibility. The province of printed wiring is clearly confined to the permanently wired units and there is little doubt that the future will see its gradual introduction into those items where it can most usefully be employed.

The telephone instrument is a good example since it is produced in very large quantities for use all over the world. The induction coil, switch, bell and capacitors are mounted on a printed-circuit base replacing the existing metal chassis. There is a saving in screws and brackets as the components are soldered directly to the base by means of their connecting wires. The new table telephone (Telephone No. 706) introduced by the Post Office and described in a recent article* makes use of printed wiring as an alternative to conventional wiring.

The Post Office is engaged on research and development on printed circuits and in particular their application to wideband amplifiers and electronic switching equipment, where oft-repeated circuit elements such as counters are particularly suitable for production in printed form. A printed-wiring digital-computer counting unit is shown in Fig. 7.

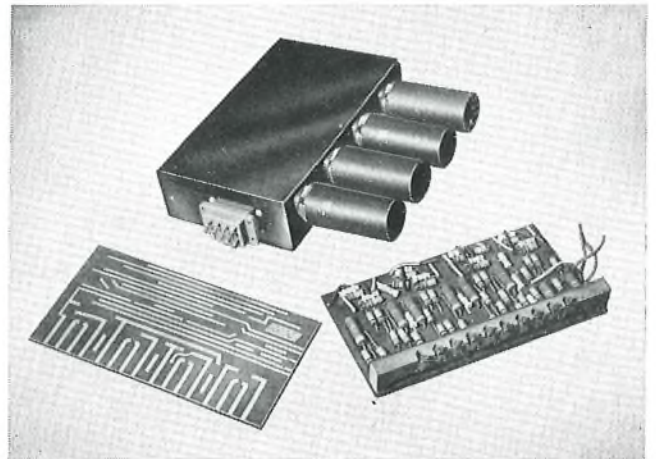


FIG. 7.—COUNTING UNIT OF A DIGITAL COMPUTER SHOWING THE PRINTED WIRING AND THE CIRCUIT ASSEMBLY

CONCLUSION

An attempt has been made to outline a technique which is in a fluid state of development. It is inevitable, therefore, that some important aspects will have been neglected whilst others may have been given undue

* SPENCER, H. J. C., and WILSON, F. A. The New 700-Type Table Telephone—Telephone No. 706 *P.O.E.E.J.*, Vol. 52, p. 1, April 1959.

prominence, and that much that is true today will be modified in the future.

The science of printed circuits is still in its infancy, yet in a few brief years it has made great progress. Its impact in this country has hardly yet begun to be felt, but it is clear that in the near future it will make electronic equipment cheaper to produce and more reliable in use.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the help he has received from colleagues in various Branches of the E.-in-C.'s Office and from many firms in the electrical and plastics industries, particularly De la Rue, Ltd., for information on copper clad, Cossor, Ltd., and Pye Ltd., for details of printing and assembly. He also wishes to acknowledge the valuable technical advice

given by the Telegraph Construction Co., Ltd., and Technograph Printed Circuits, Ltd. Fig. 3 and 7 are reproduced by kind permission of Bakelite, Ltd.

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Book Review

"Telegraphy." J. W. Freebody Whit. Schol., B.Sc.(Eng.), A.C.G.I., D.I.C., M.I.E.E. Sir Isaac Pitman & Sons, Ltd. 738 pp. 854 ill. 80s.

This comprehensive account of telegraphy as practised in the United Kingdom fills a long-felt gap in telegraph literature. As the author explains, the book is the successor to T. E. Herbert's "Telegraphy," first published in 1906, which through numerous editions remained a standard work for very many years. Considerable portions of the earlier book dealt with matters strictly proper to electro-technology and also contained chapters dealing with the construction of overhead and underground lines. Although these subjects have been eliminated from the present book, the growth of the telegraph art has presented the author with a formidable task in covering the whole of the subject in one volume. While naturally much space has still had to be devoted to telegraph machines and direct current signalling problems, the necessity for now including chapters on telegraph transmission theory, manual and automatic switching systems, voice-frequency telegraphy, facsimile and picture telegraphy, and the private wire and telex services has inevitably increased the size of the book. This now runs to well over 700 crown-quarto pages. The use of the larger size, while materially reducing the number of pages required, also permits more flexibility in the arrangement and size of the illustrations; in fact, the general layout, setting up and reproduction of both the text and illustrations is excellent, considerably facilitating reference and study.

The book commences with an introduction to the various types of telegraph codes and the signalling principles employed, followed by an interesting historical survey of early forms of telegraphy. There follow chapters on thermionic devices and electro-magnetic relays used in telegraphy, the polarized relay, due to its great importance in telegraphy, receiving full and adequate treatment. The main subject matter of the book is commenced with a chapter on telegraph transmission theory dealing with the rudiments of both direct current and alternating-current transmission. A chapter entitled "Telegraph Circuits" deals with various direct current transmission arrangements, including spark quenching and radio-interference suppression. Manual switching systems, including concentrator

and broadcasting arrangements, are dealt with comprehensively, illustrating the special type of problems met with in designing switching systems for telegraphy as distinct from telephony, and explaining the reason for the change from what has been called "pulse" signalling to "sequence" signalling. The subject of automatic switching has been dealt with in relation to the system developed for the United Kingdom inland public-message telegraph service. The automation of the United Kingdom telex service is now proceeding, and in the future the most important use of automatic switching for telegraphy will be in the inland and international telex services. While the system used for the telex service has many similarities with that provided for the public-message service, in any future edition of the book the special features associated with the telex service would no doubt be included. Voice-frequency telegraphy is adequately covered, including references to frequency modulation and methods of working over radio channels. The chapter on start-stop machines is noteworthy for the wealth of excellent explanatory drawings and is brought up to date by a description of an electronic start-stop telegraph distortion measuring set. Subsequent chapters deal with facsimile and picture telegraphy, power plant, and such subjects as phonogram queuing, instrument room arrangements, special facilities for private renters, manual telex services, use of error-correcting systems and submarine cable telegraphy.

Taken as a whole the book is a remarkably clear and informed account over the whole comprehensive range of technical questions involved in the operation of a modern telegraph system and it should be of inestimable value to engineers and students in this field. The wealth of detail included, covering as it does many developments with which he has been personally concerned, will be a lasting tribute to the industry and patience of the author. With the further development which is bound to occur, for example, the introduction of electronic systems and special facilities for data transmission, it is thought that in the interests of his readers, Mr. Freebody will, in any future edition, despite his great love for everything telegraphic, have to discard some of the older and less important information, contenting himself with the realization that for many years the present edition will remain on bookshelves as a comprehensive if weighty source of information on telegraph practice as developed over the past 25 years.

I.P.O.E.E. Library No. 2551.

E. H. J.

A Portable Equipment for Analysing Traffic at Non-Director Automatic Telephone Exchanges

K. MYERS and P. H. SKINNER†

U.D.C. 621.317.79:621.395.31

A new portable equipment, known as a route analyser, enables the telephone calls carried by a junction route from a non-director automatic telephone exchange to be analysed by recording on meters the number of times each terminal-exchange code is dialled. In conjunction with the information about the total traffic on a junction route, the traffic to each terminal exchange can be calculated.

INTRODUCTION

IN a manual telephone exchange, traffic data relating to the junction network are derived from records of the number of ticketed telephone calls and the average holding time of calls. These data are used to ensure that sufficient junction circuits are provided, or to forecast the junction requirements. Once the telephone network has been made automatic, it is still essential that individual junction routes in the network should not be overloaded, and traffic recording equipment has been provided in automatic exchanges to measure the traffic on any selected route. This equipment, however, was not designed to measure the distribution of traffic among different terminating points. A terminating point may be an exchange service termination, e.g. speaking clock or a manual assistance position, and will, throughout this article, be referred to as a "terminal." Changes to the traffic distribution in a network arise when a new exchange is introduced into a network or an existing exchange is replaced by an exchange of a different type; then, detailed traffic-distribution data can be of considerable assistance in the re-design of the network.

Equipment has now been designed to provide information from which it is possible to determine for each route carrying traffic to more than one terminal what proportion of the total traffic is distributed to each terminal. To record the traffic in erlangs to each individual terminal would require complicated equipment. However, adequate data can be obtained by employing simple equipment in small quantities on each route, and recording when the code for a terminal is dialled, i.e. a sample of the number of calls to each terminal is recorded. When sufficient calls over the route are sampled, the assumption may be made that the actual traffic to each terminal can be calculated by apportioning the total traffic on the route (measured by means of a traffic recorder) according to the magnitude of the respective "calls per code." When call-holding times vary between terminals, adjustments to compensate for these variations will be necessary when calculating the actual traffic to each terminal. Equipment capable of recording "calls per code" would be required only occasionally and need not therefore be provided as part of the exchange equipment, but preferably as an easily transportable item. Such an equipment, known as the route analyser, has been developed and is described in this article.

GENERAL DESCRIPTION

The route-analyser equipment is mounted on a trolley (a Stand, Testing, No. 28), measuring approximately 5 ft. by 1 ft 6 in. by 2 ft 6 in. It weighs less than 1½ cwt.

The only external power supplies required are an a.c. mains supply for operating the electronic equipment and a 50-volt d.c. supply for relay and uniselector operation.

A block schematic diagram of the equipment is shown in Fig. 1.

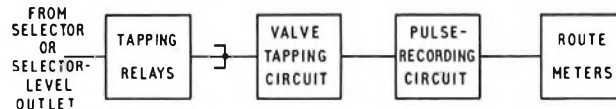


FIG. 1—BLOCK SCHEMATIC DIAGRAM OF ROUTE-ANALYSER EQUIPMENT

The exchange equipment carrying traffic to be analysed is connected by 20 tapping-relay circuits to the valve tapping circuit. When a call originates on one of these circuits the valve tapping circuit is connected to the negative and positive wires of the circuit. The dialled pulses are repeated by the valve circuit to the drive magnet of a uniselector in the pulse-recording circuit.

During the inter-digital pause a testing earth is connected to a wiper of the uniselector causing the appropriate route meter to operate when sufficient digits have been received to indicate the distant terminal concerned. The analysing equipment is then released for use by the tapping circuit on which the next call originates. Since it is possible to have different codes for the same total number of pulses the number of codes which can be analysed is limited but a clash of codes can usually be avoided by using several arcs of a uniselector and switching from one arc to another during inter-digital pauses. The actual strapping of the uniselector banks can only be decided from an examination of the trunking of the particular exchange concerned.

CIRCUIT DESCRIPTION

Fig. 2 shows the circuit elements of the route-analyser equipment. The tapping relays connect the analysing equipment to the individual outlets of the route concerned. Relay PS operates when a call originates on the outlet to which it is connected, and if the analysing equipment is disengaged, relay H operates to switch the negative and positive wires through to the valve circuit. Relay G, in conjunction with the low-resistance coil of relay H, connects the guard condition to prevent a second tapping circuit from switching to the valve equipment. Calls on other tapping circuits also have their G relays operated to ensure that when the analysing equipment is released it is not switched to an outlet on which a call is being set up. Relay AP in the anode circuit of valve V1 responds to the pulses and repeats them to the drive magnet of the uniselector in the pulse-recording circuit. Valve V2 prevents relay AP

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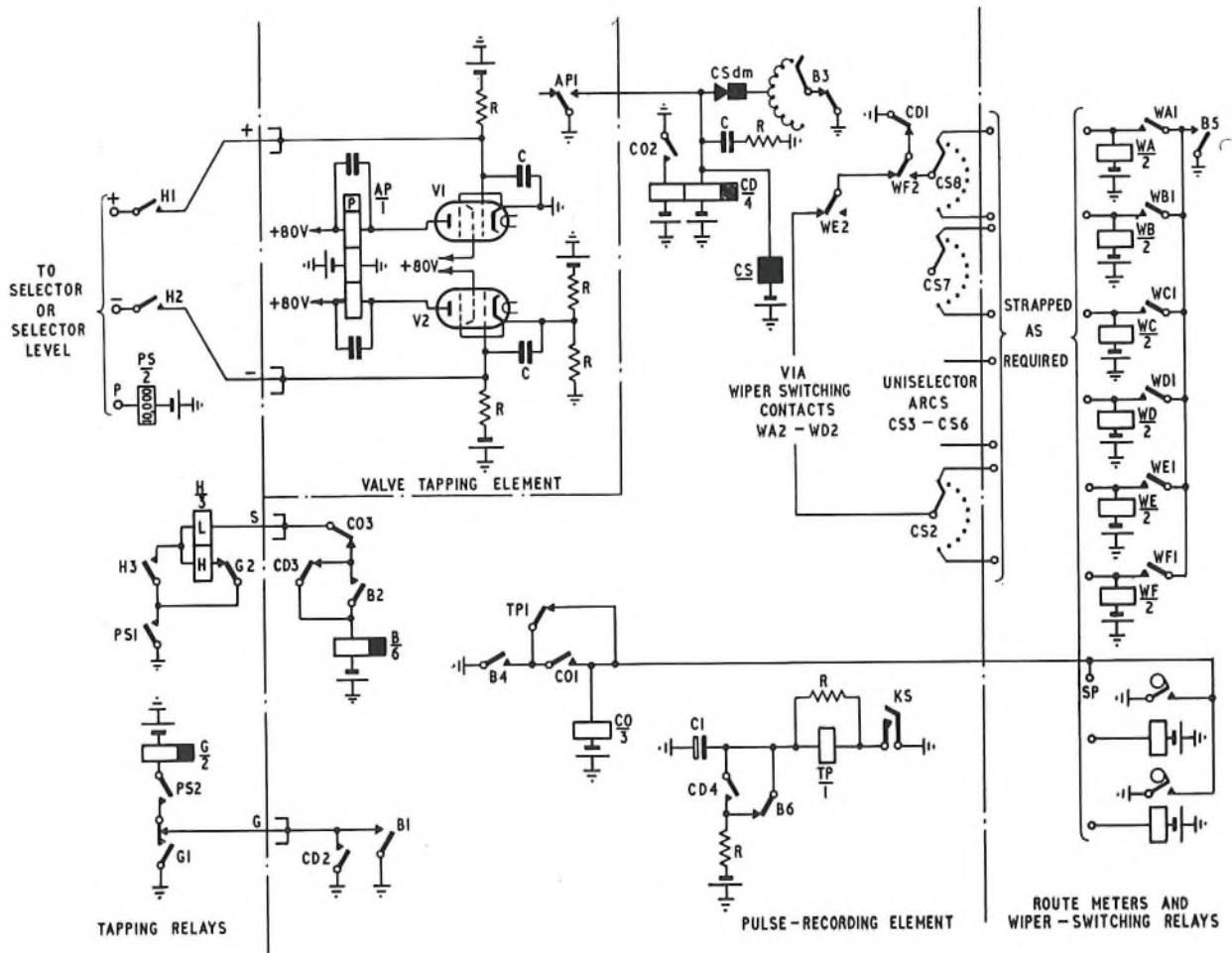


FIG. 2—CIRCUIT ELEMENTS OF ROUTE-ANALYSER EQUIPMENT

from responding to a false pulse, which can occur during inter-digital pauses, due to relay contacts operating in sequence when the call is switched from one selector to another.

The valve circuit used to receive and repeat the pulses is an adaptation of the equivalent circuit in the centralized-service-observation equipment, and its circuit operation, together with the problems encountered when tapping across a line on which pulsing or speech are taking place, have been described in a previous article.*

Relay CD, which is operated during pulsing, releases during inter-digital pauses and connects earth to the bank contact to which the wipers are connected. If the digits dialled constitute a routing code, this contact will have been strapped to the appropriate route meter, which then operates. The operation of the meter contact causes relay CO to operate, which releases relays H and B at CO3. Relay H in releasing disconnects the valve circuit from the tapping relays and relay B in releasing causes the uniselector to restore to its home contact. During homing of the uniselector, relay CD remains operated so that the valve circuit is busied to the tapping-relay circuits.

Difficulty due to different codes having the same total number of pulses is avoided by arranging that the

testing earth is transferred to another wiper of the uniselector before the code has been completely dialled. The testing earth is connected during the inter-digital pause to a bank contact of the uniselector which is strapped to one of the wiper-switching relays WA to WF, a contact of which switches the testing earth to another wiper of the uniselector. Thus, although with codes that contain the same total number of pulses the wipers rotate to the same position on the bank, the testing earth is connected to different arcs of the uniselector and so to different route meters.

To avoid the sample of analysed calls being reduced if a caller fails to dial a complete routing code, a time-controlled forced-release facility is provided in the analysing equipment. When the analyser is taken into use, the holding circuit of relay TP is dependent upon the discharge current from the capacitor C1, which gives the relay a release lag of 6–12 seconds. If the subscriber dials during this period, contact CD4 in operating will recharge capacitor C1 and relay TP will remain operated. The circuit is such that capacitor C1 is fully charged during a train of pulses to ensure that relay TP has a full release lag during the next inter-digital pause. The forced-release condition is applied if relay TP releases the analysing equipment from the tapping circuit in the same manner as for a normal call.

A routine-test circuit is included in the form of a self-pulsing relay which tests both the response of the valve

* BARNARD, A. J., and BECK, E. H. A. New Centralized Service Observation System. *P.O.E.E.J.*, Vol. 49, p. 81, June 1956.

circuit to normal pulses and the false-pulse-suppression device.

USE OF EQUIPMENT

The equipment is designed for use in 50-volt non-director exchanges employing loop-disconnect pulsing circuits. It can be used also in Siemens No. 16 exchanges, the 50-volt supply being obtained by connexion to the counter-e.m.f. cells at an appropriate point.

Since the equipment will be used only for short periods and setting up and taking down will be frequent operations, temporary connexions are made by means of U-link connectors and double-ended cords.

When traffic-distribution analysis is required on a junction route where the auto-auto relay-set immediately precedes the junction, the analyser tapping circuits are connected to the exchange side of the auto-auto relay-set (Fig. 3). If, however, junctions are trunked direct from an outgoing-selector level, the analyser tapping circuits are connected at the distant exchange to the line

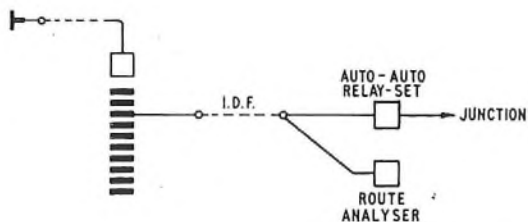


FIG. 3—METHOD OF CONNECTING ROUTE ANALYSER WHERE AUTO-AUTO RELAY-SET IMMEDIATELY PRECEDES JUNCTION

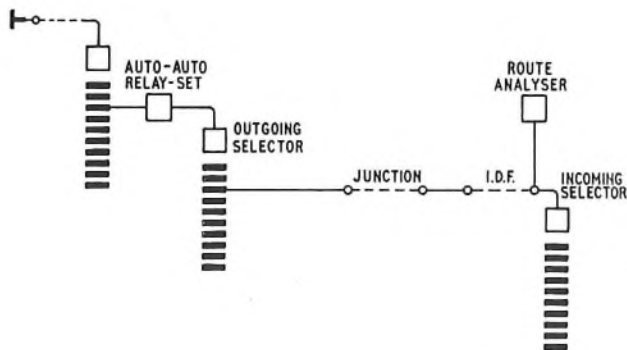


FIG. 4—METHOD OF CONNECTING ROUTE ANALYSER WHERE JUNCTIONS ARE TRUNKED DIRECT FROM OUTGOING-SELECTOR LEVEL

side of the incoming selectors (Fig. 4). Analysis can, if necessary, be carried out at an earlier switching stage, providing that the analyser tapping relays will not be operated by the calling condition from shared-service subscribers or linefinder calling equipments. This limitation arises because the pre-seizing signal from the linefinder equipment and shared-service subscribers' installations would transmit a false pulse to the analysing equipment.

To ensure a continual supply of calls for analysis, tapping circuits should be connected to early-choice trunks of the relevant grading and, where possible, analysis should be achieved on a single digit, since this results in the equipment being held for the shortest possible time and thus permits analysis of the maximum number of calls in any period. Generally it will be found that the most convenient point for connecting tapping circuits is the intermediate distribution frame. The route analyser may be placed adjacent to the intermediate distribution frame and in small exchanges access to circuits may be made by cords and jacks, whilst in larger exchanges, where excessive lengths of cord might be required, alternative access is provided by jumpering. It is possible to analyse 127 codes (comprising codes of 1, 2 and 3 digits) but the equipment is provided with only 40 route meters. Many of these 127 codes will be spare, and others will be used for routes to the same terminal. In each of these cases the calls may be recorded on one meter. For example, when second-digit analysis is taking place on, say, levels 31 to 37, with traffic on levels 31 to 35 routed to one terminal and traffic over levels 36 to 37 routed to some other terminal, then individual route meters will be required for each group of circuits; the spare levels 38, 39 and 30 are commoned to either the route meter registering spare codes or to the "SP" tag (see Fig. 2), to connect a release condition.

CONCLUSION

With the recent introduction of group charging and with the advent of subscriber trunk dialling, the quantity of manually controlled traffic will decrease, ticketed calls will be less and changes in the pattern of telephone traffic may not be apparent. The route analyser will provide a means of observing call distribution within a network; any traffic changes will be detected and the necessary trunking rearrangements may then be made.

Book Review

"Switchgear Principles." P. H. G. Crane, M.Sc., A.M.I.E.E. Cleaver-Hume Press, Ltd. 229 pp., 98 ill. 25s.

The author is a Research Assistant at present employed by the Electrical Research Association and formerly by a well known switchgear manufacturing firm. The book is intended to cover the elementary students' needs of a general knowledge of all aspects of power-circuit protection and of the different types of switchgear available. It succeeds quite well in doing this as it is simply and clearly written and in addition to a number of well-chosen diagrams, contains photographs of typical modern equipments.

The early chapters cover the supply of electricity and the main causes and effects of short-circuits and overvoltages. The various methods of protection, including fuses, switches

and isolators, and the causes and effects of arcing are considered before dealing with the principles and different types of circuit breakers in general use. A very useful chapter gives some interesting facts about the different component parts of switchgear whilst its accommodation requirements and the tests usually performed on fuses, circuit breakers, instrument transformers and isolators are described in the later chapters. A comprehensive and up-to-date list of references is given for each chapter and enables the student readily to obtain more detailed information on any aspect of this subject.

The book provides easy and interesting reading, requiring no more than an elementary knowledge of mathematics, and it will be of considerable assistance to students of electrical power engineering.

I.P.O.E.E. Library No. 2528.

R. S. P.

A Medium-Distance, Built-in Out-band Signalling, Carrier Terminal Equipment

Part 2—Description of Equipment

E. T. C. HARRIS, B.Sc.(Eng.), A.M.I.E.E., and K. C. A. KING, Associate I.E.E.†

U.D.C. 621.395.44:621.395.63

Some of the factors considered in the overall specification for a medium-distance carrier terminal equipment with built-in signalling facilities were discussed in Part 1 of this article. In Part 2 a detailed description is given of an equipment which has successfully completed its field trials.

TRANSMISSION CIRCUITS

THE block schematic diagram (Fig. 2) shows the interconnexions of the main items of equipment and indicates the method of obtaining either a 60–108 kc/s 8-channel group at group-frequency distribution-frame (G.D.F.) transmission levels or, alternatively, a 12–60 kc/s 8-channel group at high-frequency repeater-distribution-

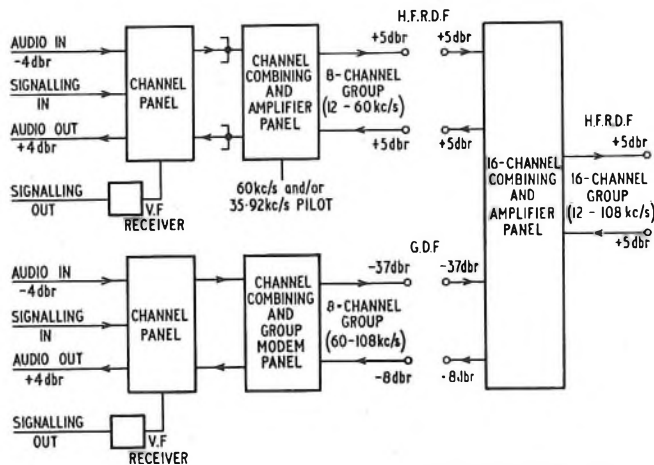


FIG. 2—INTERCONNECTION OF MAIN ITEMS OF EQUIPMENT

frame (H.F.R.D.F.) transmission levels. The required group is obtained by plugging into the appropriate position on the rack-side either a Channel Combining and Group Modem Panel or a Channel Combining and Amplifier Panel.

Also shown in the diagram is the 16-Channel Combining Panel, by means of which a 12–60 kc/s 8-channel group can be combined with a 60–108 kc/s 8-channel group, and the resulting 12–108 kc/s 16-channel group made available at a level of +5 dbr* per channel for connexion to the H.F.R.D.F. In the receiving direction of transmission this panel will provide a level of –8 dbr for connexion to the G.D.F., and a level of +5 dbr for connexion to an H.F.R.D.F. The 16-channel combining panels for two 12–108 kc/s 16-channel groups are provided on a Type C rack-side. Pilot-injection points are provided for the connexion of an 84.08 kc/s pilot in

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* dbr—Relative level, i.e. the ratio, in decibels, of the power at a point in a line to the power at the origin of the circuit (usually the 2-wire point).

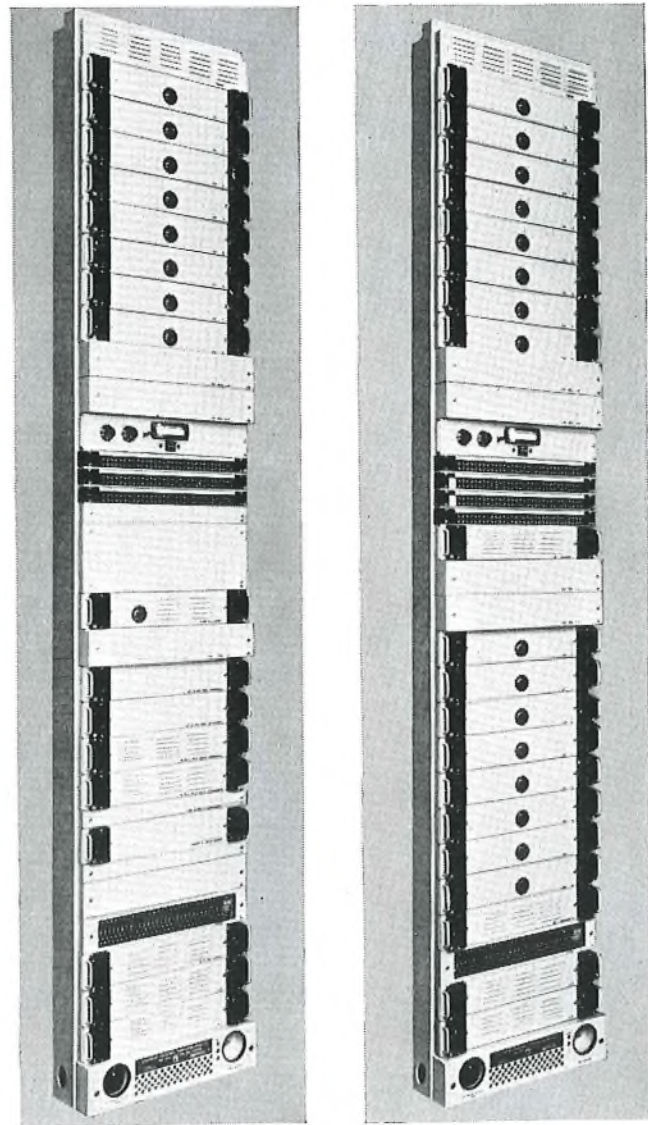


FIG. 3—TYPE A (LEFT) AND TYPE B (RIGHT) EQUIPMENTS

the 60–108 kc/s 8-channel group and/or a 60 kc/s pilot in the 12–60 kc/s 8-channel group or a 60 kc/s pilot in the 12–108 kc/s 16-channel group. The Type A and Type B rack-sides are illustrated in Fig. 3.

Channel Panel

The basic group of eight channels occupies the frequency range 12–60 kc/s. Channels are assembled into the group as upper sidebands of carriers spaced 6 kc/s apart from 12 kc/s to 54 kc/s. All the equipment for each channel, with the exception of the v.f. signalling receiver, is mounted on one 3½ in. panel.

It is well known that a large part of the cost of frequency-translating equipment is accounted for by the cost of the channel-selection filters, and therefore particular care was taken in the initial design stages to ensure that the filtration problems would be as simple as possible. The channel-selection filters finally evolved are of a simple, economical and compact design employing inductors and capacitors.

The use of built-in out-band signalling in this type of system presents some novel design problems. Foremost among these is the need to prevent mutual interference between the speech and signalling currents. It will be seen (Fig. 4) that the signalling tone is injected into the

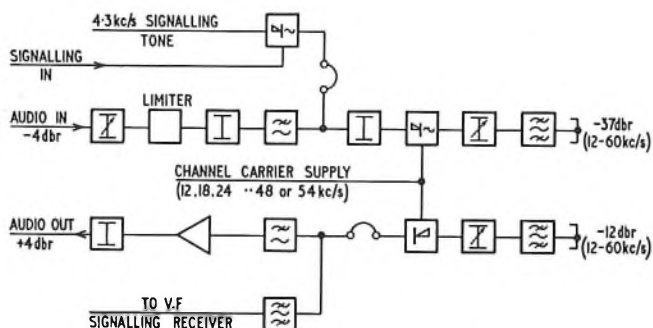


FIG. 4—BLOCK SCHEMATIC DIAGRAM OF A CHANNEL PANEL

main transmission path at the input to the modulator and after a low-pass filter. The function of the low-pass filter is to remove energy at the signalling frequency which may be present in the incoming speech, or which may be produced by the preceding stages of the equipment. From the signalling-tone injection point forward through the equipment to the extraction point after the demodulator it is important that the equipment characteristics be sufficiently linear to prevent the formation of spurious signals which could give rise to signal imitation. This requirement must be met with peaks of audio-frequency energy as high as 20 db above the nominal test level. As it would be impracticable to provide for an overload margin of 20 db a voltage limiter is provided at the input of the equipment to restrict the level of peaks in subsequent parts of the equipment to approximately 6 db above test level. Unwanted signals are most likely to be generated in the modulator and demodulator, and care is taken to ensure that the characteristics of these are sufficiently linear.

To prevent the signalling tone being audible when it is present during a conversation, a low-pass filter to eliminate the signalling frequency is provided following the signalling-tone extraction point. To avoid overloading line equipment during the transmission of continuous signalling tone on a large number of channels simultaneously, the signalling tone is applied at a level 20 db below the channel test level. The problem of reducing inter-channel speech-into-signalling interference to an acceptable amount is complicated by the comparatively low level of the signalling tone. The consequent filter requirements are reduced as the channel spacing is increased and this was a major factor in the choice of 6 kc/s for the spacing between channels rather than the conventional 4 kc/s spacing. The signalling-path band-pass filter between the output of the demodulator and the input of the signalling receiver has sufficient stop-band loss to prevent interference from signals in the

speech frequency band and has a pass-band of suitable width to give a signal-distortion performance within the specification limits.

V.F. Signalling Receiver Panel

Two v.f. signalling receiver panels are provided for each group of eight channels; each panel occupies $3\frac{1}{2}$ in. of rack-mounting space and mounts four receiver units. These units are fitted with plug-and-socket connectors so that they can be easily removed from the panel for maintenance without mutual interference. The receivers were specially designed to operate at the low signalling levels employed in the equipment, and will operate with distortion within the specification limits with variations in signalling-tone level from -7 db to +3 db from nominal, and will continue to operate over the range -10 db to +3 db from nominal with slightly greater distortion. Two double-triode valves are used, and a standard Post Office Type 2B telegraph relay is plugged into the unit.

Channel Combining and Group Modem Panel

The translation of the 12-60 kc/s group into the 60-108 kc/s band is accomplished by modulating a 120 kc/s carrier in a ring-type modulator (Fig. 5). A band-

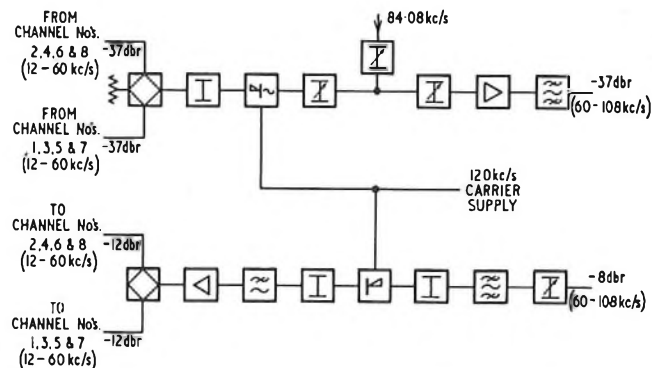


FIG. 5—BLOCK SCHEMATIC DIAGRAM OF CHANNEL COMBINING AND GROUP MODEM PANEL

pass filter follows the modulator and another precedes the demodulator. The functions of these filters are:

- to prevent interference between channels in adjacent groups when the equipment is connected to group translating equipment in a coaxial system, and
- to prevent group-to-group crosstalk when a 60-108 kc/s group is combined with a 12-60 kc/s group in a balanced-cable type system. This interference could arise from signal leak through the modulator or from the unwanted upper sideband.

The transmission levels at the output and input of this panel on the 60-108 kc/s side are such that the standard G.D.F. levels may be obtained with up to 2 db transmission loss in the cables between the equipment and the G.D.F.

Channel Combining and Amplifier Panel

A channel combining and amplifier panel can be plugged into the rack-side in the position occupied normally by the group modem panel, to provide a 12-60 kc/s 8-channel group as an alternative to the normal 60-108 kc/s 8-channel group. In the transmitting direction the panel provides an output of +5 dbr for connexion to an H.F.R.D.F., while in the receiving direction a pad is provided to reduce the +5 dbr level

received from the H.F.R.D.F. to a level suitable for connexion to the channel panel. Pilot injection points are provided before the transmitting amplifier for a 60 kc/s line pilot and/or a 35.92 kc/s group pilot.

16-Channel Combining Panels

Combining panels are provided on the Type C equipment, and in the transmitting direction have the function of combining the 12–60 kc/s group from the H.F.R.D.F. with a 60–108 kc/s group from the G.D.F. In the receiving direction another panel is provided to carry out the reverse function. Unlike conventional 24-circuit systems, filters are not required when combining the two groups, a hybrid being used instead. This important simplification is possible because the 12–60 kc/s group is supplied free from extraneous frequencies which might cause interference and, as has already been explained, the output (60–108 kc/s) from the group modem panel is also free from interfering signals. Similarly in the receive direction the group filter on the group modem panel prevents the 12–60 kc/s group interfering with the 60–108 kc/s group, and the channel filters prevent interference from the 60–108 kc/s group into the 12–60 kc/s group. The levels on the 16-channel side of the panel are suitable for its direct connexion to an H.F.R.D.F. and a suitable injection point is provided for the connexion of a 60 kc/s line pilot.

Carrier and Pilot Frequency Generating Equipment

The frequency generating equipment is mounted on the Type A rack-sides and occupies 22 $\frac{3}{4}$ in. of rack mounting-space. The carrier powers provided are sufficient to supply five groups. Therefore, one Type A rack-side will supply two Type B rack-sides to provide five 60–108 kc/s groups, or alternatively one Type A rack-side will drive one Type B rack-side and one Type C rack-side to provide two 16-channel groups. The carriers required are 12–54 kc/s in steps of 6 kc/s for the channels, 120 kc/s for group modulation and 60 kc/s for the line pilot.

The channel carriers are generated by individual crystal oscillators. Each oscillator employs a single-valve circuit using an NT-cut flexural crystal for fre-

quency control. The maximum frequency change due to ambient temperature variation over the range 5°C to 45°C is not more than 2 c/s. The channel oscillator units are a plug-in type (Fig. 6) and may be easily removed, individually, for maintenance; the eight units required are mounted on one 3 $\frac{1}{2}$ in. panel.

The 120 kc/s group carrier frequency is generated by a 2-valve crystal-controlled circuit, the crystal for which is mounted in a thermostatically-controlled oven to obtain the closer frequency/temperature tolerance required for group modulation purposes. The 120 kc/s crystal-oscillator unit and amplifier are mounted on the same panel as the 4.3 kc/s oscillator which supplies the signalling tone. The complete panel is duplicated, and facilities are provided for automatic change-over of the load from the normal panel to the standby supply in the event of failure of either the 120 kc/s or the 4.3 kc/s supplies. Manual change-over facilities are also provided.

When a 60 kc/s line pilot source is required and is not otherwise available in the station concerned, it may be supplied as required from the Type A equipment. The 60 kc/s signal is derived from the 120 kc/s oscillator by a divider circuit, and the panel is arranged to provide a level-stabilized output. This panel is also duplicated and automatic and manual change-over facilities are provided. All Type A rack-sides are provided with a matching transformer and distribution comb to provide the correct pilot transmission levels and decoupling for a suite of rack-sides, whether the 60 kc/s pilot is provided by the Type A equipment or from a local source in the station.

Power Supplies

Two versions of the equipment are available to allow for operation from either a.c. mains supplies or from standard repeater-station battery supplies. The h.t. voltage required for valve operation is 130 volts, and therefore the only differences between the two equipment versions are that, for a.c. mains operation, an h.t. and l.t. supply panel is provided, while for battery operation a noise-filter panel is fitted and the rack wiring is arranged for series operation of the valve heaters.

Alarm and Maintenance Facilities

The rack-sides are fitted with a meter and alarm panel which mounts relays and keys to provide alarm facilities in the event of power or fuse failures, or in the event of a change over to the 120 kc/s or 60 kc/s alternative-supply panel. Also mounted on this panel is a meter which, by means of rotary switches, may be connected to any valve cathode to measure cathode current, and to measure the voltage of the supply circuits.

A space is left below the meter and alarm panel on the Type A rack-side to accommodate the relay and distortion measuring panel if this is required. This panel provides facilities for the in-station testing of the signalling circuits. As will be seen in Fig. 4, a U-link point is provided at the output of the static relay and at the input of the v.f. receiver. By means of test cords connected between these points and the relay and distortion measuring panel, the signalling circuits may be tested independently of the carrier channels. The test procedure followed is to apply signals at 10 p.p.s. to the static relay and with normal signalling-tone level at the v.f. receiver input to adjust the receiver for correct operation. The receiver input level is then increased

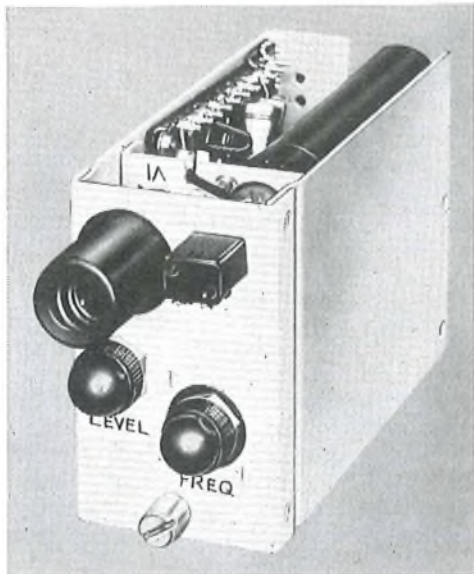


FIG 6—CHANNEL OSCILLATOR

and then decreased to check that the distortion remains within the specification limits. A test position is also provided to facilitate the adjustment of the Type 2B relay.

SIGNALLING CIRCUITS

The equipment to provide the signalling path in this system was designed specially to comply with Post Office requirements and will therefore be described in some detail.

Considering the path traversed by the signalling pulse, signals from the outgoing relay-set at the originating exchange are used to energize a static relay which modulates the envelope of the signal current. The resulting a.c. signal, after passing over the transmission link, is demodulated by a receiver circuit and converted into a d.c. signal again. The d.c. signal is then used to operate the incoming relay-set at the incoming exchange. The effect on the overall distortion of the following component parts of the signalling circuit will now be considered.

- (a) The circuit between the exchange and the carrier terminal equipment.
- (b) The static relay.
- (c) The v.f. signalling receiver.

Interconnexion of the Exchange and Carrier Terminal Equipment

The exchange equipment and the carrier equipment may be in the same building, in which case there is little likelihood of distortion due to the connecting circuits. However, it is frequently the case that the exchange is located in a building some distance from the carrier-equipment building, and the interconnexion circuit is an external cable. Distortion will then arise due to the characteristics of the cable, and it is necessary to consider the effect of the maximum length of tie-cable that will be used in practice. It was decided that a system which could cater for tie-circuits consisting of up to 5 miles of 10 lb/mile cable or 10 miles of 20 lb/mile cable at each terminal would be satisfactory.

To cater for the various conditions presented by the types of exchange likely to be met, the equipment was designed so that the pulsing contact at the originating exchange may be connected to earth, or to a negative voltage through a protective resistor. The negative voltage may be nominally 50 volts for an auto-manual exchange, or 30 or 40 volts for manual exchanges.

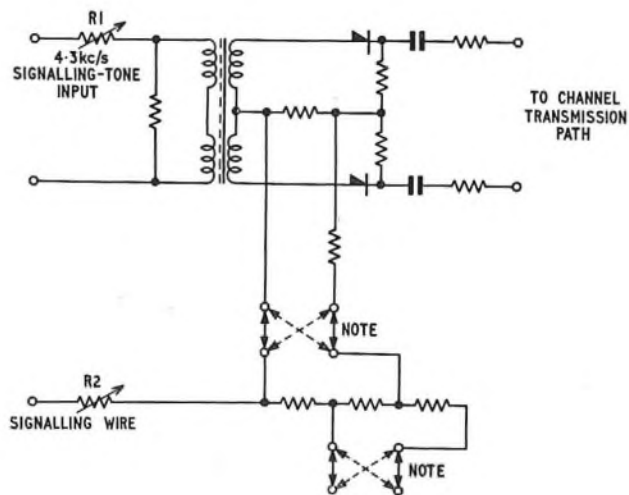
In order to reduce interference to other circuits in the same tie-cable, it is desirable to fit a noise filter following the exchange pulsing-contact, and one has been incorporated in the new design of exchange relay-sets developed specifically for association with out-band signalling systems. The filters used in the relay-sets are a low-pass type, nominally 1,200 ohms and $1\mu\text{f}$. Since the effect of the filter is to retard the growth and decay of the envelope, it is an important factor in causing pulse distortion. The new relay-sets employ earth-return signalling over the phantom circuits derived from the 4-wire 'go' and 'return' speech circuits between the exchanges and the carrier terminal stations.

A further specification requirement is that the equipment should be suitable for tandem connexion of the signalling circuits. Therefore, a signalling receiver may work into a static relay of a succeeding system, or directly into a telephone-type relay of an incoming exchange-termination. Likewise, a static relay may be

controlled from an outgoing exchange relay-set or from a signalling receiver. Since it would be undesirable to change the circuit connexion according to the operating condition, this implies that the static relay, and the condition presented by the signal receiver contacts, must be basically suitable for either condition.

Static Relay

The circuit of the static relay is shown in Fig. 7. The



Note. Alternative connexions shown are for "tone-on-idle" or "tone-off-idle" signalling conditions and for either "battery" or "earth" to R2.

FIG. 7 DIAGRAM OF STATIC RELAY

level of signalling tone applied to the carrier channel is controlled by the resistor chain R1 connected in series with the primary of the transformer. The signalling tone is modulated by the diode circuit under the control of d.c. pulses received over the signalling wire. The static-relay output-terminals are connected across the transmission circuits and cause negligible bridging loss. The units may be set to cater for the various d.c. conditions described in the previous paragraph, by means of suitable strapping connexions on the front. The correct line current is obtained by adjustment of resistor R2 in series with the d.c. input circuit.

V.F. Signalling Receiver

A circuit diagram of the v.f. signalling receiver is shown in Fig. 8, and Fig. 9 is a photograph of the unit. The input stage, comprising transformer TR1, valve VIA and transformer TR2, is an amplifier with a gain of about 40 db. The amplifier output signal is rectified and partially smoothed by capacitor C4 before passing through the primary of transformer TR4 to the load resistance R11. The operating transition of relay A is delayed by the action of pulse-bias derived simultaneously with the signal and applied in opposition; it is also affected by the action of R12 and C5 in the grid circuit, since the valve may run into grid current before the relay has operated. The pulse-bias is developed across the impedance formed by R10 and C3 via the secondary of TR4 and diode VIB. A steady bias is applied to the diode circuit, derived from the cathode resistor R20 of V2B and R17, in such a way that little negative voltage is produced across R10 for weak input pulses. As a result, an a.g.c. action of defined range is obtained which tends to

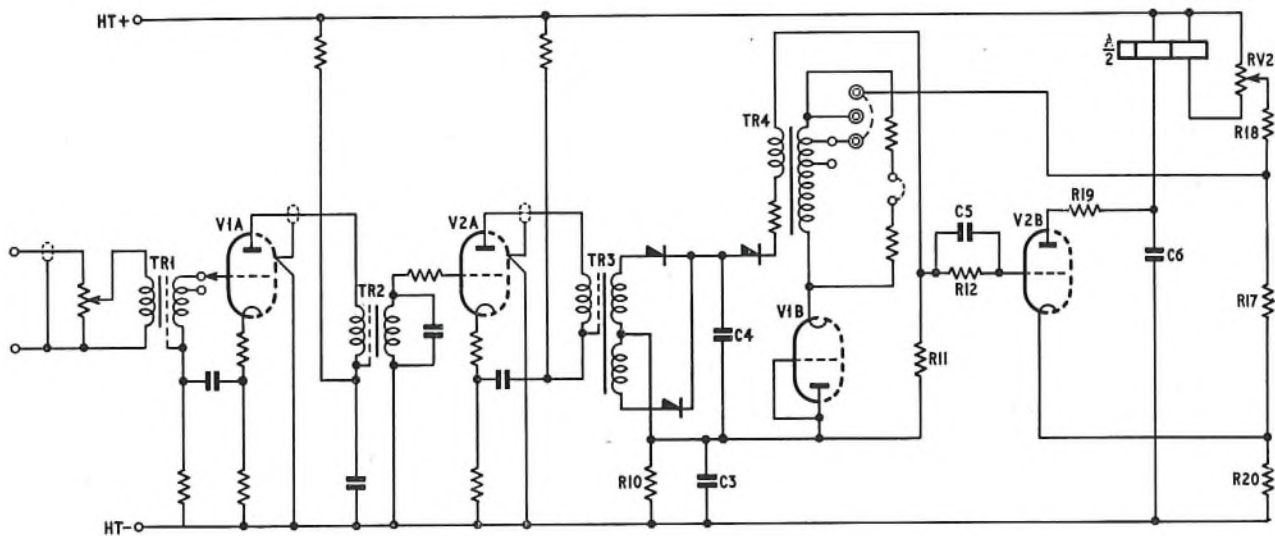


FIG. 8—DIAGRAM OF V.F. SIGNALLING RECEIVER

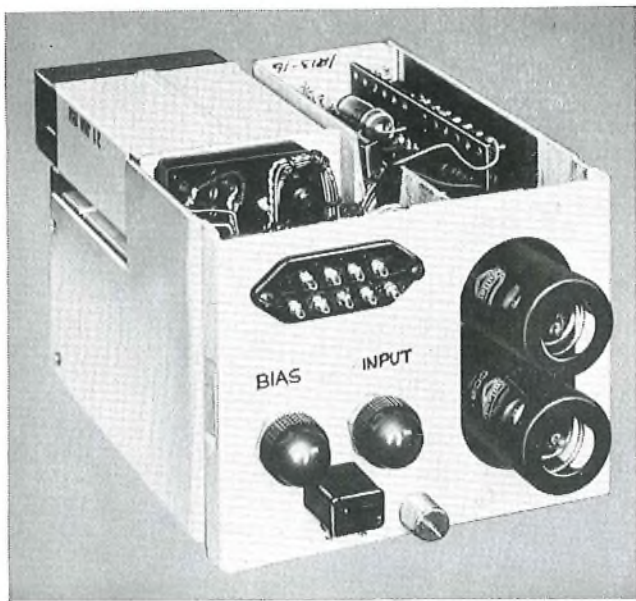


FIG. 9—V.F. SIGNALLING RECEIVER

equalize the effect of high-level and low-level pulses. An oscillogram of the anode-current waveform shows that the grid-cathode voltage of V2B increases a little, but is then reduced by the growth of bias voltage, before finally increasing to and beyond the operating point.

This bias circuit controls the operating transition only of relay A. The release transition is controlled by the series grid-limiter (R12, C5) which serves to equalize

the release lag for various signal levels. The capacitor C6 shunting the A relay coil removes the signalling frequency from the relay circuit, and also produces overshoot in the current waveform of the relay on release so as to encourage the release of the relay at a definite moment, irrespective of possible changes in adjustment of the relay. Appropriate damping is controlled by the relay bias-winding shunted by RV2, in conjunction with the damping provided by the triode drive-circuit. Current in the relay and valve is restricted in the operate condition by R19, and in the non-operate condition by R18, which ensures the correct current necessary to develop a voltage across the cathode resistor of V2B sufficient to restrict the current to an average value of 1mA. In general, time-constants in the circuit have been set as low as possible with the object of reducing characteristic and first-impulse distortion to 0.5 ms.

The relay used is a standard Post Office Type 2B. In either tone-on-idle or tone-off-idle working the average net d.c. ampere-turns provide a pressure of at least 20 grammes on the operative contacts.

CONCLUSION

The equipment described here is being installed on a number of routes and, under the particular working conditions that apply, appreciable capital savings have been made by installing this in place of standard equipment.

As mentioned earlier, an extensive field trial of prototype equipment was carried out on a Middlesbrough-Newcastle route. Some modifications to the design were made as a result of the experience gained and it is felt that the latest equipment will give very reliable service.

The Post Office and the Supply of Electrical Energy by Statutory and Non-Statutory Undertakings in the United Kingdom

S. J. LITTLE, M.I.E.E.†

U.D.C. 351.824.11:621.3.013.7

Since 1863, the powers of the Postmaster-General regarding the construction and maintenance of telegraph and telephone lines have been regulated by Acts of Parliament known as the Telegraph Acts. The development of the electricity supply industry since the latter part of the 19th century made comparable legislation necessary to regulate the supply and distribution of electrical energy, and since 1882 a series of Electric Lighting Acts and Electricity (Supply) Acts have passed into law. This article traces the history of these Acts and outlines the provisions made therein to safeguard Post Office plant.

INTRODUCTION

THE telecommunications system of the United Kingdom is regulated legally by a series of Acts of Parliament which have been passed into the laws of the country at irregular intervals since 1863. These are known collectively as the Telegraph Acts, and in that which was promulgated in 1878 is a clause to the effect that it is an offence to damage or to interrupt communication over telecommunications systems belonging to the Post Office. At that time the electricity supply industry of the United Kingdom was only in its infancy and distribution was undertaken either by local government authorities or privately owned companies. Even at that early stage in the development of the industry it was evident that some measure of state control was desirable and in 1882 the first Electric Lighting Act, which was drafted primarily to regulate the supply and distribution of electrical energy, passed into law.

The provisions of the 1882 Act applied to every local authority or private company that was authorized to supply electricity. Among its provision is a clause, on the lines of that of the 1878 Act, which states that undertakings should not, in the exercise of the powers conferred upon them by the 1882 Act, or any special subsequent Act, injuriously affect Post Office telecommunications.

STATUTORY UNDERTAKINGS

When drafting the 1882 Electric Lighting Act the policy adopted by Parliament was that a supplier of electrical energy could obtain, in respect of a defined area, the power of monopoly. This monopoly was, however, offset by various obligations and restrictions.

In general, in order to obtain the power of monopoly, it was necessary for local government authorities or private companies who wished to enter the field of electricity supply to promote a Bill before the House of Commons. This Bill would seek to obtain parliamentary consent for the setting up of a system for the generation and/or distribution of electrical energy within the area in which the undertaking was interested. After examination and approval by the House of Commons and the House of Lords, and assuming that it was not rejected by either, it received the Royal Assent and became an Act of Parliament. Local government authorities and private companies who had obtained

their powers in this way were known as "Statutory Undertakers" and were often, and still are, termed "Undertakers." Because of the terms of the Electric Lighting and Telegraph Acts these undertakings had, as mentioned earlier, certain duties imposed upon them regarding the protection of Post Office telecommunications.

Protection of the Post Office System

In 1899 a further Act, known as the Electric Lighting (Clauses) Act, which included a very important section as far as the Post Office is concerned, became law. This Act lays down very clearly that every electricity supply undertaking shall take all reasonable precautions in the construction and operation of its electric lines or other works and in working its undertaking so as not to injuriously affect by induction or otherwise the working of any Post Office telecommunications system, whether that system be, or be not, in existence at the time of construction of the power installation.

Furthermore, it is laid down that one month before commencing construction of the work the undertaking must serve on the Post Office a notice and plan, termed collectively a "Statutory Notice," describing the works. This is done to enable the Post Office to assess the effects of the construction and operation of the new plant on its own system and to take such steps as it considers necessary to protect that system from damage by the power line. The cost of such protection falls on the electricity supply undertaking.

The undertaking, having once served its statutory notice, is entitled to a reply within one month. Within this period the Post Office may approve the proposed works subject to such amendment as may seem desirable so far as its own interests are concerned. Alternatively, if it finds that the proposed work would seriously disturb its telecommunications system it could disapprove the whole scheme. The undertaking must then submit new proposals or it may appeal to the Minister of Power, who may inquire into the matter and allow or disallow the appeal or approve the proposed works subject to such amendments as seem fit.

Should the Post Office fail to give notice of approval or disapproval within one month of the receipt of the statutory notice, it is assumed that approval has been given and the undertaking may proceed. If subsequently the Post Office finds that works must be put in hand to protect its plant, it must itself bear the cost.

In addition to the statutory notice mentioned above the Post Office is entitled to a "48-Hour Notice." This is a notice which must be served by an undertaking on the Post Office 48 hours before the start of any work which has been the subject of a statutory notice. This is to enable the Post Office to send inspecting staff to the site of the new works to protect its interests. This procedure applies, in particular, to the construction of all electric power lines of whatever voltage, whether overhead or underground, although for service lines, which are generally short low-voltage lines feeding a

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consumer, a seven-day statutory notice only is required and plans are unnecessary.

If an undertaking does not proceed with the work within six months of approval of the relevant statutory notice by the Post Office, this approval lapses and fresh approval must be sought. This requirement is made because the Post Office considers that it is not unreasonable to expect the works to have been commenced within this period and if they have not been commenced it requires the opportunity to reconsider them in so far as they may affect proposals for new Post Office lines. An arrangement was, however, made with the undertakings, which still continues, that an extension of the period will be permitted by exchange of letters without the submission of fresh plans provided no alteration is envisaged to the proposed route shown on the plan which accompanied the original notice.

The Central Electricity Board

Between 1899 and 1926 a number of additional Electric Lighting or Electricity (Supply) Acts were passed into law; the early requirements relating to the protection of Post Office plant remaining substantially unaltered. Among these Acts, one of the more important was the Electricity (Supply) Act, 1926, which set up the Central Electricity Board. This Board consisted of a chairman and seven other members appointed by the Minister of Transport after consultation with representatives of local government, electricity supply, commerce, industry, transport, agriculture and labour.

The Central Electricity Board was constituted primarily with the object of rationalizing the supply of electricity in the United Kingdom, provision being made for the interconnexion of selected existing generating stations of high efficiency by new high-voltage transmission lines to ensure an efficient and reliable supply of electricity throughout the country. The electricity thus generated was sold to statutory undertakings who continued to distribute, and in some cases generate, their own supplies. As the load of the country grew, the smaller and less efficient stations fell into disuse and generation became concentrated in the larger stations. This involved the construction of further high-voltage transmission lines to connect these stations to the load points. Among the powers given to the Board in the 1926 Act was one which enabled them to acquire rights to build such transmission lines over private land by agreement with the owner. If no agreement could be reached the Board was empowered to acquire such rights compulsorily. In each case wayleave payments were offered for the right to cross the land.

Nationalization of the Electricity Supply Industry

In 1947 further developments in Britain's electricity supply industry took place. In that year the Electricity Act, 1947, became law. This provided for the establishment of the British Electricity Authority, subsequently known as the Central Electricity Authority, and for the setting up of Area Electricity Boards. In general the British Electricity Authority took over the functions of the old Central Electricity Board, but with additional responsibilities relative to the generation of electricity, whilst the Area Boards assumed responsibility for distribution from the old statutory undertakings, i.e. those owned by local government authorities or private companies.

A further enactment, the Electricity Act, 1957, abolished the Central Electricity Authority and set up

in its place the Central Electricity Generating Board and the Electricity Council. The former is responsible for the maintenance of an efficient, co-ordinated and economical supply of electricity in bulk in England and Wales and the latter for advising the Minister of Power on questions affecting the electricity supply industry and for the maintenance and development by Electricity Boards in England and Wales of an efficient, co-ordinated and economical system of electricity supply.

The clauses written into the earlier Acts for the protection of Post Office telecommunications were, however, not repealed by the 1947 or 1957 Acts and it follows that the Central Electricity Generating Board and Area Boards have the same responsibility for the safeguarding of Post Office plant as had their predecessors.

The Central Electricity Generating Board and Area Boards have no jurisdiction in Scotland, where two separate bodies, the North of Scotland Hydro-electric Board and the South of Scotland Electricity Board, are responsible for the supply and distribution of electricity. These will not be dealt with further in this article as the method adopted for dealing with power-line construction by these Boards does not differ from that now to be described.

The Construction of High-Voltage Lines by the Central Electricity Generating Board.

The legal procedure for securing the consent of the Post Office to the execution of work by an electricity supply undertaking has already been outlined but a description will now be given of the procedure followed for the construction of main high-voltage grid lines, as these have special points of interest.

In England and Wales the Generating Board is responsible for the construction of all transmission lines of the grid and super-grid systems, most of which operate at 132 kV and 275 kV. The Area Boards are responsible for their own distribution lines, which include some of 66 kV but are mainly comprised of lines operating at or below 33 kV. As far as the Generating Board's lines are concerned these are very largely overhead, and when it becomes necessary to build a new line of, say, 132 kV or 275 kV the procedure is as follows.

In the first place the ground over which the line is to run is surveyed and, a suitable route having been determined, rights of way over the land concerned are obtained either voluntarily or compulsorily as mentioned earlier. Wayleave payments continue to be offered for the right to cross the land. Having determined the route the Generating Board serves a statutory notice on the Post Office notifying its intention to construct the line. The Post Office then considers the effects of the construction and operation of the proposed line on its plant and takes such steps as it considers necessary to protect its plant from damage by the power line, the Generating Board being legally responsible for the costs of such protection.

It may be for instance that the proposed power line crosses a number of overhead telephone lines. In this case the Post Office wires will be put underground at the crossing points. Alternatively, calculations by the Post Office may show that the proposed power line could, under fault conditions, induce high voltages in nearby telecommunications circuits. In this case the induced voltage must be assessed and arrangements made by the Post Office to safeguard these lines against the incidence of voltages in excess of those recommended for such

circumstances by the C.C.I.T.T. This may take the form of quoting to the Generating Board limits for the fault current in the power line, or alternatively, the provision of suitable protective equipment, e.g. gas-discharge tubes or transformers, on the telecommunications circuits. Again the Generating Board pays for such work as may be necessary.

In practice, when replying to the Generating Board's statutory notice, the Post Office quotes a fault current which will induce in its lines the C.C.I.T.T. voltage limits of 430 or 650 volts, according to circumstances. In many cases the power-line fault currents do not exceed these quoted figures and in consequence co-existence of the two sets of plant can be permitted. On the other hand, should the fault currents exceed the quoted figures it is usual for the Post Office to work on its plant to reduce the induced voltages to acceptable values. This is because the Generating Board normally earths the neutral points of its 132 kV and 275 kV systems and thus current limitation is not possible.

The above procedure, particularly the assessment of the voltages which may occur due to induction, the fitting of equipment to counteract these voltages, and the placing of plant underground, can be a relatively lengthy operation, and although the Post Office is empowered to prevent a scheme proceeding until it is itself ready, this method is rarely, if ever, employed. Generally, it is the practice for a Board, when it has partly settled the route of a particular project, to send a "preliminary inquiry" to the Post Office outlining its proposals. This preliminary inquiry, which has no legal significance, may be given many months before the actual statutory notice is served and it enables the Post Office to assess the effects of the proposed line on its plant, to advise the Board of its findings, and to make such arrangements as are necessary to secure the safety of its lines.

By the time the actual statutory notice is served most of the Post Office work has been started and final approval can be given to the Board to proceed. The latter must, however, still serve the final 48-hour notice notifying its intention to commence operations so that the Post Office can make any further arrangements that it may think necessary.

NON-STATUTORY UNDERTAKINGS

Although, before the nationalization of the British electricity-supply industry in 1947, the supply and distribution of electrical energy was largely in the hands of statutory undertakings, it was permissible for any person or company to supply electricity for public or private purposes; that is, to operate a so-called "Non-Statutory Undertaking" in an area outside that of a statutory undertaking. In these circumstances a company or persons became a non-statutory undertaking if they supplied electrical energy by lines extending beyond the boundary of their own property. Local government authorities could not, however, operate non-statutory undertakings as, under the Electric Lighting Act of 1882, they were only able to borrow money for the purpose of generating and distributing electricity if they were a statutory undertaking.

Subsequent to the 1947 Act, which nationalized the electricity supply industry, the position changed only slightly as the Area Electricity Boards set up under that Act took over the functions of the statutory undertakings and in effect themselves became statutory undertakings.

The Area Electricity Boards had, however, no control over existing non-statutory undertakings, which continued to function as previously.

The part played by non-statutory undertakings in the development of the electricity supply industry in the United Kingdom has never been very great, and in general, with certain notable exceptions, such undertakings serve only a few consumers. Further, the importance of the non-statutory undertaking will probably tend to diminish with the passage of time since, with the steady extension of the electricity supply network by the nationalized electricity supply industry to all parts of the United Kingdom, the incentive to undertake private generation and distribution is very much lessened.

The size of non-statutory undertakings varies widely, ranging from the farmer in a remote rural area who generates electricity for use on his own farm and sells the surplus to his neighbours, to perhaps a cement manufacturing company which uses waste heat to generate electricity for its own purposes and disposes of the surplus to its employees living around the works.

Although non-statutory undertakings may build distribution lines to carry any energy generated by them to the load point, they are prohibited from supplying loads within the area of a statutory undertaking. In the past, the latter did not always find it profitable to serve every area in the country, particularly rural districts where the load was very light, and it was here that the majority of the small non-statutory undertakings developed.

In contrast to statutory undertakings, non-statutory undertakings are under no obligation to lay mains for the purpose of a general supply or to maintain a regular continuous supply of electrical energy at a declared voltage. Furthermore, they have no legal power, as have statutory undertakings, to break up streets to lay mains, etc. This has resulted in non-statutory undertakings almost invariably giving supplies by overhead lines, even though these are restricted in some areas by local by-laws. In these circumstances non-statutory undertakings endeavour to erect lines outside the jurisdiction of the local government authority for the area. In general these and other similar restrictions have resulted in non-statutory undertakings trying to build their lines over private property, which is usually not very difficult in rural areas. Nevertheless, they can still come into conflict with Post Office overhead lines and, in such circumstances, the problem is dealt with as outlined later.

Regulations

Both overhead and underground lines belonging to statutory and non-statutory undertakings may become subject to regulations made by the Electricity Commissioners, a body set up under the Electricity (Supply) Act, 1919, to promote, regulate and supervise the supply of electricity in the United Kingdom. The functions of this body have since been taken over by the Ministry of Power. It is, however, quite possible, and indeed usual, for a small non-statutory undertaking to build a line and to bring that line into operation without the knowledge of the Ministry of Power. This is because a non-statutory undertaking is under no legal obligation to advise the Ministry of its intentions. Furthermore, the Ministry have no control over a non-statutory undertaking's line until it is actually built. Some undertakings are, of course, fully aware of the Ministry's

requirements and do previously advise that body when they intend to build a new line.

To cover the more usual case, i.e. where a line is built and operated without prior knowledge of the Ministry, a procedure has been evolved where, when the Ministry hear of such a work, a notice can be served on the owner imposing conditions relative to the construction and operation of the line. These conditions are similar to those prescribed for statutory undertakings and are primarily designed to secure the safety of the public. They include, however, a regulation which requires the owner of the power line to provide protection for any Post Office lines endangered by the power line, the non-statutory undertaking, as the owner of the line, being liable for the cost involved. The non-statutory undertaking must, therefore, not only meet the regulations prescribed by the Ministry of Power but must carry out such work as is required by the Post Office to protect its lines.

Serving of the Notice Containing the Regulations

As a non-statutory undertaking is under no legal obligation to notify any official body of the construction and operation of a line, but such lines are, nevertheless, subject to official regulations, the serving of the notice calling attention to the necessity of complying with these regulations would appear to present a problem. In practice, the difficulty is not great. The Post Office has, of course, a very widespread network of both overhead and underground lines and because of the legal obligation of statutory undertakings to notify it of new works, it is in a very good position to observe any which may be built by a non-statutory undertaking that is not required to serve such notices. When officers of the Post Office observe that a private person or body has constructed a line which extends beyond the boundaries of the owner's property, i.e. has become in law a non-statutory under-

taking, the Ministry of Power is informed. It is quite possible that the Ministry may be advised of the existence of the non-statutory undertaking by some other source, but in any event the Ministry, once having knowledge of the existence of the undertaking, serves on its owner a notice requiring that the line conform with the appropriate regulations. At the same time, the Ministry advises the Post Office that this has been done.

If it is known that the lines of the non-statutory undertaking endanger Post Office circuits, the Post Office is entitled to write to the undertaking asking that a notice be served on it describing the line and including a plan showing its position and the method of construction. Having received this information, the Post Office may then serve a counter-notice on the owner, requiring such alterations to the method of construction or position of the power line as it considers necessary for the protection of its own lines or other works.

It is also laid down that one month before commencing any further works (excluding repairs or the like) a further notice and plan must be served on the Post Office, describing the new works. This is to enable the Post Office to inform the non-statutory undertaking of any alteration to the proposed work which may be required for protection of its lines. Failure of the owner to comply with such a notice is deemed to be a non-compliance with the requirements of the Ministry of Power's notice and can lead to legal proceedings in a court of law.

If the non-statutory undertaking prefers, it may, instead of securing protection of the Post Office circuits by working on its own line, ask the Post Office to secure protection of its plant by alterations to the Post Office lines. The Post Office is prepared to accept this arrangement, providing the undertaking will agree to meet the cost. Where work is carried out on the non-statutory undertaking's plant, it is done at the cost of the undertaking.

Book Review

"Electric Lifts." R. S. Phillips, M.I.E.E. Sir Isaac Pitman & Sons, Ltd. 411 pp., 235 ill. 63s.

This is the fourth (1958) edition of the well-known book, published in 1939, which has been revised to bring it up to date.

The first chapters are headed, "Design and Traffic Analysis," and "Accommodation," and the book then goes on to devote chapters to fairly detailed descriptions of all the main features of lifts of various types. All of this, whilst conforming to the principles of sound technical descriptive writing, deals little with engineering design. It is in no sense a treatise on engineering design, and is obviously not so intended. To an engineer, the wealth of pictures, instead of engineering drawings, are rather disappointing since pictures do not lend themselves to an understanding of details of mechanisms. This is particularly frustrating with the pictures of the various types of safety gear. To finish off the carping criticism it is considered that the theoretical treatise on traffic flow and the derivation therefrom of sizes, speeds and features of lifts would not likely be undertaken in practice save on rare occasions. But the book will admirably serve as a reference for architects or others who are dealing with lift installations, and who wish to have a comprehensive survey of the best current practice, how it is provided, and the structural

and other requirements. Moreover, there is indicated at all stages the basic theoretical calculations which govern the fundamental features of the machinery, such as the determination of the numbers and sizes of ropes, the horsepower of the motor, etc.

The chapter describing the facilities offered by various types of control system is followed by one on controller panels, which indicates clearly the general principles, and follows up with detailed circuit operation of a few typical units. There is a very useful chapter on maintenance and testing, full of sound practical advice. Indeed, throughout the book there are details such as clearances, tolerances and so on whose basis is empirical but which have been found to be the best practicable (or possible) for satisfactory operation. Some of this class of information has now found its way into the British Standards Specifications.

The final chapter on lift accidents presents a sensational climax to the preceding sections of the book that deal with safety gear, maintenance and inspections. Whilst it shows a reassuring trend in post-war years, the details given showing how and why a number of unfortunate people met their deaths are an arresting challenge to engineers and underline one aspect of their responsibility in this industrial age. The presentation is typical of a Welsh author impelled by strong humanitarian feelings and with a flair for creating an effect.

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F. A. H.

Waveform Distortion in Television Links

Part 2—The Measurement and Correction of Waveform Distortion

I. F. MACDIARMID, A.M.I.E.E.†

U.D.C. 621.3.018.782:621.397.2

The reasons for the use of certain standardized test waveforms in the specification and measurement of the linear transmission performance of television links were given in Part 1 of this article. In Part 2, which includes a brief description of the techniques of waveform measurement, consideration is given to the application of tolerance limits to the waveform responses of television links. An outline is given of the principles of the routine-test and acceptance-test methods of obtaining the rating factor of a link. Finally, an introduction is given to the basic ideas of the correction of waveform distortion without recourse to conventional steady-state measurement and equalizing techniques.

INTRODUCTION

THE first part of this article introduced the idea of thinking about the linear transmission performance of television links in terms of their responses to chosen test waveforms in preference to the more traditional steady-state responses. If waveform responses are to be useful in practice, it is necessary to be able to specify and measure the performance of a link in terms of its waveform response in such a way that the tolerance limits are related to subjective picture impairment. How this can be done is the topic considered first in this part of the article.

The ability to measure and specify the overall performance of links would in itself be sufficient justification for the use of waveform testing. It is, however, also possible to reduce the waveform distortion on a link to tolerable limits by the use of suitable "waveform correctors" (analogous to residual equalizers) whose values or settings are obtained entirely from waveform measurements. The correction of waveform distortion in this way is the final topic discussed in the article.

THE MEASUREMENT AND SPECIFICATION OF WAVEFORM DISTORTION

The Technique of Waveform Measurements

The idea of using a waveform displayed on an oscilloscope as the basis of precision measurements of distortion may seem a little strange to those who have not been closely associated with such techniques. This is because until recently few available oscilloscopes were suitable for much more than purely qualitative observation. However in recent years oscilloscopes have improved greatly and instruments are now available which, when properly used, are capable of quantitative measurements of high precision. The essential requirements of an oscilloscope for waveform measurements are as follows:

(a) A gain-control system and vertical amplifier and deflexion system which themselves have very small waveform distortion and whose characteristics are stable.

(b) The ability to display a completely steady trace not only when the oscilloscope itself is subject to mains fluctuations but also when the waveform to be measured has low-frequency fluctuations superimposed on it. Such fluctuations may be introduced by the effect of short-term mains variations on active equipment through which the waveform has passed.

(c) The cathode-ray tube and its deflexion circuits should give as large a display as possible consistent with very small geometrical and non-linearity distortions and should give the smallest practicable spot size. It should also be possible to prevent mains hum, which may be present on the waveform being displayed, from thickening the trace.

(d) Suitable voltage-calibration and time-calibration facilities of the required accuracy.

(e) The ability to use and easily interchange graticules in front of the cathode-ray tube.

A number of other features which must be considered when selecting an oscilloscope, such as ease of operation, are desirable rather than essential and so are not listed here.

The greatest accuracy in the measurement of waveform distortions is obtained by photographing the waveform displayed on the oscilloscope and making the measurements on the negative with a measuring microscope. Care is required to ensure that optical distortions and uneven negative shrinkage do not contribute to the inaccuracies. As in other types of measurement the greatest accuracy is obtained by comparison. To do this the output of the waveform generator is first connected to the oscilloscope and the waveform photographed. The link or equipment to be measured is then introduced and a second photograph obtained. Comparison of the microscope measurements on the two photographs will then eliminate a number of the possible causes of error. For greatest accuracy it is advisable that the traces photographed should be of the same size and in the same position on the cathode-ray tube.

For most purposes the complication and delay introduced by the use of photographs is undesirable and the somewhat smaller accuracy which can be achieved by direct measurement from the oscilloscope is acceptable. Such measurements are most conveniently made with a suitable graticule placed in front of the cathode-ray tube. Special-purpose graticules for measuring particular types of waveform distortion are described in the next section but a general-purpose graticule for measuring the relative amplitudes of parts of a waveform, e.g. percentage overshoot, is shown in Fig. 13. This makes use of the diagonal-scale principle—an old idea, but one which does not seem to have been used hitherto for oscilloscope graticules. In use, the oscilloscope controls are adjusted so that the full amplitude of the waveform is between the 0 and 100% lines, and then the waveform is moved horizontally until the desired point on it coincides with one of the intersections of the diagonal lines and the vertical lines. This enables the desired amplitude to be read to within 1%.

The principal inaccuracy in the use of graticules is the parallax error. There are various ways of avoiding this, the simplest being to provide a hood in front of the cathode-ray tube with a small eyehole to keep the viewer's eye in a fixed position. However, this is not normally required in practice as the quantities which it is desired to measure are usually small departures from a reference

† Senior Executive Engineer, Post Office Research Station.

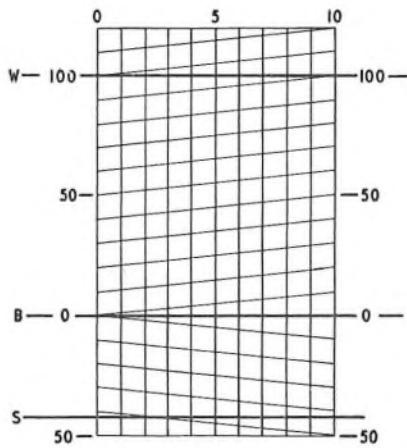
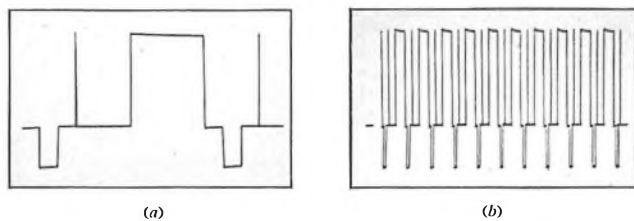


FIG. 13—DIAGONAL-SCALE GRATICULE

line on the graticule and it is not difficult to view the reference points on the trace and graticule simultaneously with the measuring points, with the eye in a fixed position.

It will be recalled from the examples given in Part 1 that, when the pulse-and-bar test waveform is used, distortions normally appear as variations in the pulse/bar amplitude ratio and/or as departures from flatness of parts of the waveform which should be straight horizontal lines. The technique of double triggering the oscilloscope to display the pulse and the bar simultaneously enables small changes in pulse/bar amplitude ratio to be detected. The departure from flatness of part of the waveform can be observed most sensitively if the oscilloscope time-base controls are adjusted to make the sloping part have an angle of about 45° with the horizontal. This is illustrated in Fig. 14, which shows the waveform response of an exponential overshoot distortion (2% magnitude and $12 \mu\text{s}$ time-constant) with two different settings of the oscilloscope time-base. In Fig. 14 (a) it is difficult to say whether the distortion is present or not, but in Fig. 14 (b) it can easily be seen. It is worth pointing out that this waveform distortion (one-fifth of the amount shown in Fig. 5 (a)*) corresponds to a variation in gain/frequency response of about 0.2 db. It will be appreciated that very much smaller amounts of this class of distortion can be observed directly on the full-size display of an oscilloscope than can be seen on the reduced-scale reproduction used here.



The distortion is exponential overshoot of 2% magnitude and $12 \mu\text{s}$ time-constant in each case.

FIG. 14—EFFECT OF OSCILLOSCOPE TIME-SCALE ON VISIBILITY OF WAVEFORM DISTORTION

The technique of viewing the waveform while adjusting the time-base controls over a wide range of sweep speeds is a particularly sensitive method of finding small distortions. It is possible in this way to find distortions which are too small to measure accurately with a graticule. The

* Part I—Vol. 52, p. 111, July 1959.

method is particularly useful when adjustable networks are being used to improve the waveform response.

The Rating Factor

The desirability of measuring waveform distortions in a manner which is quantitatively related to the subjective impairment of television pictures has already been mentioned in Part 1. A method of doing this was proposed by Dr. N. W. Lewis¹ in 1954 and has been used successfully by the Post Office and other organizations since that date. There is little to be added to the 1954 paper but it seems desirable to include a brief description of the method together with some explanatory comment based mainly on questions which have been posed verbally to Dr. Lewis and the author from time to time.

The basic aim is to find a method of placing tolerance limits on waveform responses such that for a tolerance of given size the picture impairment would be the same irrespective of how the waveform reached the limits. To meet the need to have limits of various degrees of stringency to suit the different requirements for individual items of equipment or complex chains of links, the limits are expressed numerically in terms of a rating factor, K , whose value can be chosen to suit the individual requirements. For example, it is recommended that, for the 405-line system, an international "hypothetical reference circuit" (a 2500 km circuit with two intermediate video interconnexion points) should have a rating factor not exceeding 5%, while a short video link on coaxial cable (up to 6 miles) should have a rating factor of less than 0.5% and a single video amplifier one of less than 0.25%.

The standard of comparison, used in comparing subjectively the effects of different types of distortion, is a single undistorted echo with a time delay greater than $4/3 \mu\text{s}$. The relative amplitude of this echo is numerically equal to the rating factor, i.e. a 5% echo at $2 \mu\text{s}$ has a rating factor of 5%. Any other type of distortion with a rating factor of 5% should give approximately the same degree of picture impairment when judged subjectively. It should be pointed out that in comparisons of this sort there is always a very large spread of opinion; two distortions, judged to be equal by one viewer, may give an entirely different impression to another. The waveform limits used in determining the rating factor have been arrived at partly from theoretical considerations, partly from the measurement of distortions on a large number of links, and partly from subjective observations of a large variety of distortions by a small number of experienced observers, viewing under critical conditions. The rating system is therefore essentially empirical but experience has not yet shown the need for any change in the limits since they were first introduced.

The rating system can be used in two different ways. It can be used either as a "Go/No-go" gauge to determine whether or not a link is meeting some prescribed standard of performance, or as a means of expressing the results of measurements on a link. In the latter case several different values of K are obtained corresponding to different features of the waveform response. When it is desired to express the performance of the link by a single figure the largest of the measured values of K is taken.

Two different methods of measuring the rating factor are available which are known as the "Routine-Test Method" and the "Acceptance-Test Method." In the former, the rating factor is obtained directly from

measurements on the oscilloscope using graticules and, as the name implies, the method is suitable for routine tests and many similar purposes where a quick answer is required and where simplicity is important. The acceptance-test method is more complicated and involves making microscope measurements from photographs of the waveform and calculating the rating factor from these measurements. This method gives greater accuracy than the routine-test method at the cost of speed and complication.

Routine-Test Method. The response to the $2T$ pulse-and-bar test waveform is measured with the aid of graticules of the type shown in Fig. 15 (a) and (b). The actual

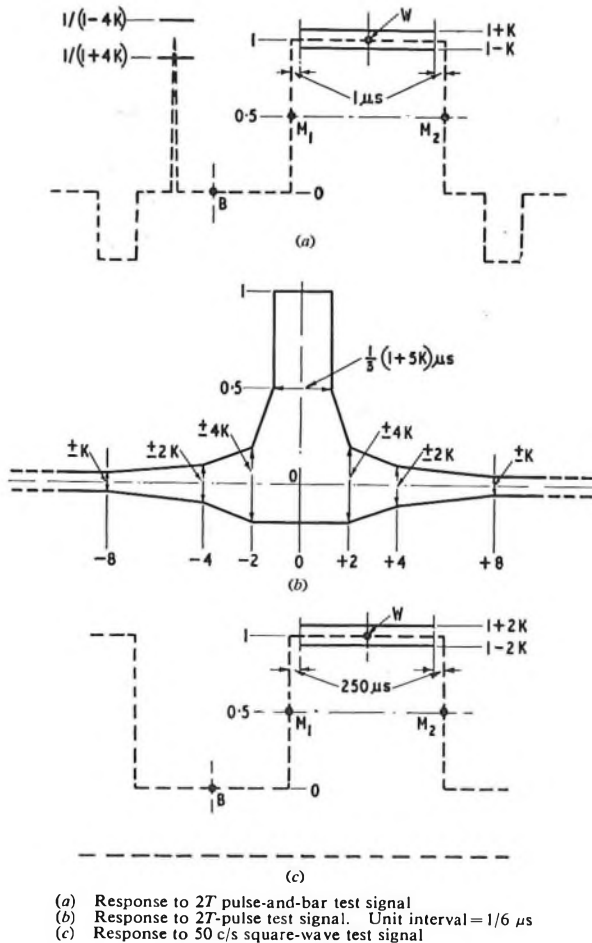


FIG. 15—WAVEFORM RESPONSE LIMITS

graticules must of course be engraved for some specific value or values of K . For example the limits shown for the top of the bar in Fig. 15 (a) would be at 1.04 and 0.96 for $K=4\%$. It is convenient to have limits for two values of K on a single graticule, e.g. 2% and 4%, other values being obtained by interpolation. Where the range of values of K encountered is very large it may be necessary to have more than one graticule of each type to cover the range.

Using the graticule in Fig. 15 (a), the oscilloscope controls are adjusted so that the trace coincides with the reference points B, W, M1 and M2. The top of the bar is inspected to see whether or not the response is within the appropriate limits or, alternatively, the value of K for the top of the bar can be estimated by interpolation.

The first microsecond of the response on either side of the transition is excluded from this measurement, as distortion in this range is indicated more sensitively by the response to the sine-squared pulse. The same graticule shows limits for the height of the $2T$ pulse with respect to the bar; this is another feature of the waveform response used in determining the rating factor.

The shape of the $2T$ sine-squared pulse is next inspected using the graticule in Fig. 15 (b). The oscilloscope controls are adjusted so that the trace has the same amplitude as the graticule and is placed centrally in it with the correct time scale. The time scale can be set most conveniently by adjusting the time-base controls to make a timing-wave, temporarily replacing the incoming signal, coincide with suitable reference marks on the graticule. As before, the graticule can be used to determine whether or not the $2T$ -pulse response is within limits or, alternatively, to determine the rating factor of the worst feature of the response. The shape of the limits on this graticule takes account of the fact that distortions such as echoes having short time delays are less visible on a picture than the same distortions with longer time delays.

The spectrum of the $2T$ pulse-and-bar waveform is confined to a 3 Mc/s band-width and consequently there is no difficulty in placing limits on its waveform response. The T -pulse, however, has a spectrum extending to about 6 Mc/s and the response of a link to a T -pulse depends therefore not only on its performance up to 3 Mc/s but also on its performance between 3 and 6 Mc/s, which is largely irrelevant to its suitability for passing 405-line pictures. It is therefore not possible to place hard-and-fast T -pulse limits on the response of a link using the routine-test method. However, a few features of the T -pulse response are measured and compared with measurements made when the link was first lined up so that any deterioration may be detected. The features to be measured, together with some very tentative figures corresponding to various rating factors, are shown in Table 1.

TABLE 1
Features of T -Pulse Response Measured in Routine-Test Method

Features	Rating factors					
	1%	2%	3%	4%	5%	6%
Half-amplitude duration, maximum (μs)	0.245	0.250	0.255	0.260	0.265	0.270
Ringing frequency, minimum (Mc/s)	3	3	3	3	3	3
First lobe (negative), leading or trailing, maximum (%)	10	12	14	16	18	20
Second lobe (positive), leading or trailing, maximum (%)	6	8	9	10	11	12

The figures in Table 1 refer only to links having a relatively sharp cut-off just above 3 Mc/s, and even in this case can be used only as an empirical guide. It may be convenient to measure the bar/ T -pulse amplitude ratio in addition to the features shown in Table 1. Distortions affecting the half-amplitude duration of the T -pulse will in most cases also affect the bar/ T -pulse amplitude ratio and it is easier to detect small changes in this quantity than in the half-amplitude duration. A graticule of the type shown in Fig. 13 is most useful for T -pulse measurements.

The pulse-and-bar test signal is only useful in measuring distortions at frequencies above the line-repetition frequency (10 kc/s), although phase distortion above this frequency, associated with attenuation distortion below this frequency, may affect the flatness of the bar top. The distortion at lower frequencies is measured by the response to a 50-c/s square-wave with added line-synchronizing pulses. The limits for this signal are shown in Fig. 15 (c) but the graticule intended for the bar (Fig. 15 (a)) may be used if the tolerance is made twice as great, i.e. limits giving $K=4\%$ for the bar correspond to $K=2\%$ for the 50 c/s square-wave. The test signal and an example of distortion are shown in Fig. 16.

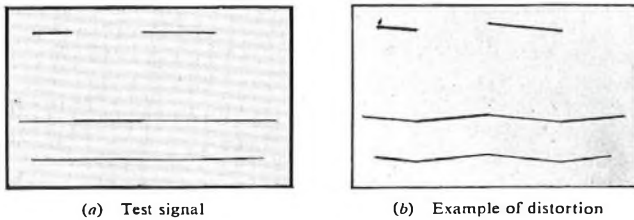


FIG. 16—50 C/S SQUARE-WAVE TEST SIGNAL

Distortion of this type will normally be removed completely by a black-level clamp at the television transmitter and so it is in a rather different category from the other types of waveform distortion. For this reason the rating factor for the 50 c/s square-wave is often quoted separately from that for other waveform distortions.

The waveform responses of a number of television links together with their rating factors have been published.¹ It may be of interest to give the rating factors of the various illustrative distortions used in this paper. Table 2 shows the figures obtained by the routine-test method for the different features measured and the overall rating factors. Comparison of these figures with the gain/frequency responses given earlier confirms that, even for distortions of a similar type (e.g. Fig. 5 (a) and 5 (c) or Fig. 9 (a) and 9 (b)*), the steady-state tolerances have no direct connexion with the rating factor.

Acceptance-Test Method. A detailed description of the procedures used in the acceptance-test method for determining the rating factor would be out of place in this introductory account of waveform measuring methods. Two papers by Lewis^{1,2} give full details of the processes used and should be consulted by anyone intending to use the method. A brief outline of the principles will, however, be given here as they contribute to a better understanding of waveform distortion.

The limits on the response to the bar and 50 c/s square-wave test signals are the same as in the routine-test method and so will not be considered further. The $2T$ sine-squared pulse is not used in the acceptance-test method. The response to the T -pulse is photographed with a suitable timing wave on the same negative. A photograph showing the T -pulse response of the test equipment alone is also required. The photograph of the link response is adjusted in the measuring microscope so that the axes of the pulse response are aligned with the microscope co-ordinates. The point mid-way between the half-amplitude points on the pulse is located and this position is used as the time reference point. The timing wave is used to determine a series of points spaced at $1/12 \mu s$ intervals on both sides of the time reference point and the amplitude of the waveform is measured at each of these times. This is equivalent to the sampling of a waveform in a time-division multiplex system and the series of samples so obtained (called a "time-series" in this case) completely describes the waveform provided that its spectrum contains no components above 6 Mc/s. The use of a sine-squared pulse ensures that this condition is met for all practical purposes.

The advantage of expressing the waveform response in terms of a time-series lies in the fact that this form of expression is particularly convenient for arithmetical manipulation. The response of a link is of interest only over the band up to 3 Mc/s but an ideal low-pass filter to restrict the band to this frequency cannot be made. However the time-series of the link may be multiplied by the time-series of an ideal 3 Mc/s low-pass filter to give a resultant time-series, with ordinates spaced at $1/6 \mu s$

* Part 1—Vol. 52, p. 111 and p. 112. July 1959.

TABLE 2
Rating Factors by the Routine-Test Method

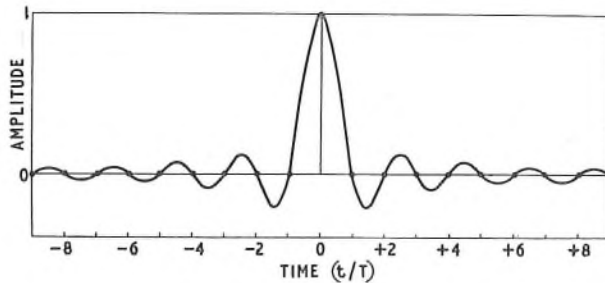
Waveform shown in Fig. No. †	Bar response %	2T bar/pulse ratio %	2T-pulse shape %	T-pulse %	50 c/s square-wave %	Overall rating factor K%
5(a)	6	-2.5	<0.5	—	—	6
5(b)	6	-2.5	1	—	—	6
5(c)	<0.5	-1.5	1	—	—	1.5
5(d)	6	+2.5	<0.5	—	—	6
5(e)	6	+2.5	1	—	—	6
5(f)	<0.5	+1.5	1	—	—	1.5
7(a)	13	0.5	2	—	—	13
7(b)	0.5	0	1.5	—	—	1.5
9(a)	5	+1.2	5	—	—	5
9(b)	0	-2.5	2.5	—	—	2.5
11(a)	0	10	6	17‡	—	17
11(b)	0	0	1	2.4‡	—	2.4
11(c)	<0.5	<0.5	<0.5	<0.5	—	<0.5
12(a)	0	6	4.5	—	—	6
12(b)	0	6	2	—	—	6
12(c)	0	<0.5	2	—	—	2
14	1	-0.5	<0.5	—	—	1
16(b)	—	—	—	—	2	2

† Fig. 5-12 are in Part 1—Vol. 52, p. 108, July 1959.

‡ These figures are calculated by the acceptance-test method.

representing the response of the tandem connexion of the link and the ideal filter.

The measurement and filtration process are carried out both for the link response and that of the test equipment. By dividing the link time-series by that of the test equipment a resultant series is obtained which is free from any imperfections of the test equipment (except non-linearity). This series represents the "filtered impulse response" of the link or, in other words, the response of the link to a pulse whose shape is defined by $(\sin \pi t/T)/(\pi t/T)$. The waveform of this pulse is shown in Fig. 17. Its spectrum is uniform in amplitude up to a frequency $1/2T$ and zero at higher frequencies.



The sampling points for the time-series with interval T are marked.

FIG. 17—IMPULSE RESPONSE OF IDEAL LOW-PASS FILTER (CUT-OFF FREQUENCY $1/2T$)

The time-series representing the filtered impulse response of the link contains all the required information about the distortion introduced by the link up to the highest frequency of interest. If the link were distortionless the filtered impulse response would be $(\sin \pi t/T)/(\pi t/T)$ and the time-series representing it would contain only one term—the one representing distortionless transmission. This is because, at each sampling interval in the final time-series with $1/6 \mu\text{s}$ spacing, the ringing associated with the ideal low-pass filter response is passing through zero, as illustrated in Fig. 17, and the only non-zero sample is the one at the time reference point which, in this case, coincides with the peak of the pulse. When distortion is present additional terms appear in the time series and in the same way each distortion term represents the magnitude of a $(\sin \pi t/T)/(\pi t/T)$ pulse whose peak occurs at the time appropriate for that distortion term. The time-series therefore contains a central or main term representing the undistorted transmission, plus a number of distortion terms at intervals of $1/6 \mu\text{s}$ on either side of the main term, the magnitude of each distortion term being the amplitude of an echo of the main term occurring at the appropriate time. The idea of expressing distortions in terms of echoes thus appears again. In this case the echoes do not need to appear in symmetrically placed pairs because they do not represent attenuation or phase distortion considered separately.

Before finding the acceptance-test rating factor one more time-series must be formed. This is obtained by multiplying the filtered impulse-response series by a series $[1/2, 1, 1/2]$ which is a simple approximation to a $2T$ sine-squared pulse. The resultant series therefore represents approximately the $2T$ -pulse response of the link, calculated from its response to a T -pulse.

Four different types of restrictions are placed on these series, each representing a limit on a different property of the waveform response and yielding a different rating factor. Details of the arithmetical operations will not be

given here but the approximate significance of the operations is useful as it permits comparison with the limits used in the routine-test method. The limits used in the acceptance-test method are as follows:

- K1 This limit is closely equivalent to the limit placed on the shape of the $2T$ response by the graticule shown in Fig. 15 (b).
- K2 This limit is closely equivalent to the limit placed on the $2T$ bar/pulse amplitude ratio used in the routine-test method.
- K3 This limit is equivalent to a restriction on a bar/pulse amplitude ratio where the test signal is a hypothetical pulse-and-bar waveform in which the pulse is an ideal filtered impulse.
- K4 This is an upper limit on the average amplitude, ignoring signs, of the 16 central echo terms of the filtered impulse-response time-series.

While $K1$ and $K2$ have close equivalents in the routine-test method, $K3$ and $K4$ have not. $K3$ takes account in one way of distortions near the upper-frequency limit of the link. In the routine-test method these distortions will usually affect the half-amplitude duration of the T -pulse response and/or the initial amplitude of the ringing. $K4$ takes account of excessive ringing, too low a cut-off frequency in the link and/or a long train of echoes whose magnitudes are not individually great enough to reach one of the other limits.

As in the routine-test method, when a single overall rating factor is required for a link, the largest value of K obtained for $K1$, $K2$, $K3$, $K4$, the bar response or the 50 c/s square-wave response is taken.

The Tandem Connexion of Links

One of the difficulties which arise from expressing the performance of links in terms of their waveform response is that of obtaining the waveform response of a tandem connexion of two or more links when the waveform responses of the links taken separately are known. For some simple or idealized distortions the solution can be obtained explicitly by means of the convolution integral (or Duhamel integral), details of which will not be given here. For most distortions experienced in practice numerical integration is required and the most convenient way of doing this is by the multiplication of time-series referred to above. However, when the waveform distortions are small, the approximate result of tandem combination of two links, whose waveform responses are known separately, can be obtained simply by adding the two distortions. The justification for this can be seen by considering a simple example.

Since it is possible to express waveform distortion in terms of echoes, it will be sufficient to consider an example where the distortion in each link consists of a single echo. Consider a link with a single erect echo of 10% amplitude at $1 \mu\text{s}$ connected in tandem with a link which has a single erect echo of 5% amplitude at $1 \mu\text{s}$. If a $2T$ -pulse is applied to the first link the output will consist of the pulse followed at $1 \mu\text{s}$ by a 10% echo. The pulse will come through the second link unchanged and so will the echo. The second link will however introduce an echo of the pulse at $1 \mu\text{s}$ and of 5% amplitude. This will coincide with the echo from the first link and add to it giving an echo of 15%, $1 \mu\text{s}$ after the pulse. The echo from the first link will, however, also cause an echo to be produced by the second link which will have an amplitude of 5% of 10%, i.e. 0.5%, and will occur $2 \mu\text{s}$ after the pulse. For many purposes

this subsidiary echo can be considered to be negligible. Thus we see that there is a "tendency of corresponding echoes to add,"² which is a most useful result when considering the addition of small waveform distortions.

A further question of practical importance is how the rating factors add up when a number of links are connected in tandem. This problem has no complete solution except where the time-series of the individual links are available. Then, by multiplying the individual time-series, that of the tandem combination can be obtained and the overall rating factor calculated.

Where only the rating factors are known the situation is more difficult. For reasonably small distortions the K_2 and K_3 rating factors, or the corresponding $2T$ bar/pulse figure in the routine-test method, all add algebraically. Where links are of a similar type and the distortions are systematic rather than random, the rating factors tend to add linearly. Where the distortions are random, as for example where they are due to component tolerances, or where individual correction to obtain the best possible rating factor has been used, or where a large number of links with dissimilar equipment are involved, the rating factors tend to add on a root-sum-square basis.

In practice, when a reasonably large number of links are involved, the rating factor of the tandem combination usually lies somewhere between that obtained by linear and root-sum-square addition of the individual rating factors.

THE CORRECTION OF WAVEFORM DISTORTION

Having obtained a suitable method of measuring waveform distortion and methods of placing limits on it, the next question is what to do if the response of a link or piece of equipment falls outside the desired limits. Continuing with the approach which has been developed in this article, it is obviously desirable to deal with the distortion on a waveform basis rather than to refer back to steady-state measurements. Although in the present state of the art this is not always possible, a good deal of progress has been made in the correction of waveform distortions on a video-to-video basis. The subject is however a large one and only an introduction to it will be attempted here.

The presence of waveform distortion in a linear transmission system is synonymous with imperfection of equalization. Consequently, to reduce the waveform distortion to tolerable limits, the equalization must be improved. Equalization, in the steady-state sense, is a highly developed art. It involves three main steps prior to the construction of the equalizer network. The first of these is the measurement of the distortion in steady-state terms. Secondly the desired equalization characteristic must be approximated within the desired tolerance by a network function which can be realized physically. Thirdly the network itself must be synthesized from the function. In practice the second and third steps are sometimes combined. Three sources of error exist in the process, viz. errors in measurement, approximation tolerances, and tolerances in the construction of the final network. It has already been pointed out that tolerances in steady-state response cannot easily be transformed into tolerances in waveform response and vice versa, with the result that improving the equalization of a television link by normal steady-state means is often a very disappointing process.

To ensure that the design tolerances in an equalizer are such that they have the minimum undesirable

effect on the waveform distortion it is essential that the measurement and the approximation processes are carried out on a waveform basis. Fortunately this is quite easy to do in many cases—easier in fact than by the normal steady-state methods. The measurement of the distortion with a suitable test waveform and oscilloscope has already been described. The approximation problem can be solved by introducing into the circuit a suitable adjustable network and operating its controls until the waveform response lies within the desired limits. The settings on the adjustable network can then be used to obtain a fixed network for permanent installation, or in some cases, such as the reduction of distortion on a long link whose characteristics may be expected to vary with time, it is often more convenient to leave the adjustable network permanently in circuit. The use of an adjustable network with a display of the waveform response is equivalent to the use of an analogue computer to solve the problems of approximation to the desired equalization characteristic by a realizable network function and the transformation of tolerances of gain and phase to tolerances of waveform distortion. In this case, however, no analogue is required as the quantities of interest can be measured directly.

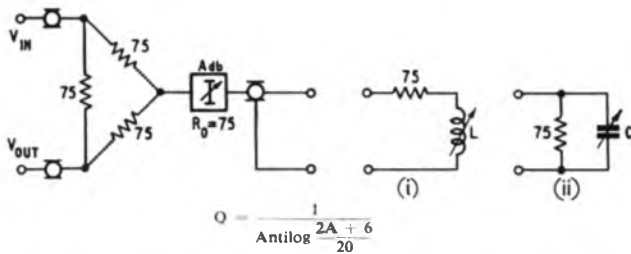
Networks designed in this way are known as "Waveform Correctors" to distinguish them from equalizers whose purpose is to make "equal" gain/frequency and group-delay/frequency characteristics. The circuit arrangements used for waveform correctors and equalizers may in fact be identical—it is only the basis of the design that is different. The first use of waveform correctors was almost certainly for the correction of telephone cable pairs for television outside broadcasts.^{3,4} In this instance the replacement of the adjustable networks by fixed networks was not considered, due to the temporary nature of the links.

Almost any form of adjustable equalizer can be used as a variable waveform corrector provided that the components can be chosen to give a waveform distortion in the opposite sense to that which must be corrected. It is desirable that the various controls should be free from interaction and should produce easily distinguishable effects on the waveform. Experience has shown, however, that these features are by no means as important as was first imagined. A variety of circuits have been used successfully as waveform correctors and there is still scope for development on these lines. By way of illustration of the potentialities of waveform correction two arrangements will be described which are commonly used on television links.

The "Exponential" Waveform Corrector

A commonly occurring distortion both on television links and other video equipment is the exponential waveform distortion illustrated in Fig. 5.* A circuit arrangement which has been found very convenient as an adjustable waveform corrector for dealing with distortions of this type is shown in Fig. 18. The alternative connexions to the adjustable attenuator are chosen according to whether an overshoot or undershoot is required. If the distortion to be corrected is an overshoot, the corrector must produce an undershoot and vice versa. Adjustment of the attenuator alters the magnitude of the correction without affecting the time-constant. Adjustment of the inductor or capacitor (either by variable components or by switching between fixed values)

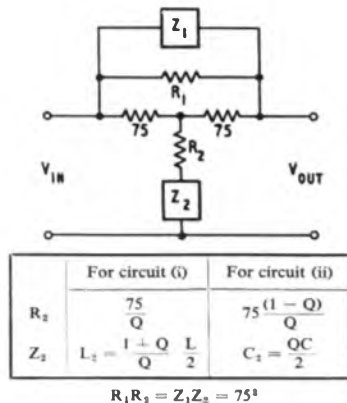
* Part I—Vol. 52, p. 111, July 1959.



Circuit (i) produces overshoot with a time-constant = $L/150$
 Circuit (ii) produces undershoot with a time-constant = $37.5C$

FIG. 18—VARIABLE "EXPONENTIAL" WAVEFORM CORRECTOR

alters the time-constant but not the magnitude. Thus the correction can be adjusted by two independent controls to bring the waveform response within limits. When a fixed corrector of the same performance is required this can be obtained in the bridged-T constant-impedance form using the values shown in Fig. 19.



$$R_1 R_2 = Z_1 Z_2 = 75^2$$

FIG. 19—BRIDGED-T WAVEFORM CORRECTOR TO GIVE THE SAME WAVEFORM RESPONSE AS CIRCUIT IN FIG. 18

In some cases simpler networks will be suitable. These can be obtained from the bridged-T form by normal equalizer equivalences.⁵

Other forms of adjustable exponential corrector are possible and may be more convenient in some cases. The circuit shown can also be used with more complicated impedances connected to the adjustable attenuator to correct more complicated waveform shapes. There is much room for the ingenuity of the designer in devising suitable circuits.

The Echo Waveform Corrector

On long television links there is usually an appreciable waveform distortion resulting from tolerances in equalization. This is particularly true of long cable links where the residual distortions may be very complex in form. The reduction of these distortions by conventional equalizer networks would require very complicated networks which would be different for every link. The waveform approach, however, suggests a different type of solution. Because it is possible to represent any distortion in a restricted band-width by a series of echoes which may arrive both before and after the main signal, a waveform corrector which produces an inverse series of echoes is capable of cancelling any distortion no matter how complicated. Correctors of this type have been designed by the author's colleague, Dr. J. M. Linke,⁶ and are known as "echo waveform correctors," one form of which is in common use and will be briefly described here.

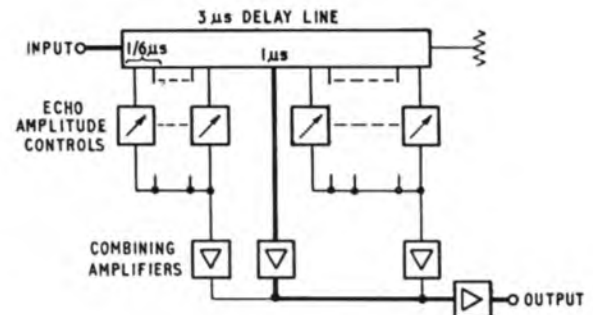


FIG. 20—SIMPLIFIED DIAGRAM OF ECHO WAVEFORM CORRECTOR

A simplified block diagram is shown in Fig. 20, from which it can be seen that the input signal is connected to a $3 \mu s$ delay line which is terminated at its far end. The main output signal is taken through suitable amplifiers from a tapping $1 \mu s$ along the line. The main signal path is shown with a thicker line in the diagram. Since the delay line is properly terminated and free from intermediate reflections the only effect of the main signal path is to delay the signal by $1 \mu s$. However, the delay line is also provided with tapping points every $1/6 \mu s$ along its length (only a few of them are shown in the block diagram). These are provided with echo-amplitude controls arranged in conjunction with the combining amplifiers so that erect or inverted echoes, whose amplitudes are adjustable through zero, can be added to the main signal. An echo from the beginning of the delay line is therefore $1 \mu s$ in advance of the main signal while that from the end of the line is $2 \mu s$ after the main signal. The intermediate tappings give echoes at $1/6 \mu s$ intervals within this range. The corrector is therefore capable of adding to the signal applied to it, an array of echoes of this signal with $1/6 \mu s$ spacing in the range -1 to $+2 \mu s$.

The waveforms shown in Fig. 9 and 12* were produced with the aid of an echo waveform corrector; Fig. 9 shows the response with single echoes added while Fig. 12 shows the response with three arrays of echoes. In the latter, the echoes do not appear as separate entities because they are spaced at $1/6 \mu s$ intervals and the signal is the $2T$ -pulse which causes each separate echo to have a substantial overlap with its neighbours.

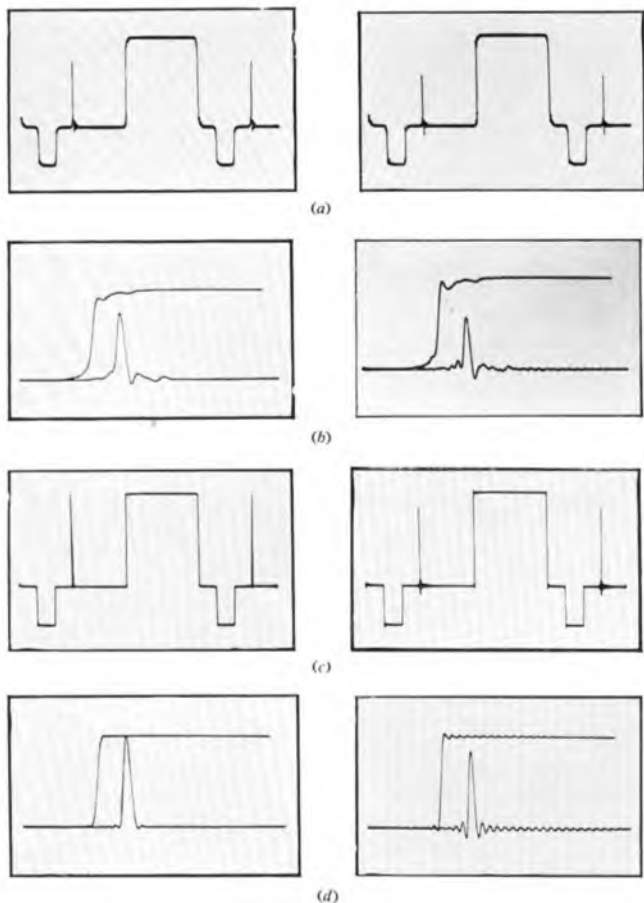
When used as a corrector at the end of a link the $2T$ pulse-and-bar waveform response is first inspected with all the echo-amplitude controls at zero. The controls are then adjusted, in turn, starting from the ends of the delay line, to restore the waveform as nearly as possible to its undistorted shape. The controls nearest to the main tapping are adjusted to give the correct T -pulse response. It may be necessary to go over the adjustments more than once to obtain the best results. An example of the correction of a typical link response is shown in Fig. 21. In this example the rating factor is reduced from about 4% to less than 1%.

Waveform correctors of this type are used for dealing with residual distortions on long links whose transmission performance may vary somewhat with time. Consequently no attempt is made to replace the adjustable corrector by a fixed equivalent.

CONCLUSIONS

Some of the advantages of specifying, measuring and correcting the linear transmission performance of television links in a consistent manner using their response

*Part 1—Vol. 52, p. 112 and p. 114. July 1959.



(a) and (b) show the waveform response of link before correction
(c) and (d) show response after correction

Note: Left-hand figures give response to 2T-pulse-and-bar waveform
Right-hand figures give response to T-pulse-and-bar waveform

FIG. 21—EXAMPLE OF CORRECTION BY ECHO WAVEFORM CORRECTOR

to standardized test waveforms have been demonstrated. These methods have led not only to a reduction in the time (and therefore cost) spent in setting up and maintaining links but also to an improvement in their performance. While the methods have been described in relation to television links, for which they were devised, they are also finding application in other items of television equipment as, for example, studio equipment, transmitters and even receivers.

It is perhaps worth stressing once more that only linear distortions have been discussed in this article. The measurement of non-linearity is a separate subject and requires special waveforms. There is a certain amount of non-linear distortion present on most long television links, but it is generally not sufficient to affect seriously what has been said about the measurement, specification and correction of linear waveform distortion. The acceptance-test method of determining the rating factor is affected to the greatest extent by non-linearity because it depends on the calculation of the step response and of the 2T-pulse response from measurements on the T-pulse. These calculations are only valid in a linear system. However, the routine-test method is still a most valuable test method even in the presence of substantial amounts of non-linearity because it measures the actual response of a link to typical elements of a television picture. The interpretation of the measurements may, of

course, be different in the presence of substantial non-linearity; further work is required on this subject.

Other subjects connected with the specification of link performance on which further work is required are:

(a) The interpretation of the T-pulse response, as displayed on the oscilloscope, for the purposes of specification and correction instead of merely the indication of changes in performance. This is particularly important in cases where there is severe non-linearity, as mentioned above.

(b) The present limit on 50 c/s square-wave response seems rather tight. However, difficulties have arisen due to distortion in the 250 μ s interval following the black-to-white transition, which is not included in the present specification. Distortion in this region can adversely affect the operation of black-level clamps, causing streaking. Some change in the specification is required but further work is necessary to determine the new limits.

(c) Another feature of the waveform response of television links and equipment which is still unspecified is the long-term step response. If there is a sudden change in the mean d.c. level of a picture as sometimes occurs, for example, on cutting from one camera to another, it is equivalent to applying a step function to the links. Since the links do not respond down to d.c. this step cannot be transmitted without distortion. The presence of black-level clamps at the transmitters normally makes this distortion unimportant, provided that the response is not such that gross overloading occurs somewhere in the chain. An oscillatory step response temporarily increases the signal excursion on the links and thus tends to cause overloading. There is no difficulty in measuring this distortion but further study is required before limits can be set.

It can be seen that the ideas about waveform response that have been set out in this article have gone some of the way towards obtaining distortionless transmission of television signals. They have also brought to light new problems, not only those mentioned above but also broader ones, such as how to design equipment to give a prescribed waveform response. As further developments on these lines can be expected, together with an increase in the use of waveform methods, the author hopes that this introductory article will be helpful in providing a better understanding of the subject.

ACKNOWLEDGEMENT

The author gratefully acknowledges the help and encouragement which he has received from Dr. N. W. Lewis in the preparation of this article.

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Generation of Meter Pulses for the Automatic Telex Service

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U.D.C. 621.373.44:621.394.34

Under automatic telex working the calling subscriber's meter will be stepped once when a call is set up and subsequently at a steady rate for the duration of the call, the rate depending on the chargeable distance. Twenty different pulse-rates are required, varying from one to 60 per minute. A description is given of the design and performance of the machine that provides the twenty pulse-rates.

INTRODUCTION

As the Telex service is converted to automatic working, charging on a proportionate-time basis will also be introduced i.e. the calling subscriber's meter will be stepped once when an effective connexion is set up and subsequently at a steady rate for the duration of the call, the rate depending on the chargeable distance. To operate the subscribers' meters, pulses at the appropriate rates must be generated at each telex exchange.¹

On the scale of charging as finally decided, twenty different pulse-rates are required varying between one and 60 per minute. Circuit considerations limit the minimum pulse-duration and the minimum interval between pulses; limits of 250 ± 50 ms for these were finally agreed as a basis for design.

The essential requirements for pulse-generating equipment were considered to be a high degree of reliability, ability to operate continuously for long periods without attention and accurate pulse-timing. Considerations of size, cost and time available for development were also important and the conclusion was soon reached that cam-operated contacts provided the only practicable solution.

DESIGN CONSIDERATIONS

The meter-pulse machine eventually produced is shown in Fig. 1. At the outset a decision had to be

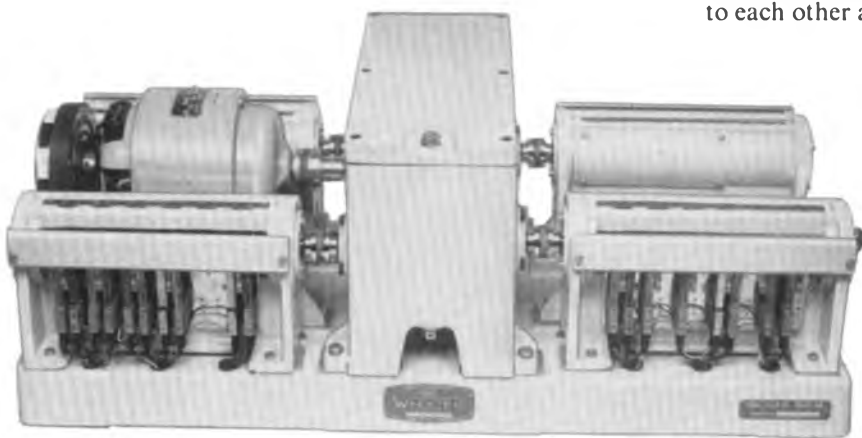


FIG. 1—METER-PULSE MACHINE

taken as to the type of contacts to be used in view of the large currents (of several amperes) which might eventually be pulsed at the largest exchanges. Tungsten contacts fitted to spring-sets of a type already in use on telephone ringing machines were known to be capable

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¹ FORSTER, A. E. T. Automatic Switching for the Telex Service. *P.O.E.E.J.*, Vol. 51, p. 193, Oct. 1958.

of pulsing 5 amp inductive loads when fitted with a $1\mu\text{F}$ capacitor spark-quench and appeared to be suitable. There were obvious advantages in adopting spring-sets already in production because of the reduction in cost and in the development period required. As design proceeded it became possible to limit the current handled by an individual contact-set to a maximum of about 1.5 amp and with this loading a long contact life is expected. Nevertheless the need to be able to replace contact-sets readily was recognised and they were located (see Fig. 1) with this in view as well as to facilitate cleaning. Laboratory tests indicated that contact erosion could be reduced still further, if found desirable, by using large 3 in. diameter Metrosil disks in place of the $1\mu\text{F}$ capacitors.

Cam design was largely determined by the choice of spring-set. The maximum diameter of cam permissible was fixed by the length of the spring-set and the cam lift by the spring-set travel. In considering the hump profile the cam wear that was likely to occur had to be taken into account, and the shape chosen, which has a relatively long "flat" at the top of the hump, allows for reliable operation of the spring-sets even after considerable wear has taken place. With this cam hump a maximum of 10 humps per cam is possible which is, however, quite sufficient from the point of view of providing the relatively large range of pulse rates without undue complication of the machine. The cams are made from synthetic resin-bonded fabric (s.r.b.f.), machined to a high degree of precision, and they are designed for individual replacement should the need arise.

DERIVATION OF PULSE TRAINS

The machine as finally designed has four camshafts driven from a common motor, accurately phased relative to each other and rotating at 12, 6, 3 and 2 r.p.m. Twelve cams can be accommodated on each shaft but spare positions have been left for the provision of possible additional pulse rates. The number of humps on the individual cams varies between one and nine. The basic pulses of 250 ms duration are all generated from cams on the 12 r.p.m. shaft to ensure maximum accuracy. Pulse outputs of 12, 24, 36, 48, 60, 84 and 108 per minute can be taken direct from these cams, but the remaining pulse rates have to be obtained by "gating" the basic-pulse trains from the 12 r.p.m. cams through contacts operated by one or more cams on the other shafts.

The principle is illustrated in Fig. 2, which shows the derivation of the 1 pulse/minute and 3 pulses/minute rates from the basic 12 pulses/minute rate. The 3B cam (3 r.p.m. shaft) operates its spring-set once for each four operations of the contacts of the 12A cam (12 r.p.m. shaft), which produces the basic 12 pulses/minute rate; only 3 pulses/minute therefore appear at the output terminal. The 1 pulse/minute rate is derived by connecting in series contacts operated by the 3A cam (3 r.p.m.

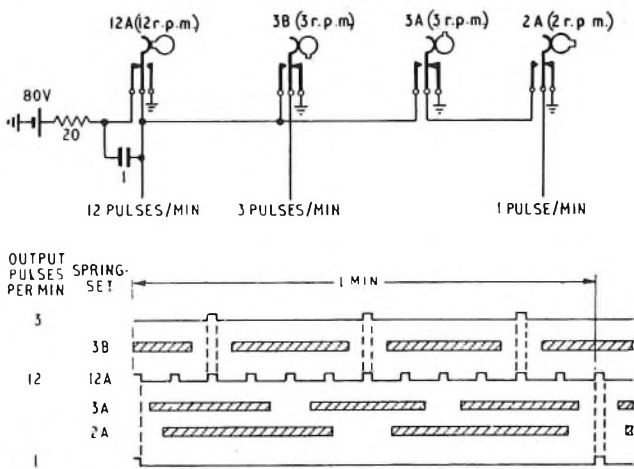


FIG. 2—TYPICAL GATING

shaft) and 2A cam (2 r.p.m. shaft). The 3A spring-set operates three times and the 2A spring-set twice per minute and their operations coincide once per minute, thereby allowing one pulse from the basic-pulse train to reach the 1 pulse/minute terminal. Similar methods are used to derive other pulse rates that are not available directly. Despite the apparent complexity the total number of cams required (36) does not greatly exceed the total number of outputs.

Some restriction was placed on gating by the fact that the same hump profile was used on all cams so that the contacts controlled by the 6, 3 and 2 r.p.m. shafts were operated for periods of 500, 1,000 and 1,500 ms respectively. It was therefore necessary in some cases to use two gating-contacts in series to ensure that only the desired pulse in the basic train was selected, without any vestiges of the adjacent pulses. Thus the 84 pulses/minute basic-train cannot be gated directly by the 14 pulses/minute contacts on the 2 r.p.m. shaft, but must first be gated by the 42 pulses/minute contacts on the 6 r.p.m. shaft. This is illustrated in Fig. 3, from which tolerances have been omitted for the sake of simplicity.

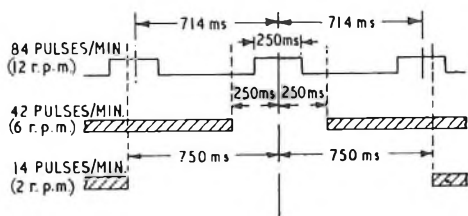


FIG. 3—TYPICAL DOUBLE GATING

The use of the same hump profile simplified the cutting of the cams and, in any case, any advantage gained by reducing the humps on the gating cams (to obtain narrow gates) would have been offset by reduced cam-life and by marginal operation of the gating contacts.

The meter pulses are taken from the + 80-volt signalling battery via 20-ohm protective resistors. Change-over spring-sets are employed so that when battery is not applied a guard earth can be connected to the pulse leads to safeguard the meters from operation from stray fault currents. It is necessary to monitor the

² COLLINS, J. H., and COLLIER, E. G. The Testing of Telegraph Machines. *P.O.E.E.J.*, Vol. 49, p. 7., April 1956.

pulse output terminals continuously so that faults can be detected immediately in order to prevent false operation of meters, i.e. either under or over operation. The principle adopted was to duplicate each pulse supply completely on the machine and to check the two supplies at each rate against each other by a simple comparator relay circuit external to the machine. Failure of either pulse supply causes an alarm to operate. To provide duplication each spring assembly comprises two change-over spring-sets; the number of cams is thus unaffected. Duplication of supplies enables the current loadings on the contacts to be reduced.

The maximum instantaneous drain on the + 80-volt supply must be kept to a minimum and to achieve this it is necessary that the pulses at different rates should, as far as possible, not coincide. This is achieved by judicious choice of the pulses to be gated (e.g. in Fig. 2 it will be observed that the 1 pulse/minute and the 3 pulse/minute supplies never coincide) and by relative phasing of the cams. At the London (Fleet) telex exchange the loads due to the 3 pulses/minute and 4 pulses/minute supplies are expected to be especially high, and in anticipation of this, separate "reserve" outputs are provided at these rates and so staggered as not to coincide in time with the main supplies or the 1 pulse/minute and 2 pulses/minute supplies.

SPEED CONTROL.

The machine is driven by a 160-volt d.c. shunt motor, the speed of which is controlled very closely at 3,000 r.p.m. by means of a 50 c/s valve-maintained tuning-fork using the same method as that employed on telegraph signal generators². Common tuning-fork equipment is used for both the meter-pulse and message signal generators at a telex exchange.

MANUFACTURE AND INSTALLATION

The cam-shafts are driven through reduction worm gearing which is totally enclosed in a gear-box. The lower gears run in the oil sump and a pump is provided which distributes oil from the sump to the upper gears. Great care has been taken in the design and assembly of the gearbox to minimize back-lash, which would upset the phase relationship between shafts and hence possibly cause mis-gating. The gears are of robust construction and intended to give reliable operation throughout the life of the machine.

To achieve the desired performance, the greatest care has been necessary in the manufacture of the machine, particularly the cams and the cam-shaft couplings. In view, however, of the possible accumulation of manufacturing tolerances it was considered necessary to check,

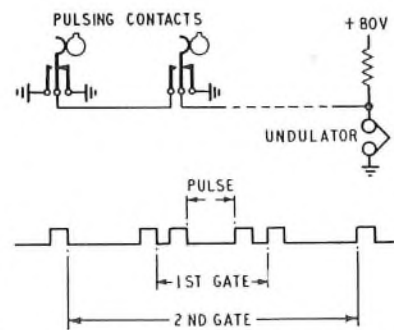


FIG. 4—TEST CIRCUIT AND TYPICAL RECORD

electrically, the gating with the machine running. For this purpose the +80-volt battery connexions were replaced by earth connexions and each output terminal was connected in turn to a single-pen recorder (a telegraph undulator was actually used) arranged to record the disconnexions during the travel of each lever-spring. The modulator record obtained from the typical double-gating of Fig. 3 is shown in Fig. 4. From such a record it is possible to deduce quite readily whether the pulses are central with respect to the gates, whether a pulse has been "clipped" by a gate and whether vestigial traces of unwanted pulses are present. This method of testing enabled the inspection of completed machines to be

carried out confidently with a minimum of effort.

The machine is designed to mount inside a glass-windowed dust-proof enclosure on a standard 2ft 9in. wide rack. The mounting shelf is on runners, which enable the machine to be pulled out on either side of the rack for maintenance attention. The various connexions to the machine are brought out on three 33-way plugs and cords. When in use the plugs are secured in their jacks by locking devices so as to prevent any accidental disconnexion of the pulse supplies. Two machines (main and reserve) are provided at each installation and are normally in use alternately, each machine being run for a week at a time.

C.M.I. Validation at Freiburg, West Germany, June 1959

U.D.C. 061.3:621.395.823

NEARLY fifty delegates representing ten European and two South American countries and Australia visited Freiburg in the Federal Republic of Germany during the week commencing 22 June 1959, in response to a joint invitation issued by the German Post Office, Railways and Electrical Industry. The British Post Office was represented by three delegates from the Engineering Department, two from the External Plant and Protection Branch and one from the Telephone Exchange Systems Development Branch

The Commission Mixte Internationale (C.M.I.), to give it its full title, has a membership which includes international organizations representing various industries in a manner similar to that in which the C.C.I.T.T. represents the telecommunications industry, i.e. railway, electricity generation and distribution and gas industries are all represented in addition to the C.C.I.T.T. The Commission is thus concerned with problems which affect any two or more of the participating organizations. Periodically the Commission organizes "Validations" which are mainly practical demonstrations of methods of dealing with these problems. No rules or regulations are formulated by the C.M.I.—these are left to the constituent organisations—but the "Validations" are obviously useful in demonstrating the problems and possible solutions and thus lead to a better understanding and enhanced co-operation between the parties.

In this instance the main object of the visit was to consider methods of overcoming interference troubles caused when single-phase a.c. railway and telecommunications systems are in close proximity and/or run parallel to each other.

Demonstrations were given of methods of measurement of the following items of interest: cable screening

factor; unbalance of exchange equipment; dial-pulse distortion under interference conditions; voltage difference between adjacent feeder-stations connected in parallel; reduction of harmonic induction by means of a resistor-capacitor circuit connected between contact wire and earth; equivalent disturbing voltages and currents of a 220 kV line. The program also included demonstrations of high-voltage protective devices for use on telephone lines, a van equipped for studies of corrosion problems, methods of prefabricated manhole construction, and a report on the hydro-electric storage and generating plant at Schluchseewerk.

This varied and interesting program was conducted in an extremely smooth and efficient manner, which succeeding hosts will find difficult to emulate. Thorough documentation of all the proceedings was also provided.

Many of the test results were in conformity with those obtained in the United Kingdom, but the conclusions to be drawn from the results would necessarily vary in different countries owing to detailed differences in design of telecommunications and traction equipment. The demonstrations and accompanying descriptions nevertheless formed a useful contribution to general knowledge on a subject which is becoming increasingly important as the electrification of railways proceeds in various countries.

As is well known, the British Transport Commission's present program of modernization includes extensive electrification of the railways using a single-phase supply at 25 kV, 50 c/s, and this will lead to induction problems which require careful analysis and investigation. After some further experience has been gained, it may become desirable for a similar "Validation" to be held in the United Kingdom.

D.W.R.C.

A Code Translator for Letter-Sorting Machines

J. D. ANDREWS, A.M.I.E.E.†

U.D.C. 681.188:681.178

In sorting mail using a letter-sorting machine, the operator must memorize up to 144 combinations of a 2-letter code required in the operation of the machine. A code translator is described which translates a 5-letter code, easily derived from the address, into the required 2-letter code.

INTRODUCTION

THE sorting of mail in Post Offices requires staff with considerable sorting knowledge as it is not uncommon for outgoing mail to the 1,700 or so post towns to be sorted into 100 or more groups and for incoming mail, which may be addressed to any one of more than 1,000 streets, to be sorted into a similar number of groups. In manual sorting an operator normally has access to 48 sorting boxes and at least two stages of sorting are necessary. With the advent of sorting machines^{1,2} the operator has access to all of the 100 or more groups; he must, therefore, have knowledge of all selections in order to fully exploit the machine.

The operator sorts the mail by memorizing up to 144 combinations of a 2-letter code and operating two keys for every address read, leaving the machine to transport the various items to the appropriate selection boxes.

The code translator to be described enables the knowledge required by the operator to be reduced; it translates an easily derived "extracted" code into the 2-letter code required for operation of the sorting machine.

When using such a code translator in conjunction with a sorting machine the operator is required to extract, according to a set rule, certain letters from the address and to type these letters serially on a typewriter-type keyboard. For the outward sorting process, as at present being performed at Southampton, a 5-letter code is extracted from the post town name by reading the first three letters and the last two letters, e.g. Bristol gives the code BRIOL. For inward sorting at a town such as Southampton the first two letters and the last two letters of the street name and the first letter of the type of thoroughfare would form a practicable 5-letter abbreviation. Thus, Byron Green Road would have the code BYENR and High Street would have the code HIGH S.

The translator can be arranged to identify these abbreviations and to associate them with any of the 100 or more outlets of the sorting machine by translating the abbreviations into the 2-letter code required by the machine. Except where more than one street or town gives the same 5-letter code or where the mail is not properly addressed, the mail can be fully sorted by using this extracted code. The translator is provided with means to identify shorter codes than the normal 5-letter codes in order to lessen the time spent typing frequently-occurring codes.

GENERAL DESCRIPTION

The functioning of the translator may be divided into two distinct processes. The first process is that of recording the signals which are received from the keyboard. Fig. 1 shows how the 5×26 matrix store may receive, from the counter, a signal down one of its columns to meet a signal, from the keyboard, along one of its 26 rows. The resulting current flows through a diode and a

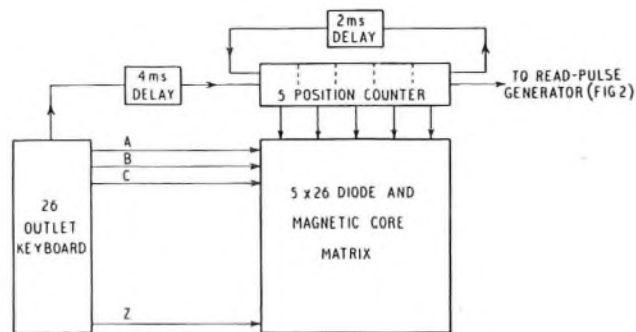


FIG. 1—BLOCK SCHEMATIC DIAGRAM SHOWING 5-LETTER CODE-STORAGE PROCESS

magnetic store at the appropriate one of the 130 cross-points to set the store in a certain magnetic state, thereby storing the code-letter. The counter is stepped to the next position 4 ms after this occurs, thus allowing the next code-letter to be stored in the next column. The translation is effected during the 2 ms delay which occurs when the counter is stepping from the fifth to the first position.

The second process in the translator is that of translating the signal which has been stored in the magnetic-core matrix. Fig. 2 shows the "read-pulse" generator which,

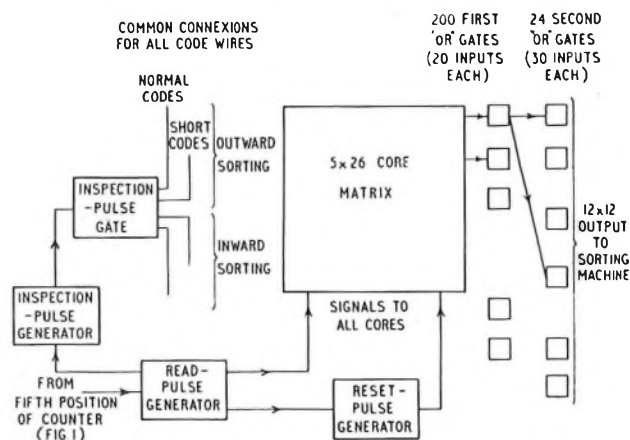


FIG. 2—BLOCK SCHEMATIC DIAGRAM SHOWING TRANSLATION CONTROL-ELEMENTS

while the counter is stepping from the fifth to the first position, switches all the cores in the matrix to the "set" condition simultaneously, at the same time triggering the "inspection-pulse" generator. The inspection pulse is passed by the inspection-pulse gate to some of the 4,000 code-wires. Of the 4,000 code-wires only the one bearing an inspection pulse and threading five "set" cores (i.e. the wire threading the marked code) is capable of pro-

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¹ COPPING, G. P. A Single-Operator Letter-Sorting Machine, Part I—Introduction and the Experimental Machine. *P.O.E.E.J.*, Vol. 51, p. 104, July 1958.

² LANGTON, H. J. A Single-Operator Letter-Sorting Machine, Part 2—The Production Machine and Future Development. *P.O.E.E.J.*, Vol. 51, p. 188, Oct. 1958.

ducing an output signal in the one "first OR gate" to which it is connected. This one of 200 possible output signals is wired to the appropriate pair of the 24 "second OR gates" which receive and store the signal in the form required by the sorting machine.

The reset-pulse generator is triggered at the end of the read pulse and it resets all cores in the matrix to the "reset" condition in readiness for the next code.

THE TRANSLATION FIELD

Magnetic Stores

The incoming extracted code is passed to a translation field containing 5×26 magnetic storage positions. These consist of small magnetic cores having a rectangular B/H or hysteresis loop (see Fig. 3). When a magnetic

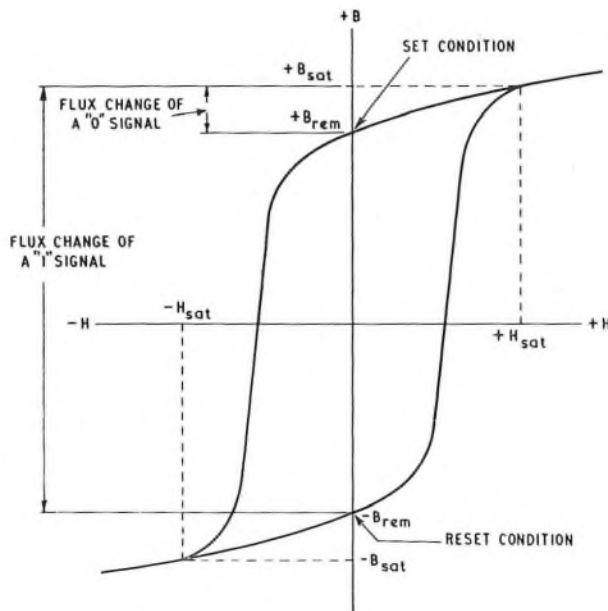


FIG. 3—TYPICAL B/H CHARACTERISTIC OF STORAGE CORES

field of $+H_{max}$ is applied to a core the flux density in the core becomes $+B_{max}$. If the field is then reduced to zero the flux density will fall to $+B_{rem}$ and remain there until a magnetizing field is again applied. Similarly, a field of $-H_{max}$ applied for a short time will cause the flux density to remain at $-B_{rem}$. The material is thus capable of remaining in one of two discrete states indefinitely and, in this article, these states are called the "set" and "reset" states.

It is possible to ascertain the state of the core by applying a "read pulse" so as to produce a magnetizing field in a known direction, and observing the value of flux change as indicated by the e.m.f. induced in a wire passing through the core. If the flux density changes from $-B_{rem}$ to $+B_{sat}$ then a large e.m.f. will be induced in a wire passing through the core (this signal is called a "1" signal in this article.) If the initial state had been $+B_{rem}$ then the induced e.m.f. would have been smaller ("0"). The actual voltage signals obtained from one-turn windings on the cores of the translation field during the read pulse are shown in Fig. 4. It will be seen that a 1 signal, which is of 0.6-volt amplitude, has a duration of $30 \mu s$. The 0 signal is smaller in amplitude and duration. By using an inspection pulse at a time when the 0 signal is very small, as is done in the translator described, a very high 1/0 signal ratio may be obtained.

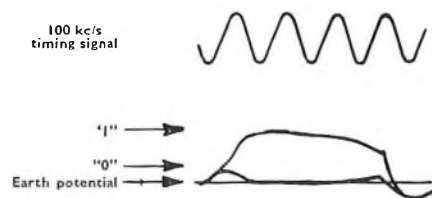


FIG. 4—VOLTAGE SIGNALS OBTAINED DURING READ-PULSE PERIOD

The cores are made of an alloy of 79 per cent nickel, 17 per cent iron and 4 per cent molybdenum and were developed at the Post Office Research Station. The alloy is made by a powder-metallurgy process and rolled to a tape having a thickness of 0.00125 in. This tape is slit to a width of 0.25 in. and formed into a "clock spring" type of core having inner and outer diameters of 0.8125 in. and 1.0625 in. respectively. The material has a saturation flux density of about 0.8 weber/metre² (8,000 gauss) and a ratio of B_{rem}/B_{sat} of about 0.8. The material requires a field of about 12 ampere-turns/metre (0.15 oersteds) to cause it to switch in $25 \mu s$, as required in this application, and this field corresponds to about 1 ampere-turn for this size of core.

The Translation

The 5×26 matrix of cores is capable of storing a 5-letter code, one code letter in each alphabet column of 26. Reading wires thread this matrix, there being one wire for each code to be identified; each such wire passes once through each of the five cores forming a code and terminates on a diode in the first set of OR gates which are arranged so as to produce the required one out of 144 outputs. These OR gates forward a signal only when they receive a signal above a certain value. Such signals can occur only during an inspection-pulse period and only from the wire threading marked cores. Thus, the required output translation may be obtained from any code combination.

The normal condition is for all the cores in the matrix to be in the reset condition. When a code is stored in the matrix the five cores forming that code are switched to the set condition. The method of reading the stored code is to drive, simultaneously, the whole matrix of cores to saturation in the direction of the set condition, by passing a current through the "read" wires which thread every core in the matrix. Cores which were in the reset condition will exhibit a flux density change of $B_{sat} + B_{rem}$ and will produce a 1 output signal. Cores which were in the set condition will exhibit a much smaller flux density change of $B_{sat} - B_{rem}$ and will produce an 0 output signal. These signals are shown in Fig. 3.

The wanted signal, i.e. the signal to be detected, is that resulting from the addition of the 0 signals produced by the five cores storing the input, extracted, code. The unwanted signal most nearly like the wanted signal is that due to the addition of the 0 signals produced by four cores together with a 1 signal from a core not previously set.

To obtain a better wanted/unwanted signal ratio and to obtain a wanted signal of opposite polarity to the unwanted ones a form of neutralization is used. The method used is to apply a neutralizing signal to all read wires such as to cancel the unwanted signal most like the wanted one. To do this a negative signal of (four 0 + 1) is required. The signal to be detected then becomes five 0 - (four 0 + 1) = 0 - 1, and is a negative quantity since the 1 signal has a greater amplitude than

the 0 signal; the signal most nearly like the wanted one has been made zero and all others are positive.

It should now be made clear that the polarity of the signals from the cores as used in the translator being described are, for circuit design reasons, the reverse of those just described, i.e. the resultant signal from the wanted-code wire is positive and all others are zero or negative. This was not introduced at the start in order to make the explanation initially more simple. The six possible signals, each dependent on the states of five cores, which may appear on a code wire are shown in Fig. 5. This shows that the $10 \mu\text{s}$ inspection pulse is

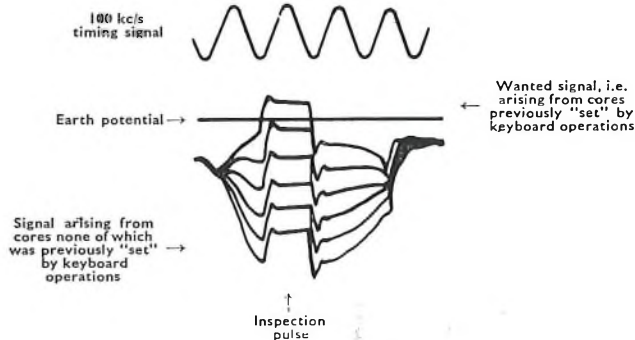


FIG. 5—THE SIX POSSIBLE SIGNALS THAT MAY BE APPLIED TO THE FIRST "OR" GATES BY A WIRE DURING THE READ-PULSE PERIOD

applied to all wires, but only on the wanted-code wire can the resultant signal rise above earth potential to cause an output signal from the first OR gates.

Each of the wires which thread the core matrix (one wire for each code) is connected at one end to a common terminal to which is applied the neutralizing signal (four 0 + 1) and the inspection pulse.

The wires then pass once through one core in each of the five columns of 26 cores. The translator is required to accept a maximum of 4,000 code wires but the codes are not evenly distributed over the alphabet and, for example, as many as 500 wires are expected to pass through the B core in column 1 when the translator is fully wired. In order to ease the considerable amount of work involved in wiring the translation matrix a copper wire of 36 S.W.G. and covered with a coloured, solderable, enamel has been chosen. The different colours available allow easy identification of the wires and the fine gauge allows the wires to pass freely through the core aperture, which has an area of 0.5 in.^2 . If completely filled with wires, this aperture could contain 7,000 wires, but 500 is expected to be about the practicable limit to the number of wires through one core. Further steps taken to ease the work of wiring include the painting of the background to the translation matrix with a matt white paint to show the fine wires more clearly, and the provision of a p.t.f.e.* covering (p.t.f.e. is a material with a very low coefficient of friction) on all the surfaces over which a wire passes.

The other ends of these code wires are each connected to a diode. These diodes are grouped to form OR gates which give an output signal only when the wanted input signal is received on one or more of the input wires. The wanted signal is actually positive in polarity and this is capable of passing through the OR gate and switching "off" a normally "on" transistor amplifier which is associated with each gate. There are about 200 of these

* p.t.f.e.—polytetrafluoroethylene

gate-amplifiers in the translator and they thus provide 200 different outputs. Each gate may be equipped with a maximum of 20 diodes to cater for a maximum of 4,000 different codes. The 200 gate outputs are intended to be condensed to 144, which are all that are required by the sorting machines into which the translator will work. The condensation (by connecting some of the 200 output signals in parallel) will enable more than 20 codes to be associated with some outlets if required.

The output from the translator is in the form of a 12×12 array such that two signals are necessary—one from each group of 12—to give the required 144 different outputs. This condensation from 200 to two out of 24 is obtained via a second set of OR gates (this time passing negative signals) which are connected to pulse generators which strike cold-cathode triode stores.

DESCRIPTION OF CIRCUITS

The foregoing section described how magnetic cores are used to give a unique characteristic, i.e. a positive e.m.f., which is detected by OR gates employing a total of about 5,000 germanium point-contact diodes.

All signal amplification is performed by transistors, the choice of the type used being almost always dependent upon the current-gain characteristic. Only in the inspection-gate circuit is thermal dissipation the predominant requirement.

Cold-cathode triodes are used to store the output of the translator because they can provide both visual indications as well as the amplitude of signal output required by the sorting machine, which itself employs cold-cathode input storage.

Writing a Code in the Translation Field

A counter is required to distribute the five sequential signals received from the keyboard into the five columns of the core matrix. This is achieved by allowing only one counter circuit to conduct at a time, thus allowing any one of the 26 keyboard-outlets to pass a current through only one of the 130 diodes in a 5×26 diode matrix to a column controlled by the counter. This is shown in Fig. 6. Associated with each of the 130 diodes is a winding on a core and any one of the 26 alphabetical characters may thus be set in each of the five columns in turn.

The keys operate micro-switches each of which can apply a charged capacitor to one of the 26 outlets from the keyboard. A current flowing in any one of the 26 outlets is made to flow through a common 10-ohm

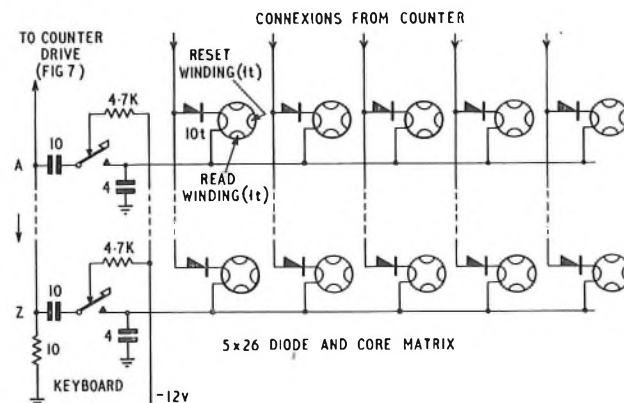


FIG. 6—THE KEYBOARD AND CORE MATRIX

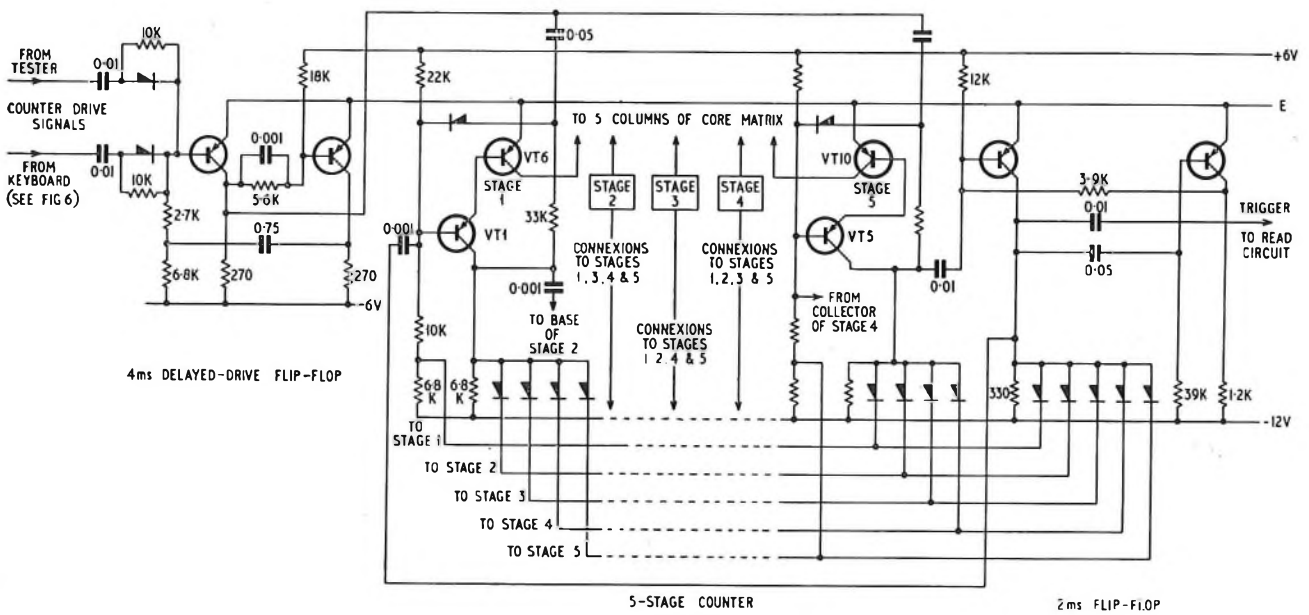


FIG. 7.—THE COUNTER

resistor; the voltage thus produced across this resistor is applied to the counter (Fig. 7) where, after a 4 ms delay, it causes the counter to step to the next position. Simple capacitive smoothing is employed to eliminate the effects of contact bounce in the micro-switches.

The counter is a form of trigger having five stages of equal rank and each able to hold the counter indefinitely in one of the five positions. A selective triggering circuit allows the conducting stage, which was "bottomed," to be turned off. This stage, in shutting down, primes the following stage, thus forming a five-way ring counter. The ring is broken by a sixth stage which is a 2 ms flip-flop, and which holds the other stages inoperative for 2 ms after the fifth stage has been turned off. The translation is effected during this 2 ms interval while none of the five stages is conducting.

The emitter current of each of the five (VT1-VT5) counter stages flows through the emitter-base circuit of an amplifying transistor (VT6-VT10) the collector of which is connected to the appropriate one of the five core columns. Thus, when a counter stage is conducting, the emitter current of about 10 mA causes the amplifying transistor to be capable of passing a collector current of not less than 100 mA.

In order to set the cores within a few tens of micro-seconds a magnetizing field of about 12 ampere-turns/metre (0.15 oersted) is required; this corresponds to about 1 ampere-turn and, together with the available 100 mA magnetizing current, fixes the number of turns required on the "write" winding at ten.

Translating Pulse Generators

When the fifth code letter has been registered in the matrix the counter is stepped to the sixth position. The translation and resetting occur during the 2 ms for which this sixth position is held. The read-pulse generator is triggered by the positive-going leading edge of the 2 ms signal which is applied to the emitter of the read-pulse generator from the sixth position of the counter.

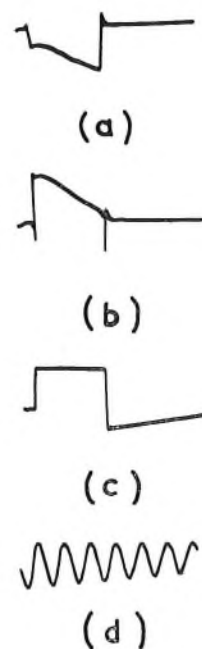
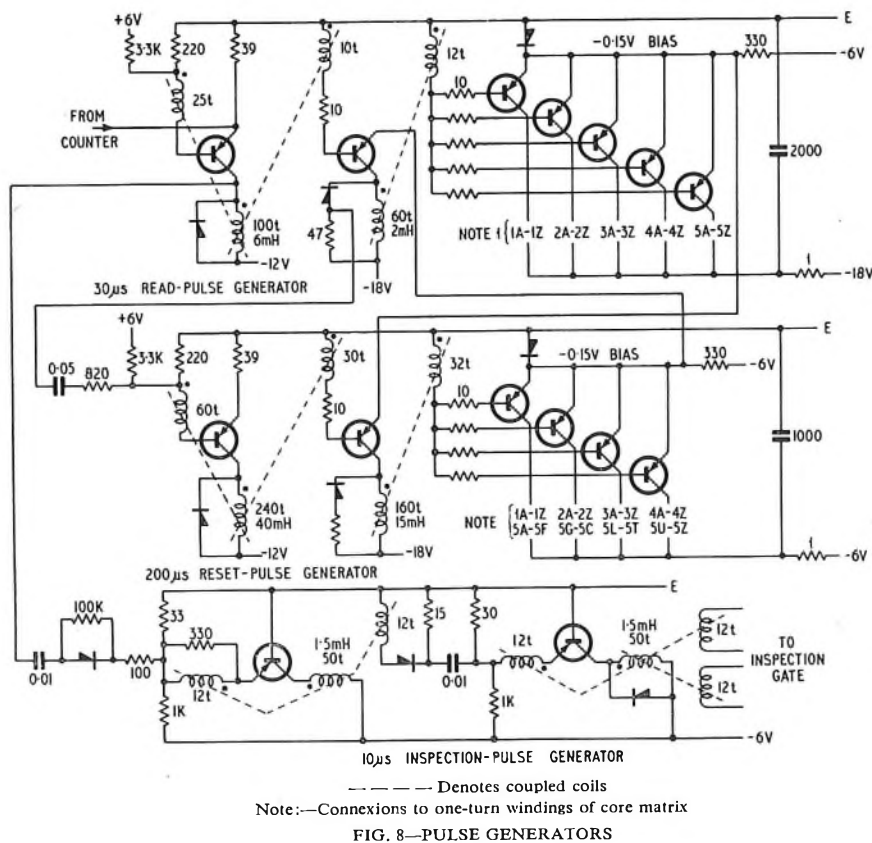
The read-pulse generator (Fig. 8) is a 30 μ s mono-stable blocking oscillator the transistor of which is

normally held "off" by a base potential arranged to be at least 0.1 volt positive with respect to the emitter when the maximum expected collector-base leakage current is flowing. The positive-going triggering signal from the counter makes the base potential more negative than that of the emitter. When this occurs collector current will flow and the e.m.f. induced in the blocking-oscillator transformer will cause cumulative switch-on in the usual way. The transistor will then go to the "bottomed" state with 3 volts induced in the base circuit and less than 0.25 volt between emitter and collector, the remainder of the supply voltage appearing initially across the inductor in the collector circuit. The current in the collector circuit will then rise linearly at a rate determined by the e.m.f. e across the inductor and the inductance L of this inductor, i.e. at a rate of e/L amp/sec. This increasing current must also flow in the 39-ohm emitter resistor causing a steadily increasing potential drop across the resistor. When this p.d., which is in opposition to the e.m.f. induced in the base circuit, has risen to such a level that the base current is no longer sufficient to maintain the rising collector current the transistor leaves the "bottomed" state and regenerative switch-off occurs.

The oscillogram in Fig. 9(a) shows the linearly increasing emitter current as indicated by the increasing potential drop across the 39-ohm emitter resistor. Fig. 9(b) shows the base current which is decreasing due to the increasing p.d. across the 39-ohm emitter resistor. Fig. 9(c) shows the nearly-square voltage waveform which appears at the collector.

The main characteristic required of transistors for use in this type of circuit is that they shall have a common-emitter current gain of more than about 10 at the peak current to be passed. Because the transistors are either in the "bottomed" or "off" state and the transit times are very short, the dissipation in the transistors is low and is not normally an important factor governing the choice of type of transistor.

The conduction time of this form of pulse generator is largely independent of transistor characteristics and of external load variation if the maximum value of the linearly-rising charging current of the inductor in the



(a) Signal Appearing Across 39-ohm Emitter Load
 (b) Signal Appearing Across 220-ohm Base Resistor
 (c) Signal Appearing Across Collector Load
 (d) 10 kc/s Timing Signal

FIG. 9—VOLTAGE WAVEFORMS IN THE RESET-PULSE GENERATOR

collector circuit is large compared with the load current, and if the p.d. that appears across the emitter resistor just before switch-off is a large proportion of the e.m.f. induced in the base circuit.

The rise and fall times of the pulse are very short (less than $0.5 \mu\text{s}$ with transistors having a cut-off frequency (f_c) of about 500 kc/s). At switch-on this may be attributed to the high initial base-current when the collector current is very low. At switch-off it is largely due to the fact that switch-off occurs because the potential across the collector load is falling, i.e. the transistor has left the "bottomed" state in which hole storage may cause a considerable delay. The holes which do remain are rapidly cleared by the reversed e.m.f. in the low-impedance base circuit.

The $30 \mu\text{s}$ signal from the pulse generator is amplified by a P.O. No. 4 type transistor in a transformer-coupled amplifier stage which provides, in the 12-turn winding, a low-impedance source having an e.m.f. of at least 3 volts to drive five OC16 type power transistors in parallel. Assuming the base potential of the power transistors falls to 1.5 volts below earth potential when the transistors are each conducting the maximum required current of about 1.5 amps, then the remaining 1.5 volts will cause a current of 150 mA in each 10-ohm base circuit. This is sufficient to ensure that the power transistors remain "bottomed" while the cores are switching. The large currents required by this circuit are obtained from a capacitor store which is isolated from the main -18-volt supply by a 1-ohm resistor. The power transistors are held in the "off" condition by the forward voltage-drop of the germanium power diode (GEX 541 type) which provides a +0.15-volt base-emitter bias voltage with only a 10-ohm base-circuit resistance.

A reset-pulse generator is triggered by the negative-going signal that occurs at the end of the read pulse due to the discharge current flowing through the 47-ohm resistor from the read-pulse-amplifier inductor. This reset-pulse generator is similar to the read-pulse generator. The difference in pulse-length, $200 \mu\text{s}$ for the reset pulse compared with the $30 \mu\text{s}$ of the read pulse, is obtained by increasing the collector transformer inductance by the ratio 200/30, thus increasing by 200/30 the time taken before the current reaches switch-off value.

An inspection pulse of $10 \mu\text{s}$ duration and starting $10 \mu\text{s}$ after the start of the read pulse is produced by means of two pulse generators, one producing the inspection pulse, the other producing the delay. These employ common-base circuits but are designed on the same principles as the read-pulse and reset-pulse generators with the same object of making the pulse length substantially independent of transistor characteristics. The diodes in the trigger leads to these two stages prevent re-triggering of the preceding stage at switch-off.

The inspection-gate circuit which employs the inspection pulse is not shown but the operation is as follows. The $10 \mu\text{s}$ pulse from the second generator is used to switch off a transistor which is holding at a potential of -1 volt the bus-bar which is the common-point connexion for all code wires. The bus-bar is then held at -0.1 volt for this $10 \mu\text{s}$ period by a second transistor. These two transistors are duplicated in a second inspection-pulse circuit provided for codes shorter than the normal 5-letter ones. One or other of these two circuits is over-ridden by one of two more transistors under the control of a short-code pulse generator which is triggered by a special key on the keyboard. One other

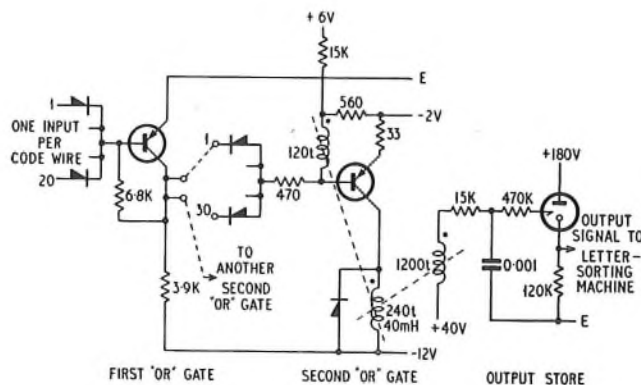


FIG. 10—FIRST "OR" GATE AND AMPLIFIER

transistor is provided in the inspection-gate circuit to permanently hold-off a whole group of wires switched to it by a manual key used for switching from one type of sorting to another, e.g. inward or outward. This is necessary in order to avoid confusion between codes used for inward sorting and codes used for outward sorting.

Translated-Signal Detectors and Stores

As indicated earlier the 4,000 code wires are connected so that each wire can energize one out of 200 outlets. This is achieved by using germanium point-contact diode OR gates each having a transistor amplifier. The first OR gates consist of panels carrying nine diodes followed by a transistor amplifier; to each of these panels may be connected another panel which carries 11 more diodes to enlarge the maximum number of inputs from nine to 20. The translator can accommodate just over 200 of these 20-input OR gates and as these represent a large proportion of the cost and bulk of the equipment, they have been constructed in the compact, economical form shown in Fig. 10; the circuit diagram of the first OR gates is shown in Fig. 11.



----- Denotes coupled coils
200 First OR Gates, 24 Second OR Gates and
24 Output Stores are employed in the translator
FIG. 11—SIGNAL GATES

The amplifiers in the first OR gates are common-emitter stages which are normally fully-conducting but held from "bottoming" because the base current is supplied, via the 6,800-ohm resistor, from the collector, thus ensuring that the collector is negative with respect to the base. This is done in order to allow the wanted signal passing through the first OR gates to achieve rapid switch-off of the transistor amplifier, which could not be achieved if it had been "bottomed," i.e. saturated with a larger input current than was required.

In order to switch off the transistor amplifier it is necessary to raise the base to a potential more positive than approximately -0.1 volt relative to the earthed emitter. To do this without collector current flowing entails supplying a current of about 1 mA through an input diode and the 6,800-ohm and 3,900-ohm resistors, in series to the -12 -volt supply. Added to this current must be another which is the sum of the reverse currents of the other 19 diodes; this may be as high as 0.3 mA at a temperature of 45°C and with a reverse e.m.f. of 3 volts. In order to pass this forward current of 1.3 mA the germanium point-contact diode used (type CV 448) may show a potential drop as high as 0.6 volt. This fixes the required input signal and is the reason for choosing a switching rate for the cores that results in an e.m.f. of 0.6 volts per turn.

The information required by the letter-sorting machine is in the form of one signal from each of two rows of 12 possible positions, thus catering for the required 12^2 combinations. The second OR gates condense the one-out-of-200 code into the two-out-of- 12×12 code. There are two outputs taken from each first OR gate to appropriate second OR gates to provide the required output signals.

The letter-sorting machine employs cold-cathode storage and this was thus a natural choice for the output stores of the translator. The low-amplitude short-duration pulse from the amplifier following the first OR gate is used to trigger the pulse generator at the output of the second OR gates. The pulse generator provides a $300 \mu\text{s}$, 50-volt pulse, which is added to a permanent 40-volt bias to fire a cold-cathode triode store. The emitters of the transistors in these pulse generators are held at a potential of -2 volts when not conducting and the signal from an amplifier must fall below this value before it can trigger the circuit. The 470-ohm series resistors are provided in the triggering input to ensure that an amplifier output can trigger two circuits having different triggering characteristics.

The simple low-pass filter coupling the pulse generator to the triode is to prevent switching transients in the triode circuit from triggering the pulse generator. A second OR gate is shown in Fig. 11 and 12.

Code-Generating Test Circuit

To facilitate testing of the circuit a repetitive code-sender is fitted. The circuit is not shown but it consists of a 100 c/s multivibrator driving a ferrite-core and transistor shift-register serving as a five-way distributor. An output signal appears on each of the five emitter outputs in turn and each may be routed to any one of the 26 alphabet-connexions from the keyboard. Five signals also appear at a common 33-ohm collector load and a connexion is made from this point to the 4 ms counter drive-circuit (see Fig. 7). The distributor thus performs the two main functions normally performed by the keyboard.

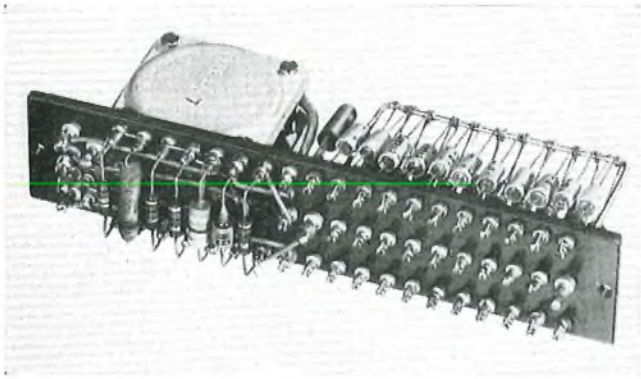


FIG. 12—SECOND "OR" GATE AND MONOSTABLE BLOCKING OSCILLATOR

As a refinement the testing circuit may also be made to check that the translation is correct before resetting the 5-way distributor for a new cycle. This is effected by switching the inputs of two cold-cathode triodes so that they are "struck" by the required translation. Diode gates are used to check that both of these triodes are struck by receipt of the correct translation and that they are extinguished by the test circuit before a fresh cycle is started.

THE FIELD TRIAL

The translator has been in use with the single-operator letter-sorting machine at Southampton since March 1958. This field trial is proving valuable for two reasons.

The first reason concerns the reliability of the equipment because a translator such as the one described will be essential to control the printed code-marking of envelopes in automatic sorting techniques which may be adopted in the future. The field trial is showing that a translator using similar principles and components can be expected to be very reliable. During the field trial it

has been in operation for about 20 hours per week and the only fault in the equipment, which includes about 300 transistors and 5,000 diodes, has been due to one poorly-soldered joint.

The second reason is that, except for the possible use by the public of a code which would specify the town and street in a code of about six characters, the only method of obtaining the information which is required by the translator appears to be by the use of code extraction from the address. Until such a scheme has been proved practicable, and the field trial is providing encouraging results, the advances in automatic sorting techniques must be held up.

Other advantages which accrue from using a translator which receives a code extracted from the address instead of direct control of the sorting machine by an operator are:

(a) staff not acquainted with the sorting scheme may be used, the only abilities required being reading and typing,

(b) the sorting scheme may be altered without the need for teaching the operators the new scheme, and

(c) the sorting errors are reduced since, of the 26^6 (about 12,000,000) possible 5-letter codes, only about 2,000 are used and the chances are small of a keying error producing a wrong, but acceptable, code.

These advantages are, for the sorting methods at present in use, outweighed by the disadvantage of a reduced operating speed, comparable figures being 40 and 50 items per minute for the two methods. Because of this it appears that the translator is unlikely to replace direct operator control except where code marks are to be put on the envelope.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the work of colleagues in Research Branch who were associated with the development.

Book Review

"Elementary Engineering Science." A. Morley, O.B.E., D.Sc., Hon. M.I.Mech.E., and E. Hughes, D.Sc.(Eng.), Ph.D., M.I.E.E. Longmans, Green & Co. 381 + xvi pp. 182 ill. 11s. 6d.

This is the fourth edition of a well proved textbook first published in 1937. It has now been thoroughly revised and is soundly based on m.k.s. units. It is undoubtedly a very good textbook for students taking the National Certificate Course S.1. or the 1st year of the new City and Guilds course for the Telecommunications Technician's Certificate, which will now be the starting point of the normal course of study of the majority of Youths-in-Training and other Post Office engineering students.

The book is simple and lucid enough for the beginner and the student who is not likely to progress beyond elementary studies, but there are two features which especially commend it to the student who wishes to use the book as an introduction to more advanced studies. Experience of senior students and their difficulties indicates that elementary knowledge of general science and particularly of mechanics and heat is too often scrappy and insecurely based. This is usually due to insufficient personal experience of fundamental

phenomena and insufficient practice in working out numerical examples based on applications of these phenomena.

In this book, as in previous editions, emphasis is placed on the need for the student to see experimental demonstrations of the fundamental phenomena, or, better still, to carry out experiments himself in the laboratory. There are ample descriptions of such experiments and of simple apparatus needed to perform them, which should encourage both teacher and student actually to carry out as many experiments as possible in the time available. In addition, there is a copious selection of numerical examples for the student to work for himself. As a result, the student who works through this book conscientiously and carefully, can hardly fail to acquire a sound elementary knowledge which will serve him in good stead when he comes to more advanced studies.

The type and general set-up of the book make it attractive and easy to read and the summary at the end of each chapter will be found most useful, not only for revision but for reference in finding quickly the scope of each chapter.

The book can be thoroughly recommended. It has been very well edited and no errors were noticed in reading it for the purpose of this review.

F.C.M.

First International Conference on Information Processing at Paris, June 1959

U.D.C. 681.142

THE first international conference on the use of computers for information processing was held at U.N.E.S.C.O. House, Paris, from 15th to 20th June, 1959. The conference was convened by the U.N.E.S.C.O. Department of Natural Sciences at the request, initially, of the American National Joint Computer Committee, and was sponsored by corresponding bodies in France, Germany, Italy, Japan, U.S.S.R. and the United Kingdom. The United Kingdom body was "The British Conference on Automation and Computation," a standing body which, among other members, includes the major engineering institutions and the British Computer Society.

There were 1,772 participants at the Paris conference from 37 countries and 13 international organizations. The big delegations came from the following countries:—

France	....	....	....	....	479
U.S.A.	....	....	....	....	408
Federal Republic of Germany	....	....	....	....	217
United Kingdom	....	....	....	....	164
Sweden	....	....	....	....	87
Italy	....	....	....	....	83
Netherlands	....	....	....	....	79
U.S.S.R.	....	....	....	....	38
Belgium	....	....	....	....	34

The remaining 28 countries represented accounted for only 163 participants in all.

Unlike international telecommunications conferences there were no formal government delegations and each participant attended as an individual. Two members of the Post Office Engineering Department attended on behalf of the Treasury Technical Support Unit and the Engineering Organization and Efficiency Branch (Computer Group).

Sixty papers were presented and discussed in plenary sessions and a further 67 lectures were given in the course of 12 symposia. During the afternoons as many as three symposia and plenary sessions were in progress simultaneously.

The major topics discussed at the conference were:

- (a) numerical analysis,
- (b) linear programming,
- (c) automatic programming,
- (d) machine design,
- (e) information storage and retrieval,
- (f) pattern recognition,
- (g) machine translation of languages, and
- (h) computer components.

The papers on automatic programming reviewed progress in methods for relieving human programmers of much of the labour in preparing computer programs. In this way also much of the specialized skill required is no longer necessary. There was evidence of a move towards the adoption of a universal set of symbols for the description of programs in such a way that they could be subsequently interpreted in different computers.

The discussion on machine design centred largely around the need for very fast and powerful machines for

scientific work, using pulses of a few millimicroseconds duration and with operation times of 2 or 3 tenths of a microsecond, and also the application of time-division multiplex principles to allow such machines to be used for several jobs simultaneously. The latter feature would allow a computer to be engaged on a low priority "base load" problem, but be able to deal with urgent problems as they arose, and to be available for engineering testing and program development.

When considering information storage and retrieval the need was foreseen for very large storage systems. It was forecast that capacities up to 10^{10} bits, access times of less than a microsecond and read-out rates of 10^7 bits per second would become available. The use of cryogenic methods using super-conductors at the temperature of liquid helium and of very thin magnetic film would be favoured techniques for future use. Attention was drawn to the problems of classification of data to be sorted and this aspect presents considerable difficulties.

A number of experimental techniques for reading printed characters were described, which attempt to circumvent the difficulties experienced in straightforward scanning methods due, for example, to deformation, tilting and dirt on the characters. The recognition of handwritten characters and also of speech were considered to be so difficult that the reading device will need to be able to improve its performance by automatically adjusting its own programme in the light of its record of successes and failures.

It was evident that there was a great deal of work being done by many people, especially in the U.S.A. and U.S.S.R., on the use of computers for translation of technical articles from foreign languages. This work although clearly in its infancy has nevertheless progressed far enough for some of the over-simplified first approaches to have been discarded. Statistical studies of grammar and syntax are in progress and there is a lively appreciation of many of the difficulties ahead.

Apart from the considerable interest in cryogenic techniques and thin magnetic films as components in future computer equipment, reference was made to experiments using parametrons, i.e. storage or switching devices using resonant circuits with variable-parameter components. A slow-speed parametron is already in use in a commercial Japanese computer but the possibility exists of using them at frequencies of several thousand megacycles per second. For the distant future, reference was made to the experimental work relating to the automatic construction of micro-miniaturized components and circuits, e.g. by building up shaped layers of insulator and semi-conductor on molybdenum film. This offers the astounding possibility of producing switching circuits with component packing density of the order of 10^{11} per cubic inch. Such a density, although far more compact than is necessary for the design of any computer at present conceived, might prove useful for constructing extensive networks intended to simulate the human brain.

J.W.F.

F.J.M.L.

Experimental Equipment for Measuring Group Delay in the Frequency Band 3.8–4.2 Gc/s

R. J. TURNER, B.Sc.(Eng.), A.M.I.E.E.†

U.D.C. 621.317.772.029.64:621.396.65

Equipment is described which measures group delays of up to 50 ns with an accuracy of ± 0.2 ns in the frequency range 3.8–4.2 Gc/s. A frequency-modulated Nyquist method is used with a modulation frequency of 1 Mc/s. The equipment uses a heterodyne method with an intermediate frequency of 70 Mc/s, and enables a point-by-point determination of a group-delay/frequency characteristic to be made.

INTRODUCTION

MICROWAVE radio links are of increasing importance in the transmission of multi-channel telephony and television. In countries where large distances have to be covered or where the terrain is difficult the microwave link may show definite advantages over coaxial-cable systems even when a band-width of only a few megacycles per second is being employed. In densely populated countries, however, it is not difficult to install and maintain coaxial-cable systems, even with close spacing of repeater stations. To show advantages under such conditions a single microwave link must be capable of carrying large blocks of traffic and links are being planned which will carry up to six broad-band channels each accommodating a 600-channel telephony system or a television signal. In order to simplify the problem of filtering the broadband channels of such a system it has been suggested that the polarization of three of the channels should differ from that of the remaining three. The problem still remains of devising broadband waveguide channel filters (branching filters) to separate the three channels having the same polarization.

These filters, and indeed the whole of the system, must satisfy a stringent phase/frequency specification. Microwave radio links commonly employ frequency modulation because at these frequencies it is difficult to obtain amplitude modulators and amplifiers that have sufficient amplitude linearity. If a frequency-modulated wave is passed through a network which has a non-linear phase/frequency characteristic then the phase change introduced by the network is a function of the frequency of the signal; since frequency is proportional to the rate of change of phase, frequency variations additional to those already present in the signal are introduced and the instantaneous frequency at the output of the network is no longer a faithful reproduction of the input signal. When the resulting signal is demodulated it is found to suffer from non-linear distortion, i.e. harmonic and intermodulation distortion and, in a multi-channel system, inter-channel crosstalk results. This effect is one of the limiting factors in the design of microwave links and it must be closely controlled. For this purpose it is convenient to measure the group delay of the network, which is the slope of the phase/frequency characteristic; constancy of group delay then indicates the absence of phase distortion such as would give rise to the unwanted effect noted above.

Microwave radio links use an intermediate frequency of 60 or 70 Mc/s at both the transmitter and receiver at which modulation and demodulation is effected. Equipment has been described¹ for measuring the group-delay characteristics of the intermediate frequency equipment or of a complete system between points operating at intermediate frequency. In the development of the waveguide part of the link, particularly the branching filters for separating the broadband channels, the constancy of the group delay of individual parts of the equipment must be carefully controlled. For this purpose accurate group-delay measuring equipment is required operating in the band 3.8–4.2 Gc/s.

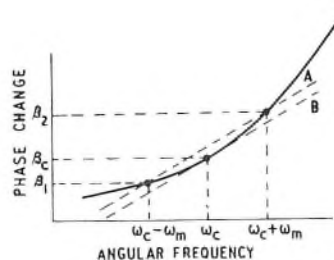
MEASUREMENT OF GROUP DELAY

The method of measuring group delay commonly employed is due to Nyquist. A carrier wave is amplitude-modulated or frequency-modulated with a lower-frequency signal and passed through the item under test. The output is demodulated and the phase of the resulting low-frequency signal is compared with that of the original. The phase change of the modulating frequency divided by its angular frequency is equal to the group delay of the network under test. If the carrier is frequency-modulated the modulation index must be less than one; the higher-order sidebands in the modulated wave are then negligible and the wave may be assumed to consist of the carrier and the first upper and lower side frequencies only. If ω_c is the angular frequency of the carrier wave and ω_m the angular frequency of the modulating signal, then the three frequencies present in the amplitude-modulated or frequency-modulated wave are $\omega_c, \omega_c + \omega_m$ and $\omega_c - \omega_m$.

The group delay of a network at frequency ω is defined as the value of the slope of the phase/frequency characteristic at that frequency. This may be written

$$\tau = \frac{d\beta}{d\omega}$$

It will be seen (Fig. 1) that the Nyquist method does not give the theoretical value of group delay but measures the slope of the line through points on the phase/frequency characteristic at $\omega_c + \omega_m$ and $\omega_c - \omega_m$ (see



Curve A—Measured group delay, given by $\frac{\beta_2 - \beta_1}{2\omega_m}$

Curve B—True group delay given by $\frac{d\beta}{d\omega}$ at ω_c

FIG. 1—MEASUREMENT OF GROUP DELAY USING A MODULATED SIGNAL

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¹ WHYTE, J. S. An Instrument for the Measurement and Display of V.H.F. Network Characteristics. *P.O.E.E.J.*, Vol. 50, p. 81, July 1955.

Fig. 1). If β_1 and β_2 are the phase changes through the network under test at these frequencies then the measured value of group delay is given by

$$\tau_m = \frac{\beta_2 - \beta_1}{2\omega_m}$$

The method can give erroneous results if the phase is changing rapidly over the measuring interval (see Fig. 2);

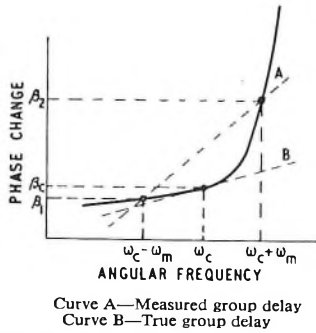


FIG. 2—SYSTEMATIC ERROR WHEN GROUP DELAY IS INCREASING RAPIDLY

this error may be termed the systematic error since it is due to the system of measurement. The systematic error may be reduced by decreasing the value of ω_m ; the direct measurement accuracy, that is the accuracy with which $(\beta_2 - \beta_1)/2$ is measured, must be correspondingly increased for a given accuracy of group-delay measurement. It follows that the value of the modulation frequency must be a compromise between the conflicting requirements of high direct measurement accuracy and high systematic accuracy. A frequency of 1 Mc/s is adopted in the equipment to be described; the phase change must be measured to an accuracy of $\pm 0.036^\circ$ to give an accuracy of group-delay measurement of ± 0.1 ns (nanosecond = 10^{-9} second).

MEASUREMENT OF PHASE CHANGE

To obtain high accuracy of measurement of group delay it is thus necessary to measure accurately the phase change at the modulation frequency of 1 Mc/s. Many methods of measuring phase are available. One of the most convenient uses a circuit which is essentially the same as the phase discriminator used in a frequency-modulation receiver (Fig. 3). Suppose the two signals of

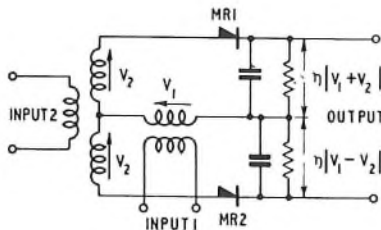
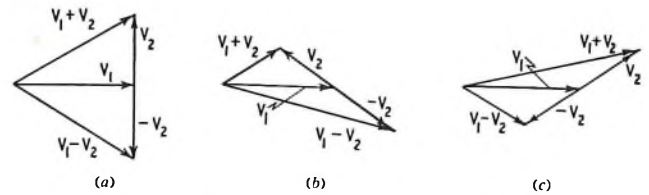


FIG. 3—BALANCED MODULATOR PHASE COMPARATOR

the same frequency whose phases are to be compared are connected to INPUT 1 and INPUT 2. The voltages applied to the rectifiers MR1 and MR2 are the vector sum and the vector difference, respectively, of V_1 and



The output voltage from the comparator is proportional to $|V_1 + V_2| - |V_1 - V_2|$

FIG. 4—PRINCIPLE OF PHASE COMPARATOR

V_2 . The d.c. outputs from MR1 and MR2 are then proportional to the modulus of the vector sum and difference, respectively, and the d.c. output of the comparator is $\eta |V_1 + V_2| - \eta |V_1 - V_2|$ where η is the diode efficiency. From Fig. 4 (a) it will be seen that when voltage V_2 leads V_1 by 90° the output voltage is zero; if V_2 leads by more than 90° the output is negative (Fig. 4 (b)) and if it leads by less than 90° the output is positive (Fig. 4 (c)). For small variations of phase from the null conditions the output is proportional to the phase angle.

The variation of the phase-comparator output with the level of the signal from the network under test must be as small as possible. If germanium rectifiers are used in the circuit they must be specially selected to give a minimum output-level variation over a range of input levels; a circuit using thermionic diodes (see Fig. 5) has been found to

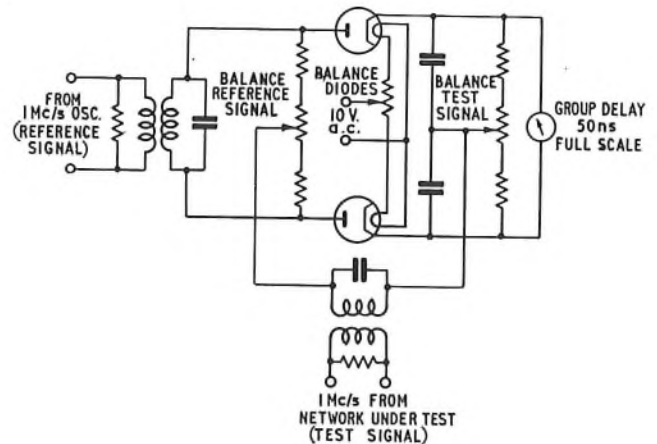


FIG. 5—PHASE COMPARATOR USING THERMIONIC DIODES

be preferable. In the initial line-up of the comparator the test signal alone is applied to the circuit and the variation of the reading for a 20 db variation in the test-signal level is reduced to less than 1 ns by a combination of the balance-test-signal control and the diode-balance control, which varies differentially the heater supply voltage to the diodes. The circuit is then balanced with the reference signal alone applied by means of the balance-reference-signal control. The dependence of the output reading on the level of the test signal is found to be reduced if the test signal is made larger than the reference signal. Thus, in the circuit shown the values are 16 volts and 8 volts for the test and reference signals, respectively, and a 2 db change in the test-signal level gives a change in the output reading equivalent to 0.75 ns. A sensitivity of at least $10 \mu\text{A}$ per nanosecond is obtainable, i.e. $10 \mu\text{A}$ for 0.36° phase change at 1 Mc/s.

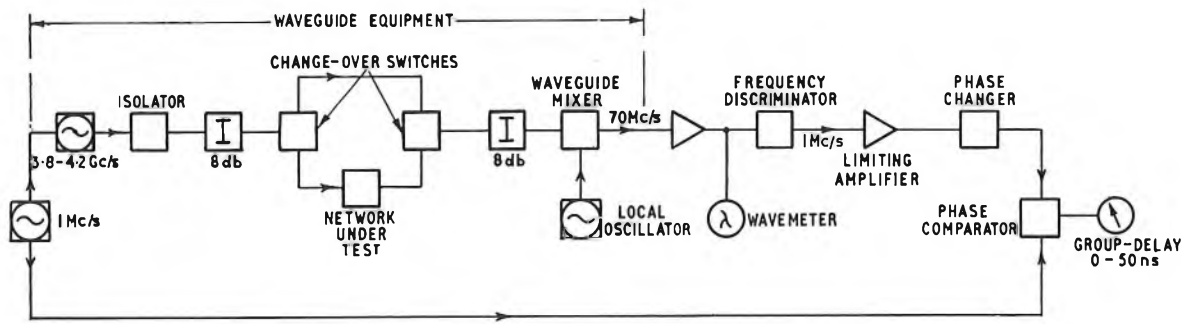


FIG. 6—BLOCK SCHEMATIC DIAGRAM OF GROUP-DELAY MEASURING SET

EQUIPMENT DETAILS

The equipment (see Fig. 6) works on a heterodyne principle with an intermediate frequency of 70 Mc/s. In order to reduce the variation of level presented to the phase comparator an amplifier with automatic gain control is used at 70 Mc/s and a limiting amplifier at 1 Mc/s. A low-power klystron oscillator covering the frequency range 3.8–4.2 Gc/s is frequency-modulated on its reflector with a modulation index of about one by means of a 1 Mc/s signal from a crystal oscillator. The network under test is connected between two waveguide change-over switches which enable its group delay to be compared with that of an equal length of plain waveguide. Attenuating pads are connected on either side of the change-over switches to provide the reference waveguide-impedance. The local oscillator is also a low-power klystron. The 70 Mc/s output from the mixer is amplified in a wideband 70 Mc/s amplifier employing automatic gain control and then fed to a 70 Mc/s frequency discriminator. The 1 Mc/s output from the discriminator has a phase change relative to the original which is proportional to the group delay. It is passed through a limiting amplifier and a phase changer to the phase comparator where the phase change relative to the original 1 Mc/s signal is measured.

Each measurement enables a point on the group-delay/frequency characteristic to be determined. The s.h.f. signal oscillator is set to the frequency at which a measurement is to be made. The local oscillator is adjusted to give an output frequency of 70 ± 0.1 Mc/s, as indicated by a 70 Mc/s wavemeter loosely coupled to the output of the 70 Mc/s amplifier. The equipment is set with the equal length of waveguide in circuit and the phase-changer setting is adjusted until the reading of the output meter is zero. The meter is then calibrated by introducing phase changes in the 1 Mc/s path corresponding to 5, 10 or 20 ns as required and by setting the sensitivity control of the phase comparator to give the appropriate reading. The change-over switches are then set to the network under test and group delays of up to 50 ns can be read directly on the meter. The group delay actually measured is the difference between that of the unit under test and that of an equal length of waveguide; hence to obtain the true insertion group delay an addition should be made to the meter reading of 0.108 ns per inch length of the network under test.

Amplitude Limiter

The importance of making the phase comparator independent of signal-level changes has already been emphasized. It is also necessary that those parts of the

equipment handling the 1 Mc/s signal should have phase changes which do not change with input level, power supplies, ambient temperature conditions, time or mechanical shock.

The limiter used in the 1 Mc/s path is of the cathode-coupled clipper type (see Fig. 7). It consists of a triode

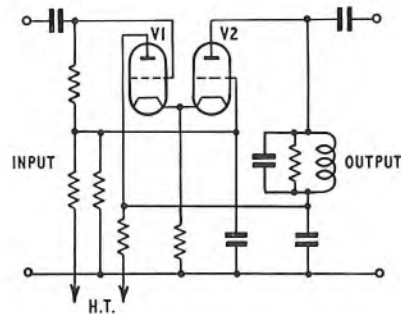


FIG. 7—CATHODE-COUPLED CLIPPER TYPE OF LIMITER CIRCUIT

cathode-follower driving an earthed-grid triode, the coupling being via the common cathode-resistor. The valves are biased to the middle of their grid bases by means of a potentiometer from the h.t. supply; with no input each valve is conducting. If the voltage at the grid of V1 (V_{g1}) is positive going the current in V1 increases and with it the voltage across the cathode resistor. The current in V2 thus decreases and if V_{g1} increases sufficiently the valve is cut off and the output voltage rises to the anode supply-voltage value.

When V_{g1} is negative-going the anode current of V1 and the voltage across the cathode resistor are reduced and hence the anode current in V2 increases. If V_{g1} becomes sufficiently negative V1 is completely cut off and the output voltage assumes a value determined by the value of the static bias. Thus, the peak value of the output wave depends only on the value of the h.t. voltage and is independent of the input voltage provided this has a peak value several times the grid base of the valve. The anode load is tuned to 1 Mc/s to extract the fundamental of the output wave; the Q-factor has been made as low as possible in order to reduce the effect of variation of capacitance and inductance on the phase shift through the limiter. Two stages of limiting are employed and the amplitude is held constant over a 15 db range of input levels; the phase delay varies over this range by 1 ns. To reduce the variation of phase with level changes it was found necessary to feed the limiters from a low-impedance source provided by a cathode follower.

Phase Changer

The phase changer is required to enable phase quadrature to be obtained between the two 1 Mc/s signals applied to the phase comparator. In the initial setting up with the straight-through condition of waveguide the phase of the 1 Mc/s test signal is changed by the group delay of the microwave and intermediate-frequency equipment and by the phase change of the 1 Mc/s equipment. This phase change, together with that in the phase changer, must give a 90° difference between the test and reference signals at the phase comparator. When the equipment is used for measuring items having group delays of not more than 50 ns the output meter gives a direct reading of the group delay. For items having a group delay greater than 50 ns, such as complete systems, it will be necessary to use the phase changer to re-establish the phase-quadrature condition and for this purpose it needs to be calibrated. The phase changer has a range of 360° , and, therefore, will cater for group delays up to the periodic time of 1 Mc/s, i.e. 1,000 ns. It is provided in two parts, each part working between valves with tuned anode-loads; the first part consists of a resistance-capacitance network with a 4-position switch to give 90° changes and the second part of a resistance and a variable capacitance to give a continuously variable phase shift from 0 to 100° .

70 Mc/s Amplifier and Discriminator

The group delay of the 70 Mc/s waveguide equipment must be constant with variation of input-signal level and power supplies. The 70 Mc/s amplifier and discriminator are standard items developed for microwave links. The amplifier² provides 50 db of gain and uses amplified automatic gain control to ensure an output signal level that is constant over a 25 db range of input level; over this range the group delay changes by less than 0.5 ns. The amplifier has a band-width between -1 db points of 44 Mc/s and a group delay that is constant within 0.1 ns over a band extending for several megacycles on each side of 70 Mc/s; changes of group delay with variation of the actual value of the 70 Mc/s frequency obtained from the mixer are thereby reduced.

The discriminator has a highly linear amplitude/frequency characteristic and has limiters which operate dynamically to suppress amplitude modulation of up to 10 per cent by about 50 db.

Microwave Equipment

The waveguide equipment is made in waveguide No. 11 ($2\frac{1}{2}$ in. by $1\frac{1}{4}$ in overall dimensions). Low-power klystron oscillators incorporating the plug-in reflex klystron type CV 2116 (E.M.I. RK 6112) have been used for the signal and local oscillators. The 8 db pads use long flat wedges of iron dust set in Marco resin material to give a standing-wave ratio of 0.98. To reduce further the effect of the load on the oscillator performance it has been found advantageous to connect a ferrite isolator between the oscillator and the pad. The waveguide change-over switches used at present are not ideal; plungers are arranged to short-circuit the guide when transmission is not required. The plungers are not broadband and the mechanism must be precise or intermittent variations are produced. The waveguide mixer is re-

² HAMER, R. and GIBBS, C. H. A Broad-Band Intermediate Frequency Amplifier for use in Frequency-Modulation Microwave Radio-Relay Systems. *P.O.E.E.J.*, Vol. 50, p. 124, July 1957.

quired to be broadband to cope with the frequency range from 3.8-4.2 Gc/s and the group delay characteristic is required to be reasonably constant with frequency so that changes of group delay due to changes of signal or local-oscillator frequencies do not occur during a measurement.

To obtain stable operation it is necessary to stabilize all h.t. supplies. The heater supplies to the 1 Mc/s equipment are also stabilized. Care was necessary in the design of the equipment to ensure that the 1 Mc/s oscillator and leads were properly screened so that there was no radiation which could give spurious signals in the phase comparator.

PERFORMANCE

To determine the performance of the equipment it is necessary to measure a component whose group-delay characteristic may readily be calculated and then to compare the theoretical and measured characteristics.

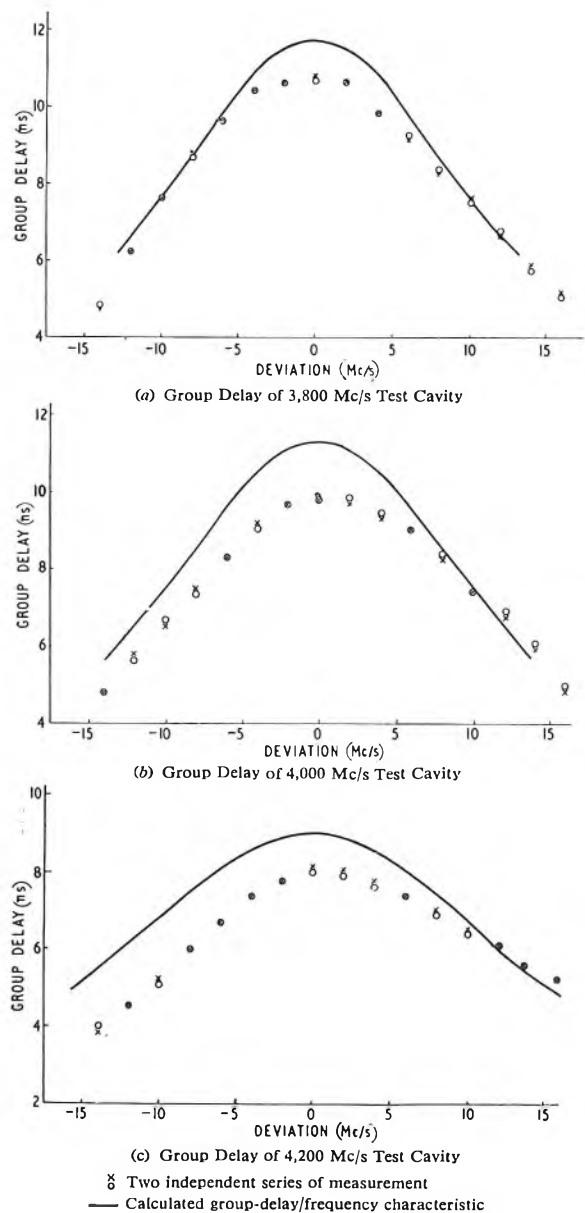


FIG. 8—MEASURED AND THEORETICAL GROUP DELAYS OF TEST CAVITIES

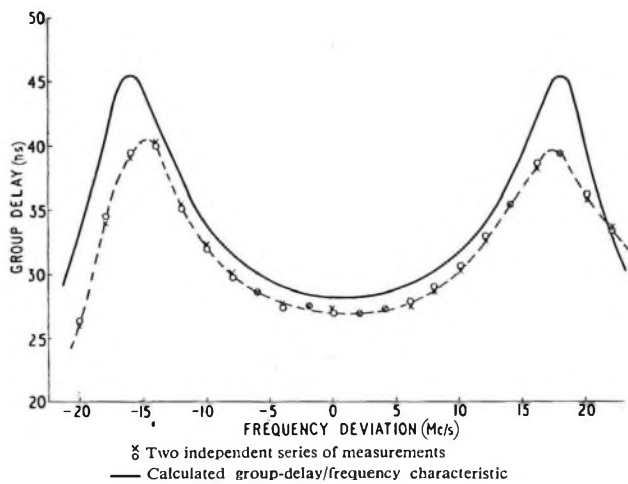


FIG. 9—MEASURED AND THEORETICAL GROUP DELAYS OF A BAND-PASS FILTER

The repeatability of measurements is checked by making a number of measurements on the same item.

A resonant waveguide cavity with iris coupling forms a convenient test component; measured and theoretical characteristics of cavities resonant at 3.8, 4.0 and 4.2 Gc/s are shown in Fig. 8. It will be seen that reasonable

agreement is obtained between the measured and calculated curves. The two sets of points represent two sets of readings made with the equipment and these agree to within 0.2 ns. Measurements made on a band-pass filter are shown in Fig. 9, with a calculated curve for comparison. At the edges of the characteristic the attenuation is 8 db greater than the pass-band attenuation and this shows the importance of catering for a wide variation of signal levels.

The equipment described is being used in measuring filter characteristics and fills a need that has long been felt. It will also be used to measure the overall group-delay frequency characteristic of the microwave section of radio links. The ideal equipment would present the characteristic as an oscilloscope trace with a frequency sweep of about 40 Mc/s and further work is proceeding on these lines.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the work of colleagues in Research Branch who were concerned in the design and development of the equipment. Acknowledgements are also due to the staff of the Radio Laboratories at Castleton who were responsible for the design of the 70 Mc/s equipment and who made freely available their experience in the design of 60 and 70 Mc/s group-delay measuring equipment.

Renewal of Relay-Spring Contacts

THE earliest-known method of renewing relay-spring contacts with the relays in position was tried by the Post Office in 1923 and abandoned as unworkable. Reports on the practices of foreign administrations have indicated, from time to time, that methods of renewing contacts are available, but inquiries have shown that little use seems to be made of them.

The need for such a system in this country does not seem to have been great enough to warrant serious investigation until 1951, when the occasion arose to recondition some apparatus for which replacement relays or springs were not available, and it was realized that a method of renewing the contacts without removing the relays from the equipment would have advantages with obsolete or obsolescent relays. The reconditioning of obsolete relays such as the Automatic Telephone Manufacturing Company's combined L and K relays and the "horizontal" type of relay was necessary, many contacts having reached the end of their useful life, but the removal of the relays would have caused many faults in the old and brittle wiring.

The original method devised used silver-wire billets and

(a) an extractor, or punch, which removed the old contact,

(b) an inserter to place the billet in the spring, and

(c) a former to shape the billet head into a contact.

The inserter and former tools showed a number of weaknesses and a revised method using preformed contacts instead of billets was tried. The tools used were

of two types, one making use of a combined inserter and riveter and the other using separate tools. The second method was eventually found to be more practical. The type of plier action to be used gave considerable trouble until it was decided to use a parallel-jaws action.

The tools finally decided on were as follows:

(a) *An Extractor*, which has a hole in one jaw to locate the pliers centrally on the contact and to receive the ejected old contact; the other jaw has a tungsten carbide punch. When the old contact has been ejected from the spring a forked-tongue slider attached to the inner face of the punch jaw is slipped forward to strip the relay spring from the punch.

(b) *An Inserter* with one jaw having a recess in which the new contact is placed, and a forked slider to retain the contact upright during insertion in the punched hole. When the slider is drawn back further pressure on the pliers causes the slight burr around the punched hole to hold the new contact until the next operation is performed.

(c) *Two Riveting Pliers* are provided, one with a depression in one jaw to accommodate the contact head and a flat face on the other jaw so that closure of the pliers swages the contact stem tight on the spring. The second riveter has a depression in both jaws so that the contact stem is formed in the domed shape required for double contacts.

A trial of the tools has demonstrated their usefulness and solved a difficult maintenance problem.

A. A. G.

The Principles and Possible Application of some Amplifiers of Low Intrinsic Noise

U.D.C. 621.375.9

WITHIN the past two or three years much has appeared in scientific and technical literature about new types of amplifier possessing low intrinsic noise, e.g. the maser. It is the object of this brief note to sketch, in the broadest outline, how these devices work and to express a view on what fields of Post Office application there may be.

The lowest level to which a signal may be permitted to fall before amplification is determined by the minimum acceptable signal/noise ratio. The noise may be externally introduced, e.g. by crosstalk, or may be the result of intermodulation within a transmission path; it is inherent in the resistance presented by the transmitting medium to the amplifier and may arise in the input and early amplifying stages. In many communication systems of sound design the limiting noise is due to the last of these factors.

By way of example consider an underwater coaxial-cable system with submerged repeaters. The resistive part of the characteristic impedance of the line together with any amplifier input terminating resistance will present a net value of R ohms. As is well known, the thermal noise power generated by R is kTB watts, where k is Boltzmann's constant, T the temperature in degrees Kelvin and B the band-width in cycles per second. If the amplifier itself generated no noise whatever then the signal could be permitted to fall to such a level relative to kTB that the signal/noise ratio was just enough to meet design standards. However, if the amplifier itself also generates noise then the signal level cannot be permitted to fall as low. The penalty for amplifier noise is either an increase in transmitted power or the need to ensure reduced attenuation between the transmitting and receiving terminals.

In amplifiers and radio receivers using conventional thermionic valves, first-stage noise is usually very low and does not present a significant limitation. However, due mainly to transit-time and reactive effects, conventional valves cannot at present be used at frequencies appreciably in excess of 2,000 Mc/s and, instead, there are employed such devices as the klystron, in which electron velocity-modulation occurs, or the travelling-wave valve, in which slow-wave interaction takes place. As first-stage amplifiers these devices are considerably more noisy than are their more conventional counterparts at lower frequencies. Typically, a low-noise travelling-wave valve will have a noise factor of 9 db, this being defined as ten times the common logarithm of the signal/noise power ratio at the input divided by the signal/noise ratio at the output. Other first-stage amplifying devices and, in radio systems, mixers, may be noisier still.

The extremely low levels of "signal" experienced in radio astronomy, satellite tracking, very-long-range radar, and in scatter propagation stressed the limitations imposed by receiving equipments of high intrinsic noise and spurred on research into devices which, in the appropriate frequency ranges, were capable of noise factors approaching zero. Amplifying devices which have been described in the literature and upon which considerable research and development effort is being

expended include the maser, the variable-reactance amplifier and the nemag. It is at present too early to attempt an assessment of the nemag (negative mass amplifier) so attention will be limited to masers and reactance amplifiers.

The solid-state version of the maser (the name is derived from the expression "Microwave Amplification by Stimulated Emission of Radiation") operates as an amplifier by reason of the fact that application of a small signal power of appropriate frequency to a spinning electron can, under favourable conditions, cause it to fall to a lower energy level with the emission of considerably greater power at the same frequency.

Consider the conditions in an active material, the molecules of which are "held apart" by an inactive material, the whole being situated in a magnetic field. In the active material there will be a preponderance of electrons at the lowest energy level, fewer at the next higher permissible level, fewer still at the next and so on. The distance apart of the discrete energy levels will be a function of the material and of the magnetic field. Representing the three lowest energy levels by E_1 , E_2 and E_3 , then if an electron in energy level E_3 falls to level E_1 it will radiate at frequency f_1 ; if it falls to level E_2 it will radiate at frequency f_2 , where f_2 is less than f_1 .

It is possible under favourable circumstances to apply energy at f_1 ("pump" frequency), and so lift a proportion of electrons from level E_1 into the E_3 level, upsetting the normal distribution. If, now, a small signal at f_2 be applied a state of affairs is produced which encourages electrons in the E_3 level to drop back to E_2 accompanied by the emission of energy at f_2 of magnitude greater than that of the stimulating signal.

If an attempt were made to operate the active material at room temperatures it would be found that thermal agitation caused the electrons to dissipate any "pumped-up" energy before it could be used for amplification. It follows that the material must be operated at very low temperatures and those in the liquid oxygen or even liquid helium range are involved.

A typical practical solid-state maser will comprise:

- (a) a suitably "doped" crystal mounted in a cavity of dimensions dependent upon the pump and amplification frequencies,
- (b) a cooling container surrounding the cavity,
- (c) a d.c. magnetic field in which the cavity is situated, and
- (d) two waveguides coupling to the cavity, these being of dimensions appropriate to the pump and amplification frequencies.

As described, the maser is a "two-terminal" device as far as the amplification frequency is concerned. One may consider that the signal to be amplified is applied to the cavity, receives additional energy and is returned by the same path to the source.

Turning now to variable-reactance amplifiers, the classical and, probably, the best introduction to this class of amplifier is to consider what would occur in a loop comprising an inductor and capacitor in series if

the capacitor were adjustable. Let the loop be carrying an alternating current at a frequency f_1 . If, at the instant when the voltage across the capacitor is a maximum, the electrodes are pulled further apart the potential across the capacitor will rise as a result of energy applied to the circuit, i.e. there will have been a conversion from mechanical to electrical energy. At the instant the potential across the capacitor drops to zero the electrode separation is restored. At the instant of maximum potential in the reverse sense the plates are again pulled apart; and so on. It is clear that in every half cycle mechanical energy is transferred to electrical energy and the signal frequency is amplified.

It is further apparent that (a) the frequency of capacitance change, i.e. the "pumping" frequency, is $2f_1$ and (b) the arrangement is phase sensitive for, if the electrodes were allowed to approach each other at every voltage maximum, then electrical energy would be converted to mechanical and the signal would be attenuated.

The capacitance or the inductance can be varied by electrical rather than mechanical means and input and output circuits (or a combined input/output circuit) can be coupled to the loop. A single-frequency amplifier is then formed which will, however, be extremely sensitive to the phase of the f_1 (signal) or $2f_1$ (pump) supplies.

Let the arrangement be extended to include:

(a) a loop resonant at the signal frequency f_1 and to which input and output signal circuits are coupled,

(b) a loop resonant at f_2 (f_2 is termed the "idler" frequency),

(c) coupling between loops (a) and (b) by a variable capacitance pumped at f_p , and

(d) the frequencies so arranged that $f_p = f_1 + f_2$.

It can be shown that the voltage developed across the loop in (b) above will always so adjust its phase that work done on the variable coupling capacitor will always cause the energy in the signal and idler loops to grow.

It is apparent that in this device:

(a) an amplifier at the signal frequency is formed by coupling into the signal loop, and

(b) an amplifying frequency-converter is formed by coupling into the idler loop.

Obviously, with appropriate circuit rearrangement, a variable inductor could be employed in place of the variable capacitor.

Within the past two years numerous variants of the variable-reactance amplifier have been proposed; they fall mainly into the three categories:

(a) diode (variable capacitance)

(b) ferrite (variable inductance), and

(c) electron beam types.

It is impossible in an article of this compass to expand upon them here.

Considering possible applications within the Post Office field of interest it may be noted first that masers and variable-reactance amplifiers have an advantage only at frequencies in the microwave range and then in respect only of low noise-factor compared with most of their competitors. It is difficult to see any Post Office application for masers particularly in view of the low-temperature requirements. Variable-reactance amplifiers appear, however, to have the following potential fields of application.

(a) As r.f. receiving stages in microwave line-of-sight and tropospheric scatter systems.

(b) As low-noise microwave frequency-changers.

(c) As r.f. receiving stages in communication links employing active or passive earth satellites.

(d) Possibly, as pre-amplifiers for television receivers operating at extreme range on channels in the higher television bands.

(e) Possibly, as r.f. stages for the fixed receivers of mobile radio-telephone systems.

F.J.D.T.

Long-Distance Transmission by Waveguide

U.D.C. 621.396.11:621.372.8

DURING the past few years many telecommunications laboratories throughout the world have been devoting effort towards the solution of the many problems posed by the transmission of signals over long distances by means of waveguide of circular cross-section. The Research Branch of the Engineering Department is playing its part.

It is the object of this brief article to give the general reader a broad picture of extended transmission by waveguide, the problems which have to be solved and the possibilities of practical application. For the reader who wishes to acquire a more detailed view reference is made to the record* of the I.E.E. Convention on Long-Distance Transmission by Waveguide, which was held in London in January 1959.

With a view to putting into perspective the potentialities of a waveguide system for trunk communication, it is noted that current estimates are that several hundreds of television channels or several hundreds of thousands of telephone channels could be accommodated simul-

taneously in one hollow tube of some $2\frac{1}{2}$ in. diameter. It is sometimes asked if such enormous channel capacity could be justified on any route; clearly, no positive answer can be given now but demands for channel capacity are ever increasing and demands for the transmission of new forms of data are arising. Again, if band-width can be made inexpensive and plentiful it can be employed prodigally with consequent economies in terminal equipment. It should be borne in mind too that there could also be a demand for junction transmission on a scale for which waveguide transmission could conceivably be attractive. Sufficient to say that most large telecommunications organizations currently consider the expense of an extensive research program to be justifiable.

To transmit energy in a waveguide it is necessary to set up a configuration of electric and magnetic fields bounded by the walls of the guide. For a given size of guide, frequencies below a certain value (the critical frequency) cannot produce a field configuration that can be propagated. Fields at frequencies above the

* *Proceedings I.E.E.* Part B, Supplement No. 13. (To be published)

critical one will propagate and the configuration of the field will depend upon guide dimensions and the field launching arrangement. Any particular configuration of field which can be supported is known as a "mode". In rectangular waveguides, such as are used to connect the transmitter or receiver to the aerial in microwave line-of-sight systems, use is made of the dominant mode, the lowest which the guide will support.

Many years ago it was discovered that a particular mode, the H_{01} , in a circular waveguide possessed the unique property that for all frequencies above the critical value the attenuation decreased as the frequency increased. Exploitation of this phenomenon was not practicable at that time because, with a guide of reasonable dimensions, the frequencies required were so high as to be beyond those which could be generated in coherent form. A guide of about $2\frac{1}{2}$ in. diameter, for example, requires the generation of frequencies in excess of about 30,000 Mc/s. However, in more recent years techniques have improved and made possible the exploration of guide phenomena in the range up to some 100,000 Mc/s, and the upper limit is extending rapidly.

If use is to be made of the very low attenuation characteristic of the H_{01} mode in a circular guide then transmission must take place at frequencies well above the critical. It follows that the guide readily supports other modes which can be stimulated all too readily.

Assume that an H_{01} mode has been generated (launched) in a solid-walled metallic guide. If the guide is dimensionally perfect and absolutely straight then the wave will be propagated at the low attenuation indicated by theory. However, if there are dimensional irregularities amounting to but fractions of a mil, or axial divergencies of but a few minutes, then spurious modes will be developed with the abstraction of power from the wanted mode. In addition, at later irregularities some elements of the spurious modes will reconvert to the wanted mode. The overall result is phase/frequency and attenuation/frequency characteristics which are anything but smooth and a mean attenuation greatly in excess of the theoretical minimum.

Clearly, a long-distance guide of near-perfect dimensions and axial straightness is impracticable and much research has been and is being done on the problem of devising a guide structure tolerant to modest dimensional inaccuracy and lack of straightness. Several solutions have been proposed, a typical one being to form the inner wall as a tight helix and to surround the helix by layers so devised as to encourage the reflectionless absorption of energy in unwanted modes.

At the present time it appears most doubtful if it will be practicable to devise a guide which can be transported from factory to site on a drum. Alternatives are to use rigid straight lengths connected with flexible sections or even to make and lay on site as a continuous process.

At present, research is being directed mainly towards achieving solutions to the following problems.

(a) The devising of a guide structure which can be made and laid under practical conditions and without unacceptably large departure from the optimum attenuation/frequency and phase/frequency characteristics.

(b) Means for negotiating sharp bends without unacceptable transmission loss and distortion.

(c) Means for suppressing such unwanted modes as may be generated.

(d) Means for launching the H_{01} mode free of all others.

(e) Determination of the optimum type of modulation.

It will not be possible to make a really satisfactory assessment of problem (e) until optimum solutions to the others have been determined. However, present-day thought is that some form of pulse code modulation will be necessary, i.e. a system of signal transmission which is tolerant of irregularities in the transmission medium and which involves signal regeneration rather than amplification. All in all one can visualize a trunk waveguide-system in which:

(a) channels are first assembled into the group, supergroup or mastergroup range by conventional frequency-division-multiplex methods,

(b) groups, supergroups or mastergroups are used to pulse-code modulate (or, perhaps, frequency-modulate) a carrier, the signal being launched into a guide of some $2\frac{1}{2}$ in. diameter and which eventually might be used to transmit signals in both directions, and

(c) regenerators (or repeaters) are used at perhaps 20-mile intervals.

A junction waveguide-system would be generally similar but, probably, of smaller diameter and less severely over-moded.

It will be apparent from the foregoing that much research and development work remains to be done before the potential of circular waveguides can be assessed. Only when these studies are well advanced and, perhaps, a field trial has been undertaken, will it be possible to apply the touchstone and determine if the cost per channel per mile makes the system competitive with others.

F.J.D.T.

Book Review

"Radio Upkeep and Repairs." Alfred T. Witts. Sir Isaac Pitman & Sons Ltd. 234 pp. 174 ill. 15s.

This little book is the eighth edition of a volume first published by this author in 1933, when radio receivers were "built" rather than mass produced and servicing consisted of genuine fault finding rather than the replacing of defective sub-chassis by new ones. Only straightforward test equipment is assumed to be available, e.g. an ohmmeter and a signal generator, and details of how to build some of this—such as a multi-range resistance bridge—are given in an early chapter of the book. A procedure for checking the performance of each section of the circuit of a conventional type of receiver is given, stage by stage, and

comments are offered on the possible causes of discrepancies in behaviour that may be found. The work has been brought up to date in this eighth edition by the addition of chapters on the servicing of frequency-modulation receivers for the v.h.f. bands, transistor receivers, and printed circuits. The treatment is general, in that specific makes or models are avoided.

After reading this book one retains the impression that it is part of a series and that it is not intended to stand alone. Although the description of the tests appears to the layman to be clear and unambiguous, a sound background knowledge of radio receiver design and particularly of current construction techniques would be needed by a servicing man worth his salt who was intending to use this book as his practical guide.

I.P.O.E.E. Library No. 2106.

C. F. F.

The Post Office Type 4 Uniselector

D. J. MANNING†

U.D.C. 621.395.658:621.395.342.21

Economy in the mounting space required by equipment used for the provision of subscriber-trunk-dialling facilities is a desirable feature, particularly for equipment which is to be installed in existing exchanges. This article describes a miniature uniselector, known as the Post Office Type 4 uniselector, which can be used to provide such facilities as digit counting and storage, and metering-rate selection, yet fits the standard drillings for, and occupies the space of, a single 3,000-type relay.

INTRODUCTION

DURING the investigation leading to the introduction of subscriber trunk dialling it became clear that increased economy in the use of apparatus mounting space was very desirable, since to give the new facility means installing additional equipment in existing exchanges, in many of which spare accommodation is becoming exhausted. Development was, therefore, required of a miniature uniselector for use in equipment such as registers for digit counting and storage, and in register-access relay-sets for metering-rate selection. A 3-level uniselector capable of being mounted in one 3,000-type relay drilling has now been introduced as the Post Office Type 4 uniselector. A general view of the new switch is given in Fig. 1.

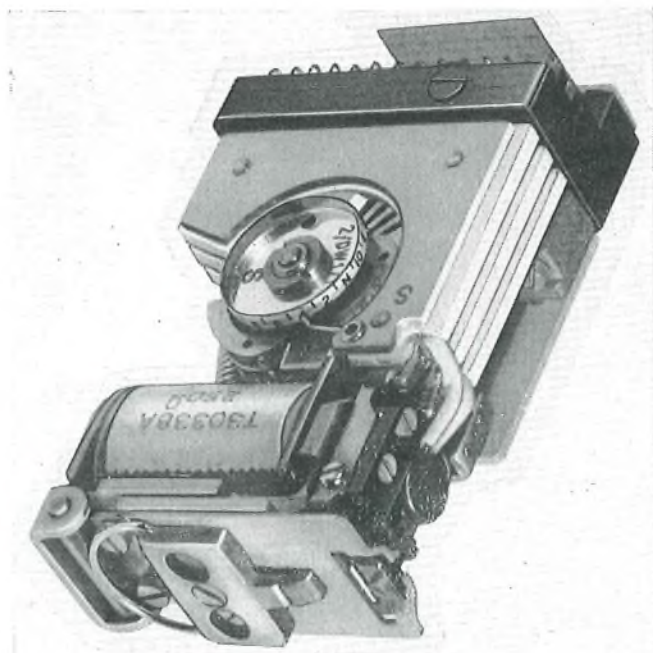


FIG. 1—POST OFFICE TYPE 4 UNISELECTOR

MECHANICAL DESIGN

Plug-in Facility

An apparatus item which has to mount in a standard relay drilling alongside relays and other apparatus and under a relay-set cover has to be limited to a space approximately 1 in. \times 2 $\frac{1}{4}$ in. \times 3 $\frac{1}{2}$ in. It was apparent

† Executive Engineer, Telephone Exchange Standards and Maintenance Branch, E.-in-C.'s Office.

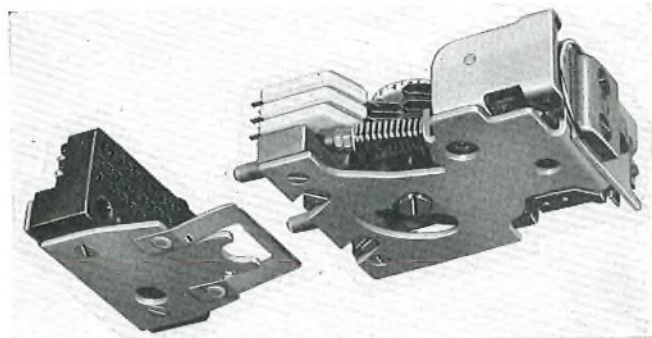


FIG. 2—UNISELECTOR AND ASSOCIATED JACK

that very few adjustments would be possible with such a switch in position on its mounting plate, and the developing manufacturer therefore designed the item so that mechanism and bank together are plugged into a 42-point jack fixed to the relay-set plate. This is the Jack No. 89A, shown separated from the uniselector in Fig. 2. The 42 spring sockets are held in the body of the jack, which is a black phenolic moulding. Screwed to the moulding is a shaped flat metal bracket, which supports the weight of the uniselector. To this bracket is rivetted a spring, tensioned slightly upwards against the weight of the uniselector. When the uniselector is plugged in, the 42-point plug is guided into the jack by two spigots, on a spigot block secured to the rear of the switch frame, engaging in two holes in the body of the jack. When it is fully home, the spring rivetted to the jack bracket clips over the head of the wiper spindle, which is then held, by the weight of the uniselector, between the clip and the shaped end of the bracket so that the uniselector plug-points cannot disengage the jack sockets. To withdraw the uniselector it is necessary only to disengage the clip from the head of the wiper spindle, by inserting the end of a screwdriver between the clip and the uniselector frame, and pull the wire handle clamped to the uniselector front plate. Thus, the mechanism and bank together are instantly replaceable, which is of advantage where the uniselector is used in common equipment whose out-of-service time must be kept to a minimum.

The jack is clamped to the mounting plate by two screws passing through the mounting-plate relay drilling into a clamping plate at the rear of the mounting plate. The two screws are so positioned that the jack is located with the same side uppermost whether fitted in a left-hand or right-hand relay drilling; thus, the uniselector always plugs in with its number wheel uppermost, and it is possible to refer to the left-hand and right-hand sides of the switch. The jack sockets are a proved type of valve-holder socket and form soldering tags at the rear of the jack. Space between the socket tags and the mounting plate is limited and the jack body is channelled at the rear to accommodate the wires to the tags. Because most of the tags are obscured by the mounting plate when the jack is fixed in position, the jack has to be pre-wired before fixing. Contact between the wires and the mounting plate is prevented by an insulating strip

clamped between the jack body and the mounting plate; this can be seen in Fig. 1.

Bank Assembly

The 42 plug-points of the uniselector are extensions of the bank contacts, as shown by the dotted lines in Fig. 3.

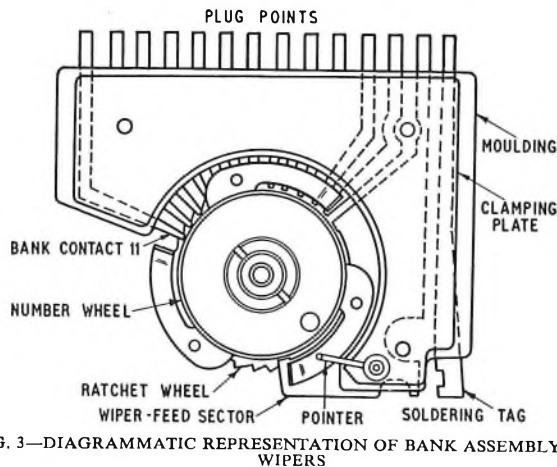


FIG. 3—DIAGRAMMATIC REPRESENTATION OF BANK ASSEMBLY AND WIPERS

The complete bank assembly is clamped by two screws to the spigot block. Each bank level consists of 14 strips of metal moulded into a wafer of white "Diakon" thermoplastic insulating material. Numbering from left to right, the first twelve of these metal strips are the bank contacts 11, 10 . . . 1, 0, the thirteenth is the wiper-feed sector and the fourteenth, on the extreme right, forms a soldering tag at the front of the bank. The three bank soldering tags, one per bank level, afford means of connexion to the magnet coil, non-linear-resistor spark-quench, and interrupter contacts. The three bank levels are separated by aluminium spacers and clamped between mild-steel clamping plates by three screws. The bank assembly also carries a short wire pointer, adjustable by bending, for the number wheel of the wiper assembly.

Wiper Assembly

The space available for the wiper assembly is such that the radius from the hub centre to the outermost contact point of a wiper tip is less than 0.6 in. The wiper limbs could, therefore, not be diametral as in larger uniselectors since the wiper blades would have been too stiff, their tension increasing too rapidly with deflexion of the wiper tips. In the Type 4 uniselector the wiper blades are of the 3-limbed "Isle of Man" shape which gives a comparatively long blade for the small centre to wiper-tip radius, and thus gives normal wiper-to-bank contact pressures. The use of a 3-limbed blade with the limbs spaced at 120° allows the bank contacts and wiper-feed sectors to be so arranged that one of the three wiper tips is always resting on a bank contact except when stepping, the next tip is always in contact with the wiper-feed sector, and the third tip is disconnected. This arrangement dispenses with the need for brush feeds to the wipers.

Viewed along the axis of the wiper assembly, as in Fig. 3, the trailing edges of the wiper tips are not radial as in other uniselectors but are raked forward slightly from the outermost to the innermost contact point.

During stepping, the innermost contact point touches the next bank contact before the remainder of the wiper tip. The wiper load is, therefore, taken up gradually during the return stroke of the armature, and the necessary pressure of the armature-restoring spring is somewhat less than would be required with radial wiper tips. The wiper assembly is built up of bridging and non-bridging wipers as required.

The wiper spindle is screwed into the frame, and secured by a lock-nut on the inside of the frame. The spindle is unsupported at its upper end, and the wiper assembly is free to move vertically along it, taking up a position on the spindle determined by the tension of the wipers against the bank contacts. If both blades of each pair are equally tensioned, the wiper assembly will position itself so that each pair of blades is approximately symmetrically disposed about the plane of its level of bank contacts and in this condition there is a clearance between the end of the wiper-assembly hub and the spindle lock-nut.

The ratchet wheel fits over the end of the wiper-assembly hub adjacent to the frame, and is fixed by one screw to a flange integral with the hub. The hole in the ratchet wheel through which this fixing screw passes is elongated so that the angular position of the wiper tips relative to the ratchet wheel can be varied.

A rimmed number wheel is clamped to the wiper assembly at its upper end. It, and the pointer fixed to the bank assembly, are viewed over the top of the coil (Fig. 1). The wipers are numbered 1, 2 and 3 in the normal manner, beginning with the one adjacent to the number wheel.

Magnet Assembly

The magnet coil and yoke assembly is similar to that of a 3000-type relay in that the coil and yoke are fixed together at the heel-end, as shown in Fig. 4. The armature-end of the yoke is machined to be square and in line with the centre of the end of the magnet core, which is slightly

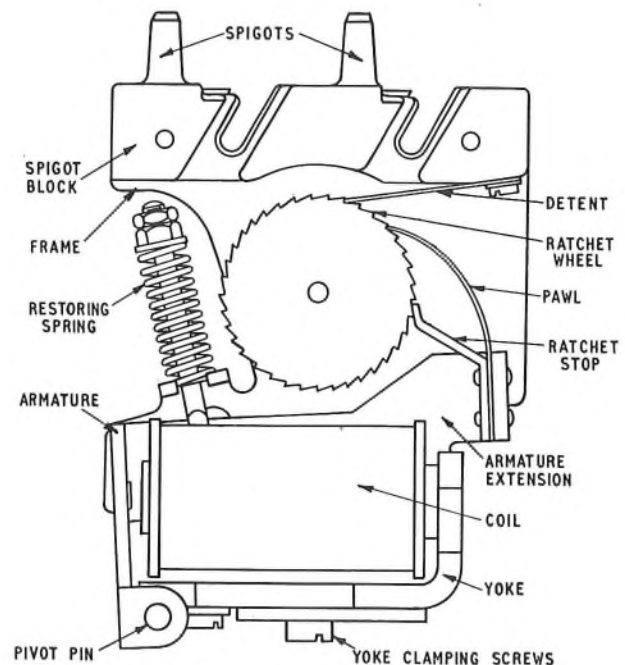


FIG. 4—EXPLANATORY DIAGRAM OF UNISELECTOR MECHANISM

domed to ensure that the residual stud is the only part of the face of the armature to touch the core. When a coil has to be changed, the complete coil and yoke assembly is replaced so that the coil does not have to be adjusted to line up the end of core and yoke. The armature hinges about a pivot pin clamped to the yoke, the clamp being adjustable so that a correct air-gap can be obtained between the machined end of the yoke and the face of the armature. The magnet coil and yoke assembly are fixed to the frame by two screws. The holes in the frame through which these screws pass are slightly elongated so that the coil and yoke assembly can be moved sideways parallel to the frame. Slight rotational movement of the magnet-assembly relative to the frame is also possible, so that the driving pawl, fixed to the armature extension, can be set squarely on a ratchet-wheel tooth.

Stroke Adjustment

Sideways movement of the magnet assembly relative to the frame alters the stroke of the armature because the armature extension, at its extremity on the right of the switch, carries a ratchet stop which bears upon a tooth of the ratchet wheel when the armature is normal (see Fig. 4). As the magnet assembly is moved to the left the armature stroke is reduced. Similarly, if the magnet assembly is moved to the right the armature stroke is increased. The stroke can be set within close limits by gauging the side-ways position of the magnet assembly relative to the frame.

Detent

The detent is a straight spring (see Fig. 4) fixed by a single screw to a slightly sloping face on the inside of the spigot block. The slope of this face is such that a straight detent screwed to it will bear upon the ratchet wheel with a pressure a little above that required. To adjust the detent tension it is necessary only to lift the detent gently away from the ratchet wheel.

Ratchet Stop

The ratchet stop is possibly the most novel feature of the switch. On release of the armature the engagement of this stop with the ratchet wheel arrests the motion of the ratchet and armature. Hence, no armature back-stop or pawl forward-stop is required. The ratchet stop is formed from 0.056 in. thick spring steel and so flexes very slightly during impact with the ratchet wheel. There is some wiper oscillation at each step of the mechanism, but the overall effect of this resilience may be a contributory factor in the long life of the mechanism. The shape and position of the ratchet stop relative to the rest of the armature is set in manufacture and not adjustable in service. They have been chosen to give maximum stopping effect on the flank of the ratchet-wheel tooth consistent with the stop clearing the tip of the next forward tooth during the return stroke of the armature.

Pawl

The driving pawl is fixed to the armature extension by the same two rivets that fix the ratchet stop, and is clamped between the ratchet stop and the armature extension. It is made from 0.022 in. thick spring steel. The reach of the pawl is dependent on its curvature and this is set in manufacture, but if the magnet assembly

or armature is replaced the pawl reach has to be checked; if it is too long there will be inadequate engagement of the ratchet stop on the flank of the ratchet tooth, and if it is too short the ratchet stop will foul the ratchet wheel during release of the armature.

Armature Restoring Spring

The armature restoring spring is a coiled spring, compressed between an upturned lug on the frame of the uniselector and a nut and lock-nut on a screwed spindle fixed at one end to the armature (see Fig. 2 and 4). This spindle is initially set so that it does not foul the sides of the upturned frame lug during movement of the armature. The coiled form of restoring spring was chosen as being easier to adjust than the more usual flat steel spring.

Interrupter

The two interrupter contact-springs are fixed by self-tapping screws to an insulating phenolic-resin block, which is secured by two screws to the heel of the magnet yoke at the right-hand side of the switch (see Fig. 1). The moving spring is pre-tensioned against the stationary spring and is lifted away from it during operation of the armature by an insulated striker, fixed to the heel of the armature extension. The point of operation is set by a screw adjustment of the position of the stationary spring, the adjusting screw bearing on the uniselector front plate via a small insulating block of phenolic resin.

WIRING

Folded away in the space between the interrupter spring-set and the heel of the armature extension are the wires joining the three bank soldering tags to the coil and interrupter contacts, together with the non-linear-resistor spark-quench. The wires are of such a length that the bank can be separated from the mechanism without unsoldering any connexions. The two bank-clamping screws may be slackened and can slide away from the wiper assembly in angled slots in the frame and spigot block; when these screws are clear of the frame and spigot block the bank can be swung aside, allowing the wiper assembly to be lifted off its spindle.

PERFORMANCE

One of the design requirements was that under fault conditions the uniselector should consume no more than 10 watts, so that surrounding relays would not be overheated. The coil resistance for 50 volt working is, therefore, 250 ohms (nominally 5,720 turns). The operate current of the uniselector ranges approximately from 50–100 mA, according to adjustment conditions. Pulse operate-and-release times and stepping speeds under self-drive conditions are very similar to those of the Post Office Type 2 uniselectors with three levels. The life of the new uniselector under service conditions is expected to be better than 50 million steps without replacement of any parts other than the wiper assembly.

ACKNOWLEDGEMENT

Acknowledgement is made to Siemens Edison Swan, Ltd., who carried out the development of the Type 4 uniselector on behalf of the British Telephone Technical Development Committee, and supplied the photographs for Fig. 1 and 2.

Parcel-Label Printing and Issuing Machines

H. E. WHITTON and R. D. GIBBON†

U.D.C. 681.173:656.882

A gummed label bearing, in addition to the value, the date and office of issue is to be sold at Post Offices to cover the parcel-post fee normally collected by the sale of stamps. The label printing and issuing machine described in this article has been developed following a field trial of an earlier model.

INTRODUCTION

FOR the acceptance of parcels for posting at public counters the counter clerk must hold a wide range of postage stamps in his folio. Many parcels require more than one stamp to be affixed to cover the fee which, for overseas parcels, may reach a high value. It is normal practice to date-cancel the stamps with a hand stamp immediately, and as many parcels are neither regular in shape nor rigid, the details of the cancellation marks are frequently illegible.

To effect an improvement in this respect and to reduce the time required for each transaction, it was decided in 1947 that a gummed label should be printed for use in the parcel-post service bearing, in addition to the value, the date and office of issue. This label would be sold at the parcel counter for immediate postings only. For security reasons the customer would not be supplied with labels for subsequent use.

Three firms submitted designs of machines. One hundred machines from one firm and two from each of the others were purchased in 1950, and were introduced in Crown Post Offices throughout the United Kingdom. The first hundred machines were known as Parcel-Label Machine No. 1.

Based on the field experience gained with these machines and the reactions and suggestions of the operating and engineering staffs, a specification for an improved machine was prepared for the purchase of a large number of machines. Six hundred machines were ordered for delivery during the last few months of 1959 and the first half of 1960.

DESCRIPTION OF EARLIER MACHINES

The Parcel-Label Machine No. 1 issued labels in any one of twelve predetermined values, as indicated on a dial, and counted the total value of the issues on two meters, one for shillings and one for pence. The required values were selected by the anti-clockwise rotation of the dial, which was similar in outward appearance to a telephone dial. Movement of the dial was checked by the finger reaching a stop, which caused the dial to remain stationary until the transaction was completed, whereupon it returned to normal. Labels were printed and issued by the rotation of a handle causing a die to be brought into contact with a pre-impregnated ink-roller. The die rolled over a gummed paper strip which was housed in a case at the top of the machine.

Experience with this machine revealed the following operational disadvantages.

(a) Labels were delivered face downwards and the imprint was obscured from the operator's view.

(b) The meters, which were on the underside of the

machine, could be read only by removing the machine from its stand.

(c) The limited range of values seriously reduced the flexibility of use of the machine. Each time a revision of postal rates was introduced an extensive modification to each machine was necessary.

(d) Cash totals could be obtained only by conversion of total shillings and total pence to a single combined figure, there being no automatic conversion or "carry over" of pence to shillings.

(e) Date setting was carried out by means of a stylus inserted into the machine from its lower face.

(f) As the machine employed a pre-impregnated ink-roller, engineering attention was required to replace rollers for each 10,000 impressions. This was too frequent to be economical.

(g) The method of printing was such that each impression was produced in two stages. Consequently the first and last label of each day had to be made waste and this in turn required a special accounting procedure.

GENERAL FEATURES OF THE NEW MACHINE

The new machine (known as the Parcel-Label Printing and Issuing Machine No. 2) will issue labels (illustrated in Fig. 1) of any denomination between zero value and 19s. 11d. in steps of a penny. The total value of issues is held in a meter on the top face of the machine and this records in pounds, shillings and pence up to £999 19s. 11d. Counting is continuous, the meters passing through zero value without resetting. An additional "batching" facility is given in the form of a meter which records up to £99 19s. 11d. and which may be reset after each transaction; it is intended to simplify the work of the counter clerk when handling several parcels from a single customer. As in the earlier model this machine is operated by the rotation of a handle which is released by pressing a button adjacent to the handle. The values are selected by the setting of two concentric dials on the front of the machine. The larger dial selects the shillings from 0 to 19 and the smaller dial selects pence. Four concentric rings on the right of the front face of the machine, below the value dials, may be adjusted to vary the date. The "year" printing drum covers a period of twelve years, after which time it will have to be replaced.

The printing is done by the impact of a spring-loaded

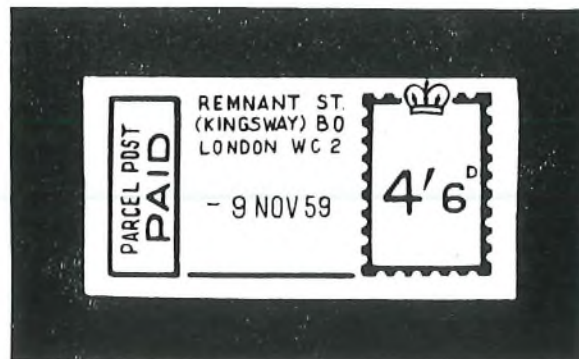


FIG. 1—TYPICAL PARCEL LABEL

† Mr. Whitton is an Executive Engineer, Power Branch, E.-in-C.'s Office. Mr. Gibbon is an Executive Engineer, London Postal Region (formerly of Power Branch, E.-in-C.'s Office).

rubber-faced platen which presses the paper against the type through a bright-red inked ribbon. The ribbon, which is advanced by a small amount during each cycle, is reversed automatically and is of such a length and quality that at least 40,000 impressions can be taken before a new ribbon must be fitted. It is estimated that engineering visits will not be required more frequently than once a year for the purpose of ribbon replacement. One advantage of this method of printing is that the entire label is produced in one operation of the handle and the accounting necessary to cover wasted labels is obviated. A general view of the machine is given in Fig. 2.

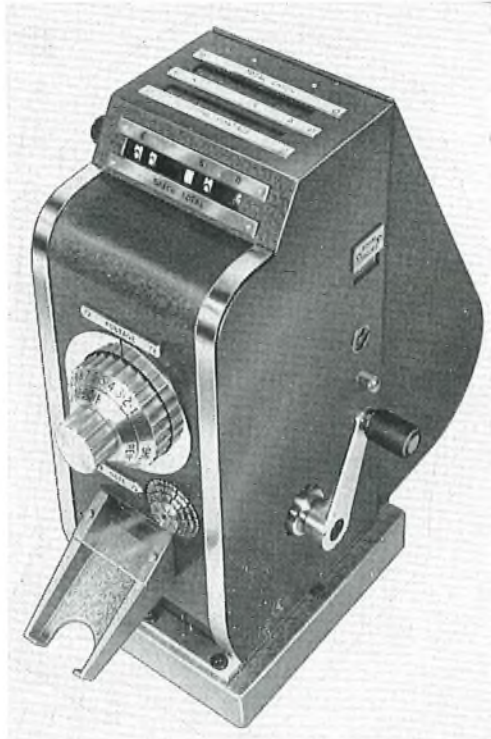


FIG. 2—PARCEL-LABEL PRINTING AND ISSUING MACHINE NO. 2

MECHANICAL FEATURES OF NEW MACHINE

The main internal features of the machine are given in schematic form in Fig. 3. A chart of the timing of the various operations which occur during a rotation of the machine handle appears in Fig. 4.

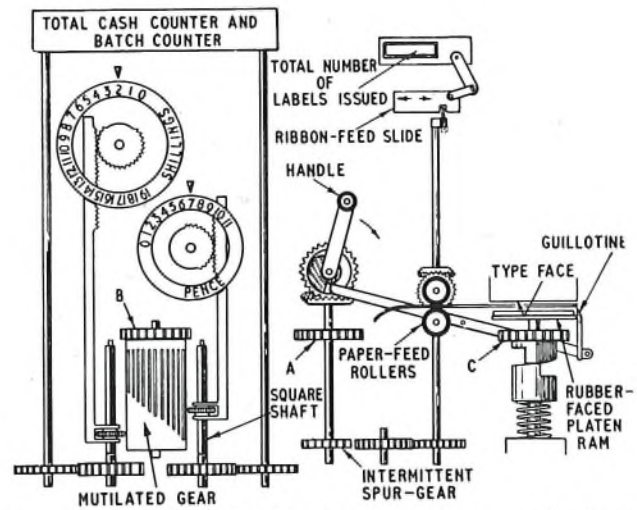
Date and Value Adjustments

The four concentric discs bearing the date in terms of day (two outer appearances), month and year are extended by four concentric tubes to gears that mesh with individual gears mounted on the date type-wheels. Correct alignment of the date impression is ensured by spring-loaded detents held between the teeth of a set of four auxiliary gears in mesh also with the date type-wheel gears.

A similar method is adopted for transmitting movement of the "pence" and "shillings" controls to the respective value type-wheels.

Handle-Shaft

The handle-shaft rotates a composite gear which consists of an intermittent spur-gear and a complete spur-gear riveted together on the same axis. The shaft



Note: Spur wheels A, B and C each have 25 teeth; B and C are geared directly to A
 FIG. 3—SCHEMATIC DIAGRAM OF MACHINE

also carries two cams which drive the guillotine blade towards the end of the cycle of operation.

The Intermittent Spur-Gear

This gear, which has teeth formed on 1/3rd only of its circumference, does not engage until about 2/5ths of the cycle has elapsed. It is connected through a gear train to a vertical shaft which drives the paper-feed rollers and the ribbon-feed slide, and which is linked to the "total issues" meter.

The Complete Spur-Gear

Throughout the cycle, this gear (A, in Fig. 3) is engaged with the printing ram and the mutilated-gear (see below) assembly. The ram is an assembly of two face-cams spring-loaded together, and shaped to cause the ram to impact the printing platen on to the dies at an early stage of the cycle. During the remainder of the cycle the cam retracts the printing platen and reloads the spring.

The Mutilated Gear

This unit is a cylinder with nominally 25 teeth cut in its circumference. However the tooth No. 1 and the teeth No. 12 to 16 are removed, leaving one set of

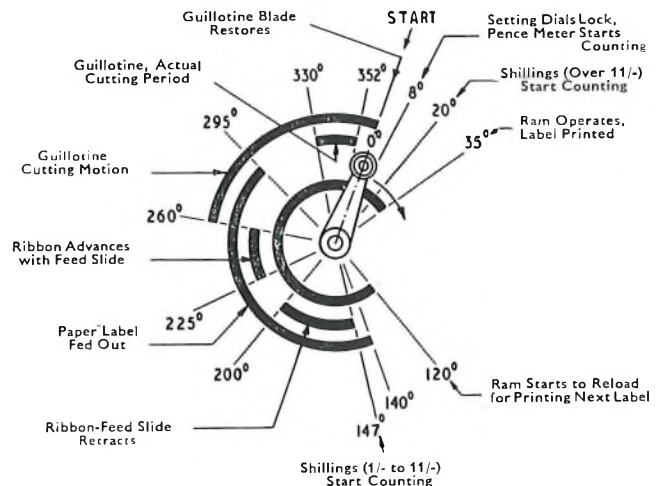


FIG. 4—TIMING OF OPERATIONS

eleven teeth and one set of eight teeth. The lengths of these teeth are made progressively shorter by the same increment when measured from the upper-end face of the cylinder. On opposite sides of the mutilated gear, two small gears are mounted each on square-section shafts lying parallel to the mutilated-gear axis. It is possible, by means of forks supporting the small gears, to cause the gears to slide to any position on the square shafts, so obtaining engagement with a larger or smaller number of teeth on the mutilated gear during a complete revolution.

Thus, by connecting the small gears through rack-and-pinion systems to each of the cash-value dials, it is possible to obtain a degree of rotation on the small gears which is proportionately related to the values set in "shillings" or "pence".

Movement of the "pence" gear along its square shaft is confined to the lower portion of the group of 11 teeth on the mutilated gear, to give the values 0 pence to 11 pence. The "shillings" gear can move over the whole range of both groups to obtain values of 0 shillings to 19 shillings.

The square shafts are geared to long vertical shafts, one on each side of the machine, which feed, separately, into the metering mechanism the appropriate amounts related to the "shillings" and "pence" settings on the dials.

ACKNOWLEDGEMENTS

The authors are indebted to Setright Registers, Ltd., the manufacturers of the No. 2 machine, for some of the information used in the article.

Book Reviews

"Trigonometry Refresher for Technical Men." 629 + x pp., illustrated, and

"Calculus Refresher for Technical Men." 431 + viii pp., illustrated, both books by A. A. Klaf. Constable & Co., Ltd. 16s. each.

These two books are primarily intended for revision purposes by engineers and technicians who have previously studied the subjects but whose knowledge may have become rusty. Nevertheless the treatment is sufficiently thorough and lucid to be quite useful to the student who has not previously reached the standard of the material presented.

A characteristic of the books is that every paragraph heading is in the form of a question, which is answered in the paragraph under that heading. Apart from this somewhat novel feature the material is presented on orthodox lines.

The topics treated are well explained and illustrated by examples drawn from electrical, mechanical, civil and aeronautical engineering, hydraulics, surveying and navigation. Many of the problems are worked out fully in the text but there is an adequate number of test questions for the student to work for himself.

With examples drawn from such a wide range of applications it is natural that some topics are included which are not normally studied by electrical engineers, e.g. spherical trigonometry, but it is useful to have this for reference purposes.

The scope and standard of the books does not correspond to any well-known British examination syllabus, but the standard of treatment is rather more than is required for the Ordinary National Certificate syllabus in these branches of mathematics.

The typescript is clear and bold, and the general style of the books makes them attractive and easy to read. Those who feel they need to brush-up their mathematics as painlessly as possible will find these books stimulating and interesting.

F. C. M.

"Foundations of Electrical Engineering," Volume II. H. Cotton, M.B.E., D.Sc., M.I.E.E., and E. W. Golding, O.B.E., M.Sc.(Tech.), M.I.E.E., Mem. A.I.E.E. Sir Isaac Pitman & Sons, Ltd. 272 pp. 170 ill. 30s.

This book, by two well-known educationalists and authors, is published in Pitman's National Certificate series. It deals mainly with alternating-current circuits and

machines to the standard required for the Ordinary National Certificate, Electrical Engineering S3 course.

Seventeen chapters deal with generation of a.c., induced e.m.f., waveforms, instantaneous, average and r.m.s. values, addition of alternating quantities, inductance, capacitance, power and power factor, series circuit, parallel circuit, resonance, symbolic notation, single-phase transformer, polyphase working, polyphase induction motor, electronic devices, and a.c. measuring instruments. The book adopts the rationalized M.K.S. units, and an introductory chapter summarizes the basic mechanical and electrical units.

The first four chapters are straightforward, with a lucid distinction between sinusoidal and non-sinusoidal waveforms. The difficult problem of complex waveforms is admirably overcome in the treatment given.

Chapters 5-11 are conventional subject matter. The treatment is very clear and obviously written with a considerable background of knowledge of students' difficulties. The parallel a.c. circuit, which students often find difficult to grasp in their initial study stages, is extremely well treated. Chapter 12 on symbolic notation again indicates the experienced lecturer. This subject matter has been separated out and a rigorous and lucid treatment of the j operator, with many worked examples, is given.

The treatment of single-phase transformers, polyphase circuits and induction motors in Chapters 13-15 is again thorough and of a high standard.

Chapter 16 on electronic devices is in the nature of an anti-climax in view of the high standard of the previous chapters. It is limited to an elementary treatment of a few aspects (simple valve theory, diode rectification, mercury-arc rectifier, simple triode valve). The treatment, though elementary, is far from lucid, particularly in the section dealing with valves and valve theory, and the value of this chapter to students is doubtful. The importance of electronic devices at the present time justifies a fuller scope than that given.

Chapter 17 on a.c. measuring instruments is a collection of digest descriptions, of rather elementary nature, of the various instruments. It is rather disappointing, the treatment being too brief to be really useful.

Numerous examples are worked throughout the text, and the book ends with a series of problems, with answers, as exercises on individual chapters.

The book is well produced, the diagrams are clear and well drawn and fit excellently with the text. Based on Chapters 1-15, which material forms the greater part of the relevant syllabus, the book is highly recommended for students taking the Ordinary National Certificate in Electrical Engineering.

I.P.O.E.E. Library No. 2553.

S. W.

Notes and Comments

Recent Awards

The Board of Editors has learnt with pleasure of the honours recently conferred upon the following engineers:

A. N. McKie	..	On loan to War Office	..	Senior Executive Engineer	..	Member of the Most Excellent Order of the British Empire
E. G. Smith	..	North Eastern Region	..	Flight Lieutenant, Royal Auxiliary Air Force	..	Ordinary Member of the Military Division of the Most Excellent Order of the British Empire

Retirement of Mr. A. C. Warren, B.Sc., M.I.E.E.

With the retirement of Mr. A. C. Warren, Assistant Engineer-in-Chief, on 31 August 1959, the Post Office and, in particular, the Regions and the Engineering Department have had to say *au revoir* to a good friend; one who has made important contributions during his 39 years of service both in radio development and in the establishment of the Regional organization. In addition, over the last four years of service he has directed his wide experience and knowledge to the solution of the many problems which came his way as an Assistant Engineer-in-Chief.



Since his retirement Mr. Warren has no doubt looked back over the years from 3 August 1920 when he entered the Wireless Section of the Engineer-in-Chief's Office as a Temporary Inspector after service in the First World War. In so doing, he would recall the pioneering and happy days when, with a few colleagues, he was breaking new ground in the design of high-power valve transmitters for the radio stations at Northolt, Portishead, Leafeld and Rugby. The monument to that team was the Rugby Radio Station, and, in particular, the long-wave GBR transmitter. He will remember with satisfaction the time he subsequently spent as an Executive Engineer (old style) from 1931 to 1936, first on radio planning and then as officer-in-charge of Rugby.

His thoughts would turn next to the entirely new problems which faced him when he left the Engineering Department in 1936 to become an Assistant Staff Engineer in the old South Western District, and to the next 19 years during which he was occupied in the field as the first Telephone Manager of the Bristol Area in

1937, and in 1944 as the Chief Regional Engineer of the South Western Region. He will be reminded of the many and varied problems he encountered during the war years, of the new ones arising in the post-war period and of members of the team he was privileged to lead as Chief Regional Engineer from 1944 to 1955.

His thoughts would next turn to the final phase of his service, his four years as Assistant Engineer-in-Chief when he again came into close daily contact with some of his colleagues of 30 years before. He would think of his work on the further integration of broadband cable and radio systems in the trunk network, the rapid expansion of the television network and the many other problems placed before him as a result of his unrivalled knowledge of Regional work.

Finally, he has most likely asked himself, as all must do at the end of their Post Office career, "What impact have I made and what has been my contribution?" To that question his many friends would reply that with his talents of technical ability, zealotness, loyalty to the Post Office and deep human understanding he has made important contributions in the many fields with which he has been concerned. Firstly, in the development of the radio art and its application to both long-distance and short-distance communication, to the setting up and operation of Regionalization and finally to using his fund of knowledge and experience so effectively as Assistant Engineer-in-Chief.

His many friends in the Engineering Department, the Regions and the Administration are loath to have to say *au revoir*, and will remember with pleasure and thanks the help and advice he has given them. All unite in wishing him a happy future.

C. F. B.

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

The appointment of Mr. R. E. Jones as Assistant Engineer-in-Chief, in succession to Mr. A. C. Warren who retired on 31 August 1959, has been received with pleasure by his many friends in both the Post Office and the telecommunications industry.

After graduating from London University in 1926, Mr. Jones joined the International Standard Electric Corporation and worked for some years on the planning and provision of main underground cable systems in several European countries.

He entered the Post Office service in 1933, when he was appointed Assistant Engineer (old style) by special selection and was employed in the Research Branch, mainly on the development of audio-frequency transmission equipment. On promotion to Executive Engineer (old style) in 1938, he remained in Research Branch but added to his duties co-operation with the Signals Research and Development Establishment in their development of line transmission equipment for use by the Army. In 1940 he co-operated with the War Group

in emergency measures for maintaining communications with the Armed Forces in Europe. Then for a brief period in 1941-42 he was employed as an Area Engineer on maintenance duties in the London Telecommunications Region, West Area.

In 1942, Mr. Jones was mobilized with the rank of Major in the Royal Corps of Signals for co-operation with the French P.T.T. during the operations in North Africa. He later served in Italy and Austria and was awarded the M.B.E. He was demobilized in 1946 with the rank of Lieutenant-Colonel and returned to the Post Office to the London Telecommunications Region, Centre Area.

Promotion to Assistant Staff Engineer in the Engineer-in-Chief's Office, Equipment Branch, followed in October 1946 and there he had charge of the provision of transmission equipment, power plants and repeater station buildings and the standards to be adopted for accommodation for all telecommunications equipment. He was promoted to Staff Engineer, in charge of Equipment Branch, in October 1951 and in that capacity his responsibilities broadened to cover the design and provision of both local and trunk telephone exchanges, including the implementation of trunk mechanization, the provision of the first S.T.D. installation, at Bristol, and the planning of the very extensive program for



installing the S.T.D. equipment that is to be brought into service in the next two years. He has been particularly interested in the economics of the provision of telephone exchanges, and under his guidance many changes have been made in the planning, design and provision of exchanges, which are helping to reduce the cost of the telephone service.

Mr. Jones has also been an active member of the Institution; he was a member of Council from 1950 to 1958 and during the last three years of that period served as Treasurer to the Institution.

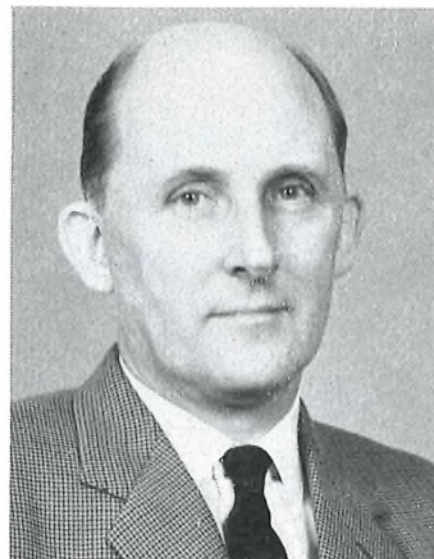
In his new post, Mr. Jones will no longer be directly concerned with telephone exchange work, and the wide circle of colleagues and friends who have had the pleasure of working with him in that field regret that this should be so but wish him every success in his new and wider sphere of responsibility.

W. A. H.

H. E. Francis, M.I.E.E.

Mr. Francis, recently appointed Staff Engineer of the Exchange Equipment and Accommodation Branch, entered the Post Office in 1926 and after training as a Probationary Inspector spent two years in the Leeds Technical Section. He was then transferred, first to the Telephone Branch and later to the Equipment Branch, being employed for some five years on automatic telephone exchange design and specification duties. On advancement to Assistant Engineer (old style) in 1936, he was appointed to the Aberdeen Area on internal construction and maintenance duties, serving in this capacity for a period of six years, which included the difficult early war years when telecommunications plant in the north of Scotland was rapidly expanded.

In 1942 he returned to Equipment Branch on promotion to Executive Engineer (old style) and was engaged on exchange area planning and design. It was his expert knowledge of theory and practice in this wide subject which resulted in Mr. Francis being seconded to the Indian Government in 1945, when he assumed responsibility for planning and design of automatic exchange areas and also organized comprehensive training in this class of work for the Indian personnel concerned. Shortly after returning, in 1950, his special abilities were again recognized, this time by secondment to the Anglo-



Iranian Oil Company for six months' service as senior engineering member of a team sent to South-West Persia to advise on development of the company's telecommunications system.

Promoted to Assistant Staff Engineer, Telephone Branch, in 1952 he worked to great effect on the problems associated with automatic trunk exchange switching and subscriber trunk dialling, being concerned in the development of much special equipment, including the electronic register-translators for the Bristol S.T.D. installation. In this post he made official visits to Germany, Sweden and Switzerland for system study and also spent some time in Yugoslavia on behalf of the United Nations Technical Assistance Authority.

In spite of the demands of official duties Mr. Francis entered keenly into the educational field in his earlier days, teaching telecommunications subjects in Leeds,

Kingston and Aberdeen. At the same time he acquired, and has since greatly strengthened, a reputation as a fluent lecturer on various aspects of automatic telephony. Of the many papers he has read or had published it must suffice to mention the two I.P.O.E.E. contributions on automatic exchange design, for each of which he was awarded an Institution Silver Medal.

The happy blending of experience, technical ability, versatility and enthusiasm in Mr. Francis has done much to ensure his success, and his wide circle of friends at home and abroad will warmly welcome the news of his latest appointment. G. E. S.

E. F. H. Gould, B.Sc.(Eng.), A.C.G.I., M.I.E.E.

Mr. Gould graduated in Electrical Engineering in 1928 at the City and Guilds Engineering College. Before joining the Post Office in 1933 he spent three years on research work in the International Telephone and Telegraph Laboratories and two years with Callenders Cable & Construction Co. on research work studying high-voltage power cables.

On entering the Post Office Engineering Department he was appointed to Research Branch where he studied problems of interference with Post Office circuits arising from power systems and electrified railways, and problems of corrosion of Post Office cables due to natural causes and



by stray currents from electric traction systems. In 1937 he was promoted to Executive Engineer (old style) in Construction Branch where he was concerned with the executive aspects of the same work as that on which he was previously engaged in Research Branch. In 1939 he was transferred to Radio Branch on radio interference and allied work, and in 1941 he returned to his previous work in Construction Branch where in 1943 he was promoted to Assistant Staff Engineer and added tools and user aspects of motor transport to his responsibilities.

On his return from a 12 months' course at the Imperial Defence College in 1948 he was transferred to the Engineering Organization and Efficiency Branch (O Branch) and was there responsible for engineering organization and establishments so far as major staff were concerned. In June 1951 he was promoted to Staff Engineer in charge of O Branch.

The things that he will probably be most remembered for in O Branch are organizational problems associated with the assimilation of the engineering staff of Cable and Wireless into the Post Office when that company was partly taken over by the Post Office; also for the report of the study group, of which he was chairman, to review the work of the Senior Executive Engineers and Executive Engineers in the Post Office.

He left O Branch in January 1954 and, until his present appointment, has been in charge of the Test and Inspection Branch of the Engineering Department. During this time he has been responsible for a number of important projects including the acceptance testing arrangements for the transatlantic submarine telephone cables.

In his younger days at Dollis Hill he took an active interest in sports such as football, hockey and tennis, and now apart from an occasional game of golf he has taken up dinghy sailing.

Mr. Gould's sense of humour, his quick wit and his ability to recognize the essentials of any problem fit him very well for his new post as Deputy Director, External Telecommunications Executive, and he goes there with the best wishes of his engineering colleagues. J. S.

J. Balcombe, B.Sc.(Eng.), A.C.G.I.

Mr. Balcombe, who has been appointed Staff Engineer



of the Test and Inspection Branch (I Branch), entered the Post Office as a probationary Assistant Engineer by the open competition in 1933 after graduating at London University. In between, he has seen many aspects of the engineering work connected with the design and provision of telephone systems.

Following the probationary training in the Sections and in the Engineer-in-Chief's Office, his first substantive appointment was to the Telephone Section where for two years he was concerned, among other things, with the development of country-satellite exchanges and U.A.X.s, and with the introduction of multi-metering. He left this to be the British member of the testing team in the S.F.E.R.T. Laboratories of the C.C.I.F. engaged on articulation studies and allied investigations. During this stay in France he acquired a useful knowledge of the language and in later years served as an interpreter at

C.C.I.F. meetings. He returned to the Telephone Branch in February 1939 to work on the provision of 2 v.f. signalling systems.

After a brief spell in the London Telecommunications Region at the outbreak of war he was promoted Executive Engineer (old style) in the Lines Branch on repeater maintenance but after a year he moved to take charge of the main-line planning duty, where he remained until 1947 when he became Area Engineer at Portsmouth. His field experience has been most valuable in his work in I Branch, to which he was promoted as Assistant Staff Engineer in 1950; there he has specialized in the application of sampling techniques to the inspection of equipment items.

For many years Jack Balcombe has taken an active interest in staff association matters and has been a Branch chairman of the Society of Post Office Engineers and a member of council of the Association of Staff and Regional Engineers. His many friends wish him every success in his new post.

E. F. H. G.

Retirement of Mr. H. G. Davis, O.B.E., B.Sc.(Eng.), A.C.G.I., D.I.C., M.I.E.E.

The first open competitive examination for Assistant Engineers (old style) to be held after the First World War



brought into the Post Office a number of now well-known personalities, including Mr. H. G. Davis. He had gained his engineering degree as well as the associate membership of his college at the Imperial College of Science and Technology, and followed these up by a year's post-graduate study in radio and telephony for which he was awarded the D.I.C.

His first work in the Post Office was in the Transmission Group of the Research Branch, where he was engaged on the design of repeater station equipment and the early applications of 2-wire and 4-wire audio repeaters to loaded underground cables. Subsequently he was concerned in the design of equipment for the first telephone trunk service to the Channel Islands, and, after his transfer to the old Lines Branch in 1930, was concerned with the setting up of new trunk networks of all types.

Promotion in 1931 brought him to the Telegraph Branch where, as Executive Engineer (old style), he had responsibility for the initial introduction of teleprinter private-wire and telex services. After five years of this work he transferred to the new Scottish Region; first as Power Engineer and then, on promotion to Regional Engineer, he became responsible for all external construction and maintenance, transmission and radio work, together with the oversight of technical training requirements. This period between 1936 and 1945, covering as it did the war period and the special defence works required for it, was notable also for the expansion of the Scottish backbone cable and radio network, the re-cabling of the Forth Bridge, using a completely redesigned type of cable suspension and cable expansion joints, and the laying of the first underground cable between Glasgow and Oban.

A further field for his activities was opened to Mr. Davis in 1945 when he was promoted to Chief Regional Engineer of the North Western Region where, as elsewhere, there was a heavy program of post-war reconstruction to be undertaken. In addition there were numerous technical advances to be exploited under his control, including the Manchester trunk mechanization units, the preparatory work for the Liverpool trunk non-director unit, and automatic telex working.

In addition to these technical preoccupations, he took a very lively interest in the establishment of good staff relations within the Region and was a strong advocate of full co-operation and frequent informal discussions with the staff on matters affecting their interests. These were matters with which he was particularly well equipped to deal, having a genial and sympathetic but forthright manner which encouraged confidence and made for mutual trust and harmony.

Amongst his extra-Regional activities he was a member of the Engineering Panel of the Working Party on Regionalization, and he also took a very live interest in the North Western Centre of the Institution of Electrical Engineers, serving on the Centre Committee for a period of four years.

When he was honoured with the award of the O.B.E. in 1953 it was a matter of gratification to his friends and colleagues of all ranks and was regarded as a very fitting recognition of his sterling work in the North Western Region.

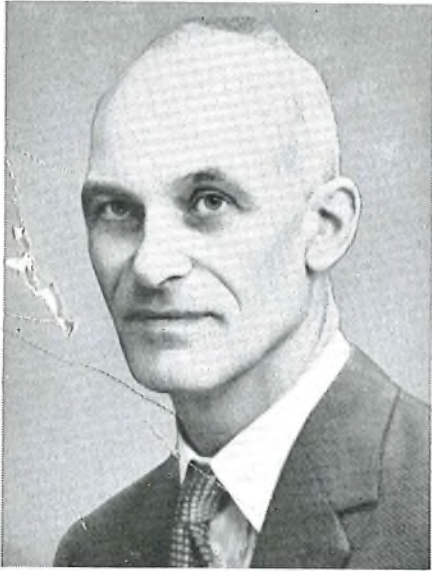
His retirement means a considerable loss to the Department, and his colleagues as well as his staff will miss his commonsense and direct approach to his daily problems as much as his genial and friendly personality, and all will wish him well in his retirement.

J. J. E.

Lt.-Col. F. N. Lucas, B.Sc., M.I.E.E.

Lt.-Col. Lucas, who took up duty as Chief Regional Engineer of the North Western Region in August 1959, entered the Post Office by open competition as Assistant Engineer (old style) in 1931, and was appointed to the office of the Superintending Engineer, Scotland East. Regionalization in 1935 led to his transfer to the Edinburgh Area. A period of 6 months in the Regional Office preceded promotion to Headquarters, S Branch, on 1 April 1939, from which he was called up at the outbreak of war, serving first as a Staff Officer at Scottish Command and later forming and commanding 13 L. of C. Signals.

On demobilization, Lt.-Col. Lucas was appointed



Area Engineer, Newcastle, and in September 1947 was promoted to Regional Engineer, Scotland. After some 10 years of planning buildings for which he could not get the equipment, and then redesigning the equipment for which he had still not got the buildings, Lucas transferred to the staff load and set about organizing staff for which he found he had not got enough money. Whatever he finds he has not got in Manchester, he will set about getting it with characteristic persistence and with the transparent honesty of purpose that contributed so much to the negotiations arising out of redeployment.

R. J. H.

Awards by the Institution of Electrical Engineers

The Board of Editors has noted with pleasure that the following members of the Post Office Engineering Department have been awarded premiums by the Institution of Electrical Engineers for papers published during the 1958-59 session:

D. L. Richards, B.Sc.(Eng.), A.M.I.E.E., and J. Swaffield, Ph.D., B.Sc.(Eng.). M.I.E.E. Electronics and Communications Section Premium, for their papers, "Rating of Speech Links and Performance of Telephone Networks" and "Assessment of Speech Communication Links."

I. F. Macdiarmid, A.M.I.E.E. Electronics and Communications Section Premium, for his paper, "A

Pulse-and-Bar Waveform Generator for Testing Television Links."

Radio and Electronics Industry Awards for Published Technical Articles

The former Radio Industry Council scheme for awarding Premiums for Technical Writing has been re-named the Radio and Electronics Industry Awards for Published Technical Articles. The scheme is now being organized by a joint committee of the Electronic Engineering Association and the Radio Industry Council called the Radio and Electronics Industry Awards Committee.

Each year the committee awards premiums of 25 guineas each to writers of published technical articles which, in the opinion of the panel of judges, are likely to make more widely known British achievements in radio, communications and electronics.

Any writer will be eligible who is not paid a salary wholly or mainly for writing and is not earning 25 per cent or more of his income from fees for articles or from book royalties.

Writers are invited to submit published articles (eight copies of the journal, or of the relevant pages, proofs or reprints), together with signed declarations of eligibility, to the Secretary, The Electronic Engineering Association, 11 Green Street, Mayfair, London, W.1, with a request that the article should be considered for an award. Articles will be considered for awards at the end of each year and the results announced early the following year. Writers are, however, urged to send in their entries during the year as soon as possible after publication; all entries must reach the Secretary before the end of the year.

Articles published in this Journal are eligible for the awards; it will not, however, be necessary for writers of articles published in this Journal to send copies to the Secretary of the Electronic Engineering Association when requesting consideration for an award because copies of each issue of the Journal are sent to the members of the panel of judges.

Notes for Authors

Some notes have been written to help authors prepare the manuscripts of their Journal articles in a way that will assist in securing uniformity of presentation, simplify the work of the Journal's printer and draughtsmen, and help ensure that authors' wishes are easily interpreted. Any author preparing an article for the Journal who is not already in possession of the notes is asked to write to the Managing Editor to obtain a copy.

I.P.O.E.E., Additions to the Library (continued from p. 226)

2553 *Foundations of Electrical Engineering, Vol. II.* H. Cotton and E. W. Golding (Brit. 1959).

Covers (with Volume 1) the requirements of the National Certificate Course in Electrical Engineering—explains and uses the rationalized M.K.S. system of units.

2554 *Electrical Safety.* H. W. Swann (Brit. 1959).

A comprehensive survey of the subject.

2555 *Youth in a Technical Age.* D. M. Silbertson (Brit. 1959).

Covers the history of day release courses, the purpose and content of these courses, the problems they

present, and the future outlook. There is particular reference to day release in the Post Office.

2556 *Transmission and Propagation.* E. U. D. Glazier and H. R. L. Lamont (Brit. 1958).

Deals with the properties of electrical lines, audio-frequency and radio-frequency considerations, wave-guides, radiation and propagation, and aerial systems.

2557 *Watch and Clock Making and Repairing.* W. J. Gazeley (Brit. 1958).

Explains the principles and construction of watches, clocks and chronometers, and includes practical information on cleaning and repairing.

W. D. FLORENCE,
Librarian.

Institution of Post Office Electrical Engineers

Essay Competition 1959-60

To further interest in the performance of engineering duties, and to encourage the expression of thought given to day-to-day departmental activities, the Council of the Institution of Post Office Electrical Engineers offers five prizes, a first prize of six guineas and four prizes of three guineas, for the five most meritorious essays submitted by members of the Engineering Department of the Post Office *below the rank of Inspector*. In addition to the five prizes, the Council awards five certificates of merit. Awards of prizes and certificates made by the I.P.O.E.E. are recorded on the staff docketts of the recipients.

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

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

Copies of previous prize-winning essays have been bound and placed in the Institution Central Library. Members of the Associate Section can borrow these copies from the Librarian, I.P.O.E.E., G.P.O., 2-12 Gresham Street, London, E.C.2.

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

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

Name (in Block Capitals)
 Signature
 Rank
 Departmental Address

 Date

The essays must reach
 The Secretary,
 The Institution of Post Office Electrical Engineers,
 G.P.O.,
 2-12 Gresham Street,
 London, E.C.2.

by 31 December 1959.

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

S. WELCH,
 General Secretary.

Additions to the Library

Library requisition forms are available from Honorary Local Secretaries, from Associate Section Centre Secretaries and representatives, and from the Librarian, I.P.O.E.E., G.P.O., 2-12 Gresham Street, London, E.C.2.

2535 *Higher Electrical Engineering*. J. Shepherd, A. H. Morton and L. F. Spencer (Brit. 1958).

A textbook for a general A1 year of Higher National Certificate followed by an A2 year consisting of a

common "Principles" section together with a choice of heavy-current engineering or electronics. Also covers much of London University Part 2 and certain sections of Part 3 syllabuses, and most of C. & G. Electrical Engineering Practice.

2536 *Junction Transistor Electronics*. R. B. Hurley (Amer. 1958).

Provides the basic knowledge of the characteristics and circuit applications of transistors.

2537 *Mathematician's Delight*. W. W. Sawyer (Brit. 1943).

Designed to convince the reader that mathematics is not a forbidding science but an attractive mental exercise.

2538 *The Atom and the Energy Revolution*. N. Lansdell (Brit. 1958).

A broad introduction to the subject; points out the social and political implications of this scientific development.

2539 *Metals in the Service of Man*. W. Alexander and A. Street (Brit. 1954).

Illustrates the parts played in life and civilization by the many metals in common use.

2540 *Prelude to Mathematics*. W. W. Sawyer (Brit. 1955).

Emphasizes those branches of mathematics which are existing in themselves and not through having any great practical utility.

2541 *Minerals in Industry*. W. R. Jones (Brit. 1955).

A concise account of the many minerals and mineral products employed in modern commerce.

2542 *Balance Carried Forward*. R. R. Comber (Brit. 1953).

Written primarily for those who run their own businesses; explains the theory and practice of book-keeping.

2543 *Uses and Abuses in Psychology*. H. J. Eysenck (Brit. 1953).

An examination of the claim of this science to be of practical use in human affairs.

2544 *Psychiatry Today*. D. Stafford-Clark (Brit. 1952).

A summary of up-to-date knowledge of the problems of mental illness and abnormality, their causes, treatment, and medical and social implications.

2545 *Man and Automation*. L. Landon Goodman (Brit. 1957).

Covers the technical aspects as well as the social, economic and other aspects.

2546 *How to be Happy Though Human*. W. Beran Wolfe (Brit. 1957).

Deals with many of the important problems of everyday life.

2547 *Economics of Everyday Life*. G. Williams (Brit. 1953).

Includes such issues as the rise and fall of prices, the dollar gap, international trade, and the wages question.

2548 *Atomic Radiation and Life*. P. Alexander (Brit. 1957).

Gives the facts and indicates the great gaps in our present knowledge of the subject.

2549 *Elements of Magnetic Tape Recording*. N. M. Haynes (Amer. 1957).

A comprehensive book covering all aspects of the subject.

2550 *Television Servicing Handbook*. G. J. King (Brit. 1958).

A practical handbook—includes Band III converters.

2551 *Telegraphy*. J. W. Freebody (Brit. 1959).

A clear and detailed account of principles and practice, covering the equipment used by the G.P.O.

2552 *Matter, Earth and Sky*. G. Gamow (Amer. 1959).

Intended for the general reader—covers physics, chemistry, astronomy and meteorology.

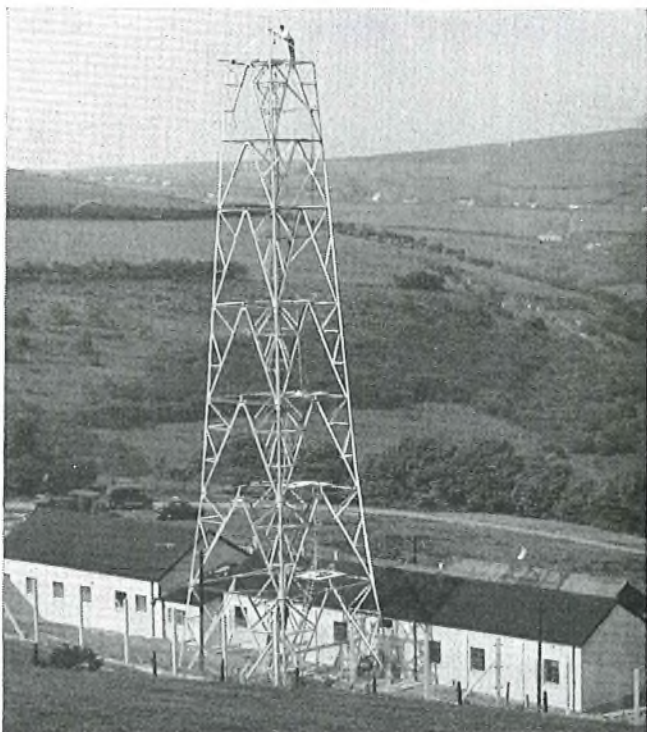
(continued on p. 225)

Regional Notes

Northern Ireland

ERECTION OF TOWER AT BALLYGOMARTIN FOR THE CARLISLE-BELFAST RADIO LINK

Ballygomartin, the Northern Ireland terminal of the Carlisle-Belfast microwave link, which provides for both commercial television and telephone services, is situated on Divis Mountain at a height of 850 ft above sea level. It is approximately $5\frac{1}{2}$ miles from Belfast, and from the outskirts of the city the narrow road rises steeply through a wooded glen to the station site.



ERECTION OF TOWER AT BALLYGOMARTIN

Building work commenced on 1 December 1958 and, apart from a period of 10 days when frost stopped all operations, went on without further interruption during the winter months, in spite of inclement weather and the immense difficulties of transporting building materials and equipment to the site. As the station is actually built on the hill side, which has a varying slope of about 1 in 5, the building contractor was unable to use a mechanical excavator; thus, all site works had to be carried out by pick and shovel, a dumper being used to distribute the spoil.

Of all the work involved in the building of this station, by far the most formidable task was the foundation works for the 100 ft steel tower. Over 600 tons of earth and boulders had to be excavated to form a level site before actual work could start on the foundations for the tower. The four concrete foundation blocks supporting the tower are 7 ft 9 in. square and 7 ft 4 in. deep. Each block had to be cast in one operation and vibrated to ensure a crushing strength of 4,000 lb/in². The quantity of concrete prepared on site and poured to form these bases was of the order of 120 tons.

The work of setting out the bases and the steel foundation assemblies had to be performed with meticulous care as the tower was prefabricated in the maker's works and little tolerance in the drilling of the tower base plates was per-

missible. Each leg of the tower is anchored to its concrete base by nine $1\frac{1}{4}$ in. diameter galvanized rods inserted through galvanized steel tubes and threaded into steel channels, which have packing blocks welded between and below the flanges to act as guides and threaded sockets for these rods. Two pairs of channels, arranged at 90° to each other, are provided for each base and are located accurately 6 in. from the bottom of the block. Silver-steel pins, driven through preformed holes in each rod and the packing piece, lock the rods in position.

Sheet-steel templates, each drilled in accordance with the drillings in the tower base plates, were provided by the manufacturer. These were used to ensure accurate location of the anchor rods, by being lined up and bolted in position until all concrete work was finished. In addition, a triangular-shaped template of timber was designed locally and used to ensure correct positioning of each group of anchor rods. Finally, to avoid any possibility of movement during formation of the concrete bases, each assembly was firmly held in position by suitable timber struts. Frequent checks were made while pouring the concrete and each base, when completed, was checked against the other bases. Sample test cubes of the concrete were prepared as the work proceeded, left to cure and subsequently tested by Queen's University, Belfast, to confirm that the crushing strength was up to the specified limit of 4,000 lb/in².

The tower is a self-supporting, galvanized structure, fabricated from steel angle with a maximum size of 4 in. × 4 in. × $\frac{5}{8}$ in. and a minimum of 3 in. × 3 in. × $\frac{1}{4}$ in. It is 10 $\frac{1}{4}$ tons in weight and has a width of 25 ft at the base, tapering to 10 ft at the top. It was constructed and assembled in a horizontal position at Vickers Armstrong's works. After inspection at the works it was dismantled and galvanized before shipment to Northern Ireland. Apart from the difficulties of delivery to site, the tower was erected without incident by a firm of steeplejacks under the supervision of representatives from the manufacturers and the Engineering Department. At the time of writing, the tower is completed and ready to receive the paraboloid aerials, two 10 ft diameter cast-aluminium reflectors, each weighing $\frac{3}{4}$ ton.

E. G. L.

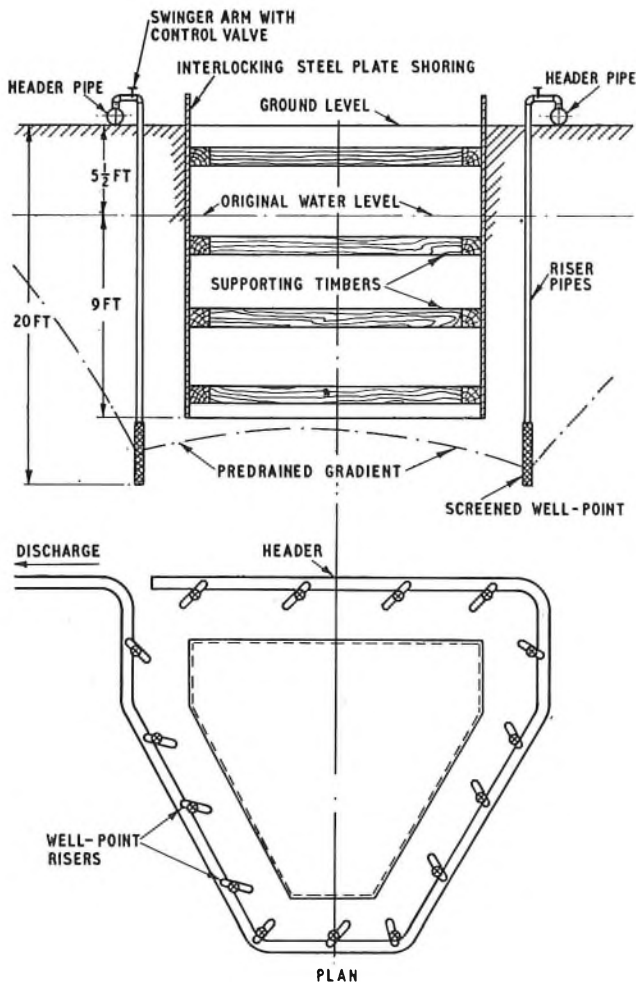
CONSTRUCTION OF NON-STANDARD MANHOLE OUTSIDE TELEPHONE HOUSE, BELFAST

The building extension at Telephone House, Belfast, involved the provision of a duct lead-in to the new cable chamber, to cater for growth and the diversion of MU and CJ cables for trunk mechanization.

An RT8-type manhole was required to be built across the existing 36-way duct track for interception and lead-in of trunk and junction cables to the new repeater station, television and exchange apparatus rooms. The thoroughfare concerned is a busy one-way street carrying heavy traffic, and the presence of a 24 in. trunk gas main, large barrel sewer, water, gas, electricity and miscellaneous services in the area to be occupied by the manhole was known, but their precise positions could not be accurately determined.

Pilot holes were not permissible as the police and local authorities expressed concern at the possibility of dislocating the traffic, and strict target dates for starting and finishing the work were stipulated. In consultation with the local authorities, and the Northern Ireland Ministry of Finance (Works) architectural and civil engineering staff, it was decided to proceed with the scheme and build a turning manhole as near as possible to RT8-type standards.

The subsoil at the site is sand and the water level is about $5\frac{1}{2}$ ft below the surface. The site is almost at sea level and is only 300 yd from the tidal portion of the river Lagan. It was decided, therefore, to use the well-point system of de-watering and 15 well-points, or riser pipes, were sunk into the ground at approximately 6 ft intervals around the

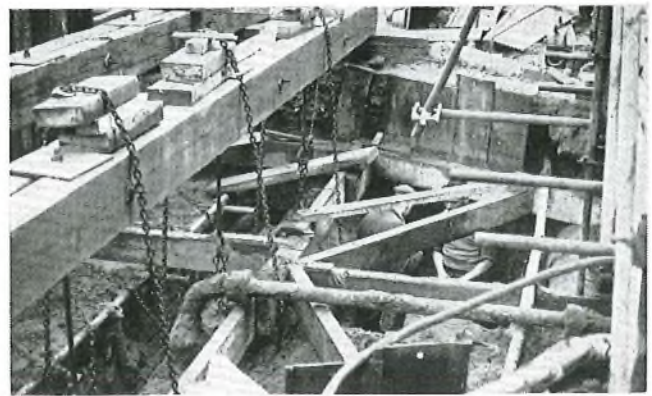


LAYOUT OF WELL-POINT SYSTEM AROUND EXCAVATION FOR MANHOLE

site of excavation and connected together to form a closed-ring installation. Each well-point was flushed, or jetted, into the ground using water under pressure, so that a hole was eroded slightly larger in diameter than the well-point tube, thus permitting its descent. A vacuum pump caused atmospheric pressure to force water from the subsoil through a lower screen section on the tubes, and the water was drawn off and discharged through a centrifugal-pump unit. With the vacuum maintained a lowering of the water level of the site was obtained. The de-watering plant was in continuous operation for 16 weeks and the material excavated was completely dry.

During excavation operations it was soon evident that a standard structure could not be built and, as alteration of the trunk gas main was not possible, it was decided that the manhole would have to be built below the level of the gas main. The duct track, however, could not be lowered to the required level due to its location between the sewer and gas main, so the manhole section was re-designed as an "L" shape, the roof being the horizontal portion with the gas main supported above on a fillet of sand, and the duct track in the vertical section. The width of the chamber was increased so that the cables could be lowered to the level of the outgoing duct track to the cable chamber. Some idea of the extreme care required during construction of the manhole can be seen from the photograph.

The structure, designed in consultation with the Northern Ireland Ministry of Finance (Works) architect and civil engineers, consists of 9 in. reinforced-concrete inner walls, an asphalt membrane and a 4½ in. brick outer wall. Two



MANHOLE SITE DURING EXCAVATION

sections of the brickwork of the vertical wall between the incoming duct track and the gas main were constructed with a weak cement mixture to permit removal, if necessary, for access to the joints in the trunk gas main alongside.

The interception of the existing 36-way duct track demanded great care as several of the trunk and junction cables are over 25 years old and the area has been subject to both chemical and electrical corrosion. The work is now complete and no serious interruptions to any services have been caused.

Many difficulties were encountered throughout and, but for the close co-operation of the Northern Ireland Ministry of Finance and the contractor with the Post Office engineers concerned, the scheme could not have been carried out so successfully.

J. M. P.

North Western Region HORWICH V.H.F. STATION

An urgent request was received in the middle of March, from the Engineering Department, for the erection of an experimental v.h.f. station at the top of Winter Hill (approximately 1,500 ft above sea level). The station, for the South Lancashire Radiophone Service, was required by the end of July. This allowed just over four months for site requisition, building erection, and cable and equipment installation. The site selected is near to the existing I.T.A. television site and opposite an electricity sub-station, which serves the I.T.A. station and a number of police v.h.f. stations. A difficult feature of the site was the surface layer of peat which was known to vary from 3 ft to at least 10 ft in thickness, and which quite often catches fire.

On account of the exposed position of the site, it was decided to erect a brick structure, although a timber B1-building was put on order in case site purchase proved to be rather lengthy. A test hole was then dug at the proposed position of the building, and showed that the peat was 4 ft 6 in. deep. As a structure the size of a B1-building was required, it was decided to modify a flooded-area-type B1-building. This required the reinforcement in the concrete raft to be increased so that it would stand on concrete walls formed by filling trenches in the peat with weak concrete. Concrete foundations were also required for the 187 ft 6 in. mast and the channelling for the aerial feeders from the mast to the cable-turning chamber in the side of the building.

In the meantime, the Ministry of Works were able to seek planning permission and negotiate for occupation of the site by 11 May. An access road, approximately 50 yd long, had then to be cut through 4 ft 6 in. of peat before the building could be started. Even so, construction work, including mast erection, was completed in nine weeks. Of the three concrete stay blocks provided, one required a deep excavation as the peat was 8 ft deep at that point.

Access to the main cable network was obtained by providing approximately ½ mile of 78 pr., 20 lb/mile cable from

the existing coaxial cable serving the I.T.A. station. As the site was exposed and liable to lightning discharges, an urgent order was placed for a supply of trunk-type polythene-insulated cable; this was supplied and laid by 21 July. Isolation transformers were also fitted on all pairs in the radio building, and lead-covered P.C.Q.T. cable was provided in the first length of the spur cable to act as a fusible link.

Arrangements were made to complete as much of the wiring of the line-termination cabinet as possible prior to actual installation in the radio building. Delays were experienced with some items of signalling equipment which had to be specially designed, since d.c. signalling was not possible on account of the line-isolation transformers. The radio and line-terminal installation was then completed in one week.

The station was finally ready for test on 23 July, just 10 weeks after the commencement of building work. This was made possible by the excellent co-operation given by all Post Office staff, the Ministry of Works, the building contractor, and last, but not least, the Lancashire weather.

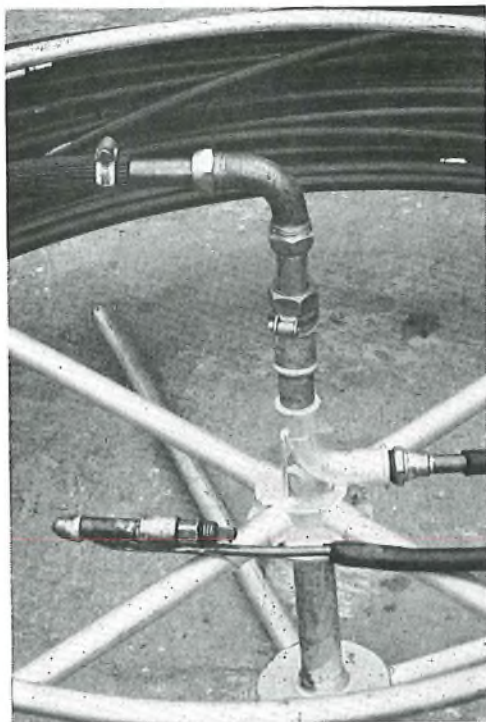
J. H. S. and G. E. T.

South Western Region

REMOVING SILT OBSTRUCTION FROM DUCTS

Considerable difficulty has been experienced during cabling operations in some Areas due to the ducts being blocked by the accumulation of silt. Research into this problem has shown that these obstructions can be removed by maintaining a high-pressure jet of water at the leading end of the rod as it is pushed along the duct, the silt being carried away by the returning flow of water.

An experimental method is being tried out in the Southampton Area which makes use of a continuous length of high-strength polythene tubing. The first trials were carried out with a tube having an internal bore of $\frac{1}{2}$ in. and an overall diameter of 0.686 in. Results over short lengths were encouraging but, owing to the increasing resistance between the tube and duct wall, there was a tendency for the tube to spiral and it could not be pushed beyond



ADAPTOR, COUPLING AND PART OF STORAGE REEL FOR TUBING

80-100 yd. For these longer lengths, this tube is now used in conjunction with continuous rods by lashing the two together at intervals. An adaptor has been constructed to carry the water from the tube to a jet fitted to the leading end of the rod, as shown in the photograph.

This led to trials with a much stronger tube of the same manufacture having an internal diameter of $\frac{3}{4}$ in. and an overall diameter of 1 in. This additional strength has enabled the tube to be pushed through obstructions up to 140 yd without difficulty, although when used in steel or cast-iron pipes this distance has been reduced to about 100 yd, due to the increased friction between the tube and rust on the wall of the pipe.

The tubing is stored inside a lightweight reel similar to that of the inner wheel of the continuous-rod reel but constructed of 1 in. electric-light conduit for lightness, and mounted to rotate on a central spindle; this lightweight construction enables it to be easily carried by two men.

From the first trials it was obvious that some form of universal coupling was required to enable the flow of water from the pump to the polythene tube to be maintained as the reel was being turned. The reel was, therefore, equipped with a universal coupling mounted at the centre, made up locally from a $\frac{3}{4}$ in. plumber's union packed with a polythene washer. This enables the coupling, shown in the photograph, to rotate while still maintaining a watertight joint, and to allow easy movement the metal cone-shaped faces inside the coupling are kept well greased.

Experiments have been carried out using water at various pressures from 10-12 lb/in² up to 80 lb/in². A Pegson Marlow 2 in. manhole pump was fitted with a modified outlet to convert it to supply water under pressure at approximately 10-12 lb/in². Whilst some progress was achieved with this low pressure it was found that by the time the water had passed through 500 ft of tubing the force of water was considerably reduced and the clearing of obstructions was rather slow.

A Beresford 1 in. petrol-driven centrifugal pump was hired locally. This pump is capable of giving pressures of up to 80 lb/in², depending upon the size of jet fitted at the end of the tube. This increased pressure produced a stronger jet of water, which gave a quicker washing action. A Beresford Set A 1 in. centrifugal pump, complete with pedestal and shaft extension, has now been purchased and fitted to an Alco generating-set frame. The pressure outlet has been equipped with a pressure gauge, output stop-cock to cut off the water pressure to avoid stopping the engine, and priming stop-cock to allow quick self-priming of the pump.

Water is frequently available at the site of operations from ponds or rivers, but where an ample supply is not available it is taken to the site in 40-gallon oil drums, three or four being sufficient according to the length to be cleared. The rates of water consumption are approximately 160 gallons per hour with a $\frac{1}{2}$ in. jet on the larger tube, and 80 gallons per hour with a $\frac{3}{8}$ in. jet on the smaller tube, the ends of the polythene tubes being fitted with couplings to allow the jets to be changed.

During the past nine months 1,600 yd of silted duct have been cleared by rodding from one or both ends with the polythene tubes, or with the tube lashed to the continuous rod. On no occasion has it been found necessary to break down the ducts, with the result that there has been a saving of an estimated total of 15-20 carriageway or footway openings. Naturally, a considerable amount of time was spent in endeavouring to rod in the conventional manner before transporting the equipment to the site, this preliminary work being unavoidable as the obstructions did not become apparent until the rodding operations commenced.

Although some of these experiments have not always proved to be economical, valuable experience has been gained and the time taken to effect a clearance has been reduced from about two days at the outset down to as little as three hours for similar lengths of duct.

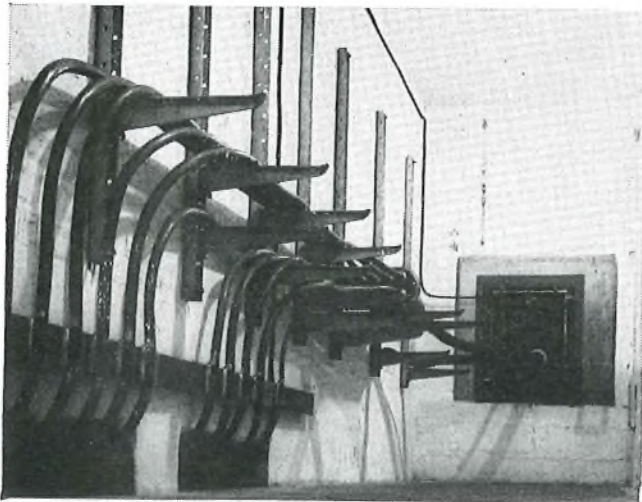
In the light of long-term experience, if the duct is in the grass margin and it is obvious that one opening would clear the trouble it may prove to be more economical to break down and clear the obstruction, although once the track is broken it is always a potential source of trouble, due to silt entering over a period of time. However, in the case of carriageway or footway openings the water-rod method is more economical, particularly where it saves breaking down a multi-way duct.

L. C. P.

OVERGROUND CABLE CHAMBER AT MEVAGISSEY

The site available at Mevagissey for a new U.A.X. 14 has an unusually high water table and spongy sub-soil. The Ministry of Works had, therefore, to adopt a shale-fill and concrete-raft form of construction, on which the building would float as a unit. The provision of a normal cable trench in the raft would have involved complicated and expensive grid construction. Discussions between the architect and Post Office engineers resulted in the adoption of a novel overground cable chamber, constructed as an abutment to the end of the standard Type F building.

The ducts were sloped up from the exchange manhole in the road to above ground level at the point of entry to the chamber. The cable joints were made on the wall of the chamber and the E.S. and W.C.Q. cables passed down through floor-level chutes to a shallow trench at the M.D.F.



CABLE CHAMBER AT MEVAGISSEY

No practical difficulties were experienced; jointing work was able to proceed without impairing access to the frame for terminating and jumpering, etc. The layout commends itself for consideration in cases of similar difficulty.

C. J. R.

RE-ALIGNMENT OF AERIAL-CABLE ROUTE

Because of road-widening works at Dean, Somerset, it was necessary to re-site an aerial-cable route over a distance of 1,300 yards. The cables involved were the 216 pr. 20 lb/mile Frome-Yeovil MU cable, weighing 11.6 cwt per 100 yd, and a 28 pr. 10 lb/mile subscribers' cable; these were carried on 7/10 and 7/14 suspension wires, respectively, with the MU cable on the hedge side of the 27 medium-class supporting poles.

From the outset, the planning group decided that the subscribers' cable would be interrupted and re-provided as a 75 pr. 6½ lb/mile development-size cable lashed to a new suspension wire on the hedge side of the re-aligned route. The other cable was to be moved sideways and supported on a new suspension wire on the road side of the new poles. The

method of accomplishing this sideways move without causing any interruption of service and without any undue expenditure was the subject of much discussion. The sequence of operations finally agreed, together with notes on the actual operation, are given below.

First, the new poles and associated stays were erected. These were put up with the same longitudinal spacing as that between existing ones, but the transverse separation varied from 6 in. to 25 ft. Then followed the erection and tensioning of the new 7/14 suspension wire to carry the subscribers' cable, and then this cable was interrupted and the new one was lashed to the new suspension wire. Next, the new 7/10 suspension wire was erected and tensioned ready for the transfer of the MU cable.

Tubular-steel scaffolding poles were then provided between each pair of old and new telephone poles. These scaffolding poles were lashed to steps fixed in such positions that the cross-supports passed from the steel suspension wire and the ringed cable on the old route, and finished approximately level with the new suspension wire on the new route. It was found by experience that no buckling occurred if the cross-member had an unsupported length of not more than 8 ft. Consequently, tubular-steel uprights were provided at this spacing, as necessary.

Blocks and tackle were fitted at the first five pairs of poles so that the transfer of the cable could be controlled when the retaining clamps were removed; as there were some large angles in the line of the original route these measures were essential. After all cross-members had been greased the old suspension wire was released from the first five clamps; because of the configuration of the road this was the best length to deal with at any one time. The cable and old suspension wire were eased into the new position and the cable was transferred to the new suspension wire using the old rings for re-ringing.

Finally, the old suspension wires and poles were recovered and the new cables cut-in. It had been envisaged that there would be some slack in the MU cable when in its new position and this proved to be the case. During the re-ringing this slack was worked from each end of the route towards a joint and this was then re-made and the slack eliminated.

The whole operation was accomplished without any interruption to service and 300 hours were saved on the estimate. This was largely made possible by the use of a Simons hydraulic platform for all the overhead work. It proved extremely valuable at all stages, particularly so during the actual moving and re-ringing operations. All the staff concerned deserve credit for their enthusiasm for an unusual project, and keenness never flagged despite a biting wind.

L. J. P. and D. W. P.

Midland Region

LIGHTNING DAMAGE AT BREWOOD

A distribution pole at Brewood, Staffordshire, where pole-top protection has been installed, was struck by lightning. It was witnessed by a subscriber who described the strike as a ball of fire moving along the open wires. The distribution pole, which was cross-armed and fed by a metallic-sheathed aerial cable, was protected by standard Protector-electrodes No. 1B inserted in the Insulators No. 16.

Nearly all the electrodes operated, including those at a power crossing approximately half a mile away, fuses were blown at some subscribers' premises, and other damage included open wire and pole leads burned through on isolated circuits, and internal wiring damaged at one subscriber's premises.

No damage was done to the metal-covered aerial cable. A new earth wire had been provided when the protective devices were fitted and this also was undamaged.

This case confirms that protection at the distribution pole will save cable damage, at the expense of a few electrodes.

G. A. R. M.

Associate Section Notes

London Centre

As the 1959-60 session drew to a close excitement increased and focused upon the two teams who had battled their way through to the final of the inter-Area technical quiz. The finalists, East Area and West Area, met at Waterloo Bridge House on 12 May. After such questions as "What are the advantages of battery testing?" and "What is the purpose of the 60 kc/s tone transmitted on 12-channel carrier groups?", East Area emerged the victors with 45½ points to West Area's 40½ points, out of a possible total of 60 points. Mr. Greening, our Regional Liaison Officer and Mr. Broadhurst, Liaison Officer of the Circuit Laboratory branch, in their capacity as referees, helped to make the evening entertaining as well as instructive by their judging of the answers given by the teams. Scores throughout the contest were consistently high, the average being over two-thirds of the possible marks, and in each round the winning team only narrowly beat their opponents. The quiz shield was presented to East Area by Mr. Greening at the annual general meeting of the London Centre in May. Now that interest has been aroused more Areas are planning to participate in a further contest which it is hoped will be arranged this session, while losers in the last contest look forward to success in a future match. The general purposes committee are at present engaged in compiling questions for future rounds and any assistance in this direction would be welcomed.

The annual general meeting was also the occasion for the first presentation of the C. W. Brown Award. The award, which keeps alive the memory of our first President, is, to quote the wording on the certificate, "given annually to the member who, in the opinion of the central committee, has contributed most to the ideals and aims of the Associate Section by loyal and enthusiastic service." It consists of a certificate and a cheque. Out of six recommendations from the L.T.R., Mr. W. M. Smyllie of West Area was chosen as the most suitable candidate.

The penultimate lecture of the 1958-59 session, entitled "Plastics and Their Applications," was given by Messrs. Ward and Newell of Ericsson Telephones, Ltd. After an introduction by Mr. Ward, we were taken on an imaginary tour of the Company's plastics factory at Beeston by Mr. Newell and shown the various stages of manufacture and equipment involved. The talk was illustrated by excellent colour slides. Examples of plastic mouldings were shown, their strength being forcefully demonstrated in several tests. The small attendance was thought to be due to last-minute preparations for the City and Guilds examinations. The concluding lecture, which preceded the annual general meeting, was given by Mr. D. L. Campbell of the B.B.C. and dealt with "Trick Work in Television Production." The lecture was supplemented by a film showing the various trick effects employed, and the lecturer's easy delivery and humour provided a fitting conclusion to the session. The 102 seats in the Mezzanine Theatre were filled to capacity.

Turning now to forthcoming lectures in the new session, the first, "Exploring Space," by Dr. T. A. Margerison of the magazine *New Scientist*, will be over by the time these words appear in print. The next, entitled "The Automatic Telex Service," to be given on 13 October by Messrs. E. E. Daniels and W. A. Ellis, Telegraph Branch, Engineering Department, will deal with the new "Twopenny Telex," and will cover the pilot scheme being operated between London and Leeds, and future developments in this rapidly expanding field of communications. On 11 November Mr. J. L. Garland, Long Distance Area, will be giving his lecture on "The Continental Semi-Automatic Switching Unit." This equipment, installed at Faraday Building, will ultimately enable operators in London to dial any European subscriber directly. The technical film show on 2 December

will include "Bridge across Space," "Fact and Fancy" and "Antarctic Crossing," the latter supplementing the "Trans-Antarctic Expedition" lecture by Mr. George Lowe that opened the last session.

The Circuit Laboratory radio group has obtained accommodation in the basement of Armour House, and after construction of the various benches they are pressing ahead with the setting up of a transmitter. The editorial section has also secured space in an adjoining store room and production of the new issue of the Quarterly Journal will start as soon as supplies of paper are available at the end of the printing dispute.

It is hoped that an initial order for the new Associate Section tie will shortly be placed. The order will depend upon acceptance of the manufacturer's sample after a check has been made to avoid duplication of any existing design.

No changes have taken place in the London Centre committee for the 1959-60 session. The officers and their Areas are: *Chairman*: Mr. A. G. Welling (North); *Vice-Chairman*: Mr. H. A. Horwood (West); *Treasurer*: Mr. W. C. Peck (City); *Secretary*: Mr. D. W. Webber (Circuit Laboratory); *Assistant Secretary*: Mr. W. H. C. Upton (South-West); *Librarian*: Mr. S. A. Challoner (South-West); *Radio Secretary*: Mr. E. R. Lamb (Circuit Laboratory); *Visit Secretary*: Mr. B. C. Hatch (Centre); *Editor*: Mr. E. S. Glynn (Circuit Laboratory).

D. W. W.

Cornwall Centre

The annual general meeting of the Cornwall Centre was held on 15 April 1959, at the "William IV," Truro. The following officers were elected: *President*: Mr. K. E. Spurlock; *Chairman*: Mr. D. Jenkin; *Vice-Chairman*: Mr. A. Furse; *Secretary*: Mr. A. R. Brown; *Treasurer*: Mr. D. L. Moore; *Committee*: Messrs. G. Tregilgas, H. Pearce, R. Sweet and K. Barlow.

The April meeting was a lecture on "Telephone Development in the Isles of Scilly," given by Messrs. S. T. Stevens and D. Moore (who deputized for Mr. Lanfear, absent on official business). May brought the first of the external visits, with a visit to Falmouth Docks which, in spite of bad weather, was well attended.

The highlight visit of the summer was on Saturday, 6 June, when a visit to the North Hessary Tor television transmitter and B.B.C. studios, Plymouth, was arranged. Some 75 members attended, the party being divided into two groups. The B.B.C. engineers arranged every facility, including an excellent lunch, to make this visit most successful.

A. R. B.

Glasgow and Scotland West Centre

At this point, the "closed season" of our session, there is very little obvious activity, the only sign of life being the circulation of periodicals and, behind the scenes, the arrangement of the 1959-60 program. We are endeavouring to increase the attendances at our lectures, and towards that end have appointed committee members who are well placed to contact their colleagues and keep them notified personally of all meetings, in addition to the normal circular letter and poster already in use.

The members of the committee are: *Chairman*: Mr. G. R. Lunn (Area Engineer); *Vice-Chairman*: Mr. R. T. Shanks; *Secretary*: Mr. J. Fleming; *Organizing Secretary*: Mr. W. Fotheringham; *Treasurer*: Mr. J. Murray; *Librarian*: Mr. J. Fuller; *Assistant Librarian*: Mr. A. C. Campbell; *Committee*: Messrs. J. Graham, K. Gordon, W. Goldie, J. Bell, E. Carty, J. R. A. Boag, C. Faith, A. Kerr and A. Anderson.

J. F.

Haverfordwest Centre

The annual general meeting of the Haverfordwest Centre was held on 5 May 1959 at the RAFA Club, Haverfordwest. The chairman reviewed the activities of the past year during which the centre had five lectures, one demonstration of Invicta stereophonic sound equipment and two film shows. The treasurer reported that the finances of the centre were very healthy and the membership was now 71.

The following were re-elected as officers and committee: *Chairman*: Mr. R. J. Jenkins; *Secretary*: Mr. J. H. G. Rees; *Treasurer*: Mr. B. J. Davies; *Committee*: Messrs. F. A. Loomes, E. G. Richards, E. V. George, J. I. Evans, A. J. Panton, S. C. Maule and E. R. Collins.

Up to the time of writing these notes the Centre's summer activities have included a couple of motor-car treasure hunts, which are very popular and a good means of augmenting the Centre funds. There has also been a conducted tour of the new oil-refinery site at Milford Haven, ending up with lunch at the Lord Nelson Hotel, by courtesy of The Esso Petroleum Co. This, too, proved to be very interesting and was well supported.

J. H. G. R.

Sunderland Centre

The annual general meeting in April was combined with a film show on the structure of motor vehicles, which was of great interest to the members present.

Officers for the coming year were elected and plans made for the 1959-60 session, when we again hope for a successful year and look forward to support from you all.

W. C.

Tunbridge Wells Centre

The annual general meeting was held in April at the Telephones Club, York Road, and the following officers were elected: *Chairman*: Mr. F. Archer; *Secretary*: Mr. D. Malcolm; *Assistant Secretary*: Mr. F. T. W. Payne; *Treasurer*: Mr. F. McGill; *Librarian*: Mr. J. Vidler; *Scribe*: Mr. R. A. Davey; *Auditors*: Mr. B. Ray and Mr. J. Vidler; *Committee*: Messrs. L. Summerfield, K. Muggerridge, S. Kirk, C. Coleville and R. Winn.

Membership is up to 195 and the average attendance at meetings, reading of papers and visits is about 30. In the coming year we aim to increase the latter figure by providing an interesting program and giving it wide publicity, e.g. displays on the notice boards in the Area, and membership cards for each member showing the full program for the year.

Last year's program included visits to the B.P. oil refinery at the Isle of Grain, Briggs Motor Bodies, Dagenham, and the Post Office Research Station, Dollis Hill. Of the seven papers read during the session, five of them were given by our own members. The subjects covered were: "Sales Duties," by Mr. Riley; "Auto Telephony," by Mr. F. Archer; "Works Supervision," by Mr. Harrison; "Cable Pressurization," by Mr. Wickenden; "Storage Batteries," by Mr. L. Hurst; "Cable Corrosion," by Mr. T. Light and "Carrier Telephony," by Mr. Vidler.

An interesting program is being arranged and the chairman and committee look forward to seeing members and prospective members during the coming session.

R. A. D.

Bradford Centre

The annual general meeting of the Centre took place on Thursday, 11 June 1959. The following officers were elected: *Chairman*: Mr. A. J. Procter-Blain; *Secretary*: Mr. R. C. Siddle; *Treasurer*: Miss E. P. Hawkins; *Librarian*: Mr. D. Relton; *Committee*: Messrs. E. Dennison, M. Firth, R. A. Gill, W. Burnett, M. Bleazard and R. Winterburn.

We are now arranging the program for the 1959-60 session when we hope to include visits to the I.T.A. studios

at Manchester, "Ernie" at Lytham-St-Annes, and the radio telescope at Jodrell Bank.

The membership of the Centre is now over 170 and we hope to be well supported in the coming session.

R. C. S.

Huddersfield Centre

The following program has been arranged for the 1959-60 session:

September: "Cable Development," by Mr. A. C. Holmes.

October: Afternoon visit to Manchester Ship Canal Co.

October: "Gardening," an illustrated talk by Mr. G. Howarth.

November: Evening visit to C.I.D. Block, West Riding Police, Wakefield.

December: "Outline of Amateur Radio," a demonstration and talk by Mr. G. Mallinson.

January: Afternoon visit to H. J. Heinz, Ltd., Kitt Green, Wigan.

February: "Sales and Service," by Mr. Stansfield.

March: Full-day visit to Automatic Telephone & Electric Co., Ltd., Liverpool.

April: Afternoon visit to Slazengers, Ltd., Horbury, Wakefield.

May: Annual general meeting.

Officials for the session have been elected as follows:

Chairman: Mr. P. H. Wade; *Treasurer*: Mr. B. B. Howell;

Secretary: Mr. D. Booth (Tel: Huddersfield 300, Extn. 46);

Journal Secretary: Mr. W. A. G. Cowling; *Committee*:

Messrs. A. Longstaff, B. Stephens and H. A. Burden

(Internal); Messrs. D. Harley, J. S. Nelson and J. Hirst (External).

D. B.

Leeds Centre

On Friday, 20 March 1959, members of the Leeds Centre paid a visit to Ericsson Telephones, Ltd., Beeston, Nottingham. The party travelled by coach and were welcomed at the factory by Mr. Mountney, who had arranged a very interesting tour of sections of topical interest. It was gratifying to see the rapid development which had taken place in extending the factory, and the increase in automation which was evident in all departments. It was interesting to see the precision methods which were in use for the production of the sensitive high-speed relay for guided-missile experiments. The tests which were carried out on these relays were very interesting, and the members of the party were fortunate in having their questions answered by the head of that particular department. Members were entertained to lunch and tea in the staff dining-room, and grateful thanks were conveyed to the company for a most enjoyable visit.

On Tuesday, 14 April, an illustrated talk, "Recent Developments in Aerial Cable Construction," by Mr. J. Bluring, External Plant and Protection Branch, Engineering Department, was given at the Griffin Hotel, Leeds. Mr. Bluring presented the subject in all its aspects, explaining the various methods of construction, coupled with the common faults which were frequently encountered. The talk was very well illustrated, and the chairman thanked Mr. Bluring for his visit and a most interesting talk.

The annual general meeting was held at the Griffin Hotel, Leeds, on Tuesday, 16 June 1959. The officers elected are: *Chairman*: Mr. C. Baker; *Secretary/Treasurer*: Mr. E. B. Lancaster; *Committee*: Messrs. Lancaster, Bateman, Crowther, Newton, Cotterill and Senior; *Librarian*: Mr. L. J. Harris. The evening was concluded by an illustrated talk by Mr. Knight, Director of Leeds Parks Department. The subject, "Some of my Favourite Plants," was of great interest to all, and much enthusiasm was shown in the question period by members seeking advice on their gardening problems.

The following program has been arranged for the 1959-60 session:

- 10 September 1959: "Coaxial Line Equipment Development," by Mr. W. G. Simpson, Research Branch, Engineering Department.
- 12 October 1959: "Transistors Illustrated," by Messrs. Gardner and Nicholson, Mullard Ltd., London.
- 18 November 1959: Full-day visit for 12 members to Mullard valve factory, Blackburn.
- 11 December 1959: Dinner and dance.
- 6 January 1960: Full-day visit to Manchester dock, to a boat, and to A. Guinness, Ltd., Manchester.
- 4 March 1960: Full-day visit to Chloride Batteries, Ltd., Clifton Works, Swinton, Manchester.
- 13 April 1960: "Subscriber Trunk Dialling," by Mr. T. Barker, North Eastern Regional Office.
- 31 May 1960: Annual general meeting and film show.
- 10 June 1960: Full-day visit to new factory of H. J. Heinz, Ltd., Wigan.

C. B.

Sheffield Centre

During April another visit was made to the Sheffield trunk exchange. Since the last occasion the telex automatic equipment and the junction tandem exchange have been brought into service, and these proved to be of particular interest to the 40 or so members and friends who attended. Refreshments, served in the canteen, made a welcome break for both guides and visitors in a very full program.

The annual general meeting was held during June, when the following officers were elected: *Chairman*: Mr. J. McInnes; *Vice-Chairman*: Mr. F. S. Brasher; *Secretary*: Mr. L. G. P. Farmer; *Assistant Secretary*: Mr. K. T. Gray; *Treasurer*: Mr. C. S. Sheperd; *Librarian*: Mr. G. Woodhouse; *Scribe*: Mr. J. E. Simons; *Registrar*: Mr. C. B. Gray; *Auditors*: Messrs. F. Bough and S. G. Cole. *Committee*: Messrs. J. H. Brown, S. Cottage, F. Gosling, A. Knowles, J. Watts, W. Wilks, G. T. Ridsdale and D. Ashton.

It was with regret that we accepted the resignation of Mr. G. T. Ridsdale from the office of secretary, and we should like to record our thanks for his enthusiastic work during the past two years, which have been particularly successful ones for the Sheffield Centre. Fortunately, we shall still have his services on the committee, on which he previously served for 11 years.

A visit to the Sheffield Fire Brigade Headquarters was offered at short notice, but we had no difficulty in finding a full quota of visitors who spent a most entertaining and instructive evening. We were amazed at the variety of vehicles, from a self-contained water tender with two small hose-reels for making a quick attack on a fire to a 6-hose pump and a 100 ft turntable ladder. The emergency tender carries a complete mobile workshop which can cope with anything from jacking up a tramcar to extracting a small boy's head from between iron railings.

In the control room the switchboard and fire-alarm circuit terminations were of particular interest. There seemed to be a prearranged plan of action for every type of fire, with arrangements to bring in help from outside authorities if required. It was interesting to note that the area covered by the brigade was determined in some cases, not by the city boundary, but by the area of those telephone exchanges whose "999" calls are routed into Sheffield.

We made another trip to Liverpool on 2 July, this time to

the works of British Insulated Callender's Cables at Prescott. Again a limited number of members visited the works, while the remainder, along with friends, spent the day in Liverpool. At the works, processing starts with the purification of the Rhodesian copper, which is then rolled into heavy-gauge wire either in the pure form or, after being compounded, as an alloy such as cadmium copper. The process of making mineral-insulated cable was particularly interesting. A cable-length starts as a 2 in. copper tube about 12 yd long. The centre cores, up to seven in number, are initially located in holes through a steel ram which runs the length of the outer tube. This is then raised to a vertical position and the insulant, magnesium-oxide powder, is fed in and compressed by the ram, which is gradually withdrawn. Finally, the whole assembly goes through a series of drawing and annealing processes until it is reduced to the desired gauge.

After lunch the afternoon was spent in the telephone-cable division, where we saw, from start to finish, almost every type of cable, from local distribution to coaxial, being made. An unexpected consequence of the printing strike was discovered—the manufacture of paper-cored cable might have been held up if the shortage of ink prevented printing of identification markings on the paper tape! We are greatly indebted to B.I.C.C. for an interesting visit coupled with first-class hospitality.

J. E. S.

London Power Centre

Preparations for the 1959-60 session are in hand. The biggest single problem confronting the secretary is, of course, to ensure the materialization of the technical discussion papers promised by members months ahead of the presentation dates.

The coming session should be good. With many papers in course of preparation and several already completed, it has been possible to program the first three months' meetings at the time of writing, viz.:

October 1959: "The Electronic Letter-Sorting Machine," by Mr. A. H. J. Towner.

November 1959: "Maintaining the E.L.S.M.," by Mr. J. Jarvis.

December 1959: "Domestic Hot-Water Supply," by Mr. T. M. Mitchell.

Provisionally programmed for the succeeding months we have:

January 1960: "Thermionic-Valve Amplifiers," by Mr. W. J. Titmarsh.

February 1960: "Semi-Conductor Rectifiers," by Mr. D. Winterbourne.

March 1960: "The New W.D.O.," by Mr. W. Sutton.

April 1960: "A New Look at the P.O. Railway," by Mr. A. G. Weech.

The program of monthly visits to manufacturing firms, etc., is being maintained and is as popular as ever.

The London Power Centre librarian now holds service data sheets and circuits for most makes of television receivers. These are available on loan to our members.

We were delighted to secure yet another award in the last essay competition and take this opportunity of congratulating Mr. B. D. Lock for his efforts on behalf of the London Power Centre.

P. J. F.

Staff Changes

Promotions

Name	Region	Date	Name	Region	Date
<i>Staff Engineer to Assistant Engineer-in-Chief</i>			<i>Assistant Engineer (Limited Competition)—continued</i>		
Jones, R. E.	E.-in-C.O.	1.9.59	Hall, B. E.	E.-in-C.O.	4.5.59
<i>Staff Engineer to Deputy Director</i>			Pope, D. G.	E.T.E. to E.-in-C.O.	4.5.59
Gould, E. F. H.	E.-in-C.O. to E.T.E.	19.9.59	Murphy, J.	L.T. Reg.	4.5.59
<i>Regional Engineer to Chief Regional Engineer</i>			Hansford, D. J.	E.T.E.	4.5.59
Lucas, F. N.	Scot. to N.W. Reg.	4.8.59	Green, R. A.	L.T. Reg.	4.5.59
<i>Assistant Staff Engineer to Staff Engineer</i>			Aviss, H. W.	H.C. Reg. to E.-in-C.O.	4.5.59
Francis, H. E.	E.-in-C.O.	1.9.59	Gorton, R. K.	N.W. Reg.	4.5.59
Balcombe, J.	E.-in-C.O.	19.9.59	Fielding, F. W.	L.T. Reg. to L.P. Reg.	4.5.59
<i>Area Engineer to Assistant Staff Engineer</i>			Turner, J. E. L.	E.-in-C.O.	25.5.59
Knee, H.	S.W. Reg. to E.-in-C.O.	20.7.59	Musgrave, K. G.	Mid. Reg. to W.B.C.	25.5.59
<i>Area Engineer to Regional Engineer</i>			Clark, G. W.	E.-in-C.O.	25.5.59
Dixon, J.	N.W. Reg. to W.B.C.	10.8.59	Pemberton, J.	E.-in-C.O. to W.B.C.	25.5.59
<i>Senior Executive Engineer to Regional Engineer</i>			Hazell, R. J.	S.W. Reg.	25.5.59
Adams, W. E.	E.-in-C.O. to Scot.	4.8.59	Burns, R. A.	N.W. Reg. to N.E. Reg.	25.5.59
<i>Executive Engineer to Area Engineer</i>			Yates, R. F.	E.-in-C.O.	4.5.59
Sims, A. E. J.	L.T. Reg.	8.4.59	Moon, R. J.	E.-in-C.O.	25.5.59
Smith, F. J.	L.T. Reg.	24.4.59	Harper, R. D.	E.-in-C.O.	4.5.59
<i>Executive Engineer to Senior Executive Engineer</i>			Nolan, A. V.	N.W. Reg. to Scot.	4.5.59
Lamb, A. H.	N.E. Reg.	4.6.59	Kerry, W. C.	L.T. Reg. to E.-in-C.O.	4.5.59
Halkes, G. R. H.	E.-in-C.O.	6.7.59	Williams, R.	W.B.C. to Mid. Reg.	25.5.59
Chick, P. G. S.	E.-in-C.O.	13.7.59	Fewtrell, S. V.	L.T. Reg. to E.-in-C.O.	25.5.59
<i>Executive Engineer (Open Competition)</i>			Steele, M. R.	S.W. Reg. to Mid. Reg.	25.5.59
Meads, E. F.	E.-in-C.O.	2.6.59	Gardner, D. J.	E.-in-C.O.	4.5.59
Fiddes, R. G.	E.-in-C.O.	29.6.59	Adcock, D. P.	L.T. Reg. to E.-in-C.O.	25.5.59
<i>Assistant Engineer to Executive Engineer</i>			Westlake, N. B.	L.T. Reg.	25.5.59
Search, C. J.	H.C. Reg.	11.5.59	Trowell, N.	L.T. Reg. to E.-in-C.O.	25.5.59
Watson, G. G.	H.C. Reg.	24.4.59	<i>Inspector to Assistant Engineer</i>		
Goodall, W. G.	E.-in-C.O.	24.4.59	Williams, D.	W.B.C.	19.5.59
Newman, W. L.	L.T. Reg.	24.4.59	Jennings, M. W. E.	L.T. Reg. to L.P. Reg.	22.5.59
Byrne, S. H. L.	L.T. Reg.	24.4.59	Caloe, S. J.	N.W. Reg.	20.7.59
Cawood, R. J.	N.E. Reg.	22.5.59	<i>Technical Officer to Assistant Engineer</i>		
Clark, R.	N.E. Reg.	20.5.59	Bennet, W.	Scot.	27.4.59
Donohue, C. P.	E.T.E.	20.5.59	Whitehead, H.	N.E. Reg.	14.5.59
Anderton, C.	E.T.E.	20.5.59	Bourne, A. T.	Mid. Reg.	28.4.59
Walter, A. C.	L.T. Reg.	8.6.59	Waite, K. I.	Mid. Reg.	28.4.59
Mawsley, A. T.	N.W. Reg.	1.7.59	Beswick, W. S.	Mid. Reg.	28.4.59
Howes, F. L.	W.B.C.	4.8.59	Randall, J.	Mid. Reg.	28.4.59
Roberts, W. A.	L.T. Reg.	10.7.59	Crockett, G. C.	Mid. Reg.	28.4.59
Searle, P. R.	E.-in-C.O.	22.7.59	Wilson, G. L.	E.-in-C.O.	28.5.59
Redman, F. W. G.	E.-in-C.O.	16.7.59	Scanlan, W.	N.W. Reg. to E.-in-C.O.	28.5.59
Allan, T.	E.-in-C.O.	16.7.59	Ballingar, R. W.	L.T. Reg. to E.-in-C.O.	28.5.59
Warburton, D.	E.-in-C.O.	16.7.59	Sears, R. J.	W.B.C. to E.-in-C.O.	28.5.59
Cooper, G.	E.-in-C.O.	16.7.59	Kitsell, J. H.	E.-in-C.O.	28.5.59
Holmes, T. E.	E.-in-C.O.	16.7.59	Naisbitt, R. D.	L.T. Reg. to E.-in-C.O.	28.5.59
Gorton, B. D.	E.-in-C.O.	16.7.59	Watcham, S. A.	H.C. Reg. to E.-in-C.O.	28.5.59
Watkins, A. H.	H.C. Reg. to E.-in-C.O.	25.7.59	Kilsby, K. B.	L.T. Reg. to E.-in-C.O.	28.5.59
Longmore, D. S.	E.-in-C.O.	16.7.59	Richards, J. P.	E.-in-C.O.	28.5.59
Spencer, H. H.	S.W. Reg.	8.7.59	Kenyon, G.	N.W. Reg.	21.5.59
Halliday, C. M.	E.-in-C.O.	30.7.59	Bowers, W. J. R.	Scot.	10.3.59
Pattemore, T. E.	E.-in-C.O.	30.7.59	<i>(In absentia)</i>		
Wait, D. W.	L.T. Reg. to E.-in-C.O.	25.7.59	Spencer, C. L.	L.P. Reg.	5.5.59
Baker, A. E.	E.-in-C.O.	25.7.59	Scott, R. J.	L.P. Reg.	5.5.59
Fensom, H. W.	E.-in-C.O.	25.7.59	Farquhar, W. H.	H.C. Reg.	11.6.59
<i>Assistant Engineer (Open Competition)</i>			Felgate, J. E.	H.C. Reg.	11.6.59
Spittle, A. H.	E.-in-C.O.	26.3.59	Coles, R. W.	E.T.E.	5.5.59
Askew, J. B.	S.W. Reg.	1.4.59	Webb, J.	N.E. Reg.	1.6.59
Weatherburn, R.	E.-in-C.O.	6.7.59	Southgate, G. F.	N.E. Reg.	22.6.59
<i>Assistant Engineer (Limited Competition)</i>			Perrin, F. D.	E.T.E.	24.6.59
Gibbons, A. K.	E.-in-C.O.	4.5.59	Edmonds, A. W.	Mid. Reg.	28.7.59
Day, L. R.	S.W. Reg.	4.5.59	Roberts, G. A.	N.W. Reg. to E.-in-C.O.	24.8.59
Brice, G.	S.W. Reg.	4.5.59	Gorard, S. R.	L.T. Reg. to E.-in-C.O.	6.7.59
Yaxley, A. F.	E.-in-C.O. to H.C. Reg.	4.5.59	Brennan, J.	N.I. to E.-in-C.O.	20.7.59
Meikle, A. G.	S.W. Reg. to E.-in-C.O.	4.5.59	Lawrence, D. A.	E.-in-C.O.	6.7.59
Moon, G. N.	E.-in-C.O. to L.T. Reg.	4.5.59	Green, D. C.	L.T. Reg. to E.-in-C.O.	13.7.59
Holland, D.	N.W. Reg.	25.5.59	Richardson, F. D.	E.T.E.	24.6.59
			Milton, D. L.	S.W. Reg. to E.-in-C.O.	17.8.59
			Haarer, J. A.	L.T. Reg. to E.-in-C.O.	6.7.59
			Holloway, E. E.	L.T. Reg. to E.-in-C.O.	6.7.59
			Wall, H.	E.-in-C.O.	6.7.59
			Palmer, G. B.	E.-in-C.O.	10.8.59
			Baker, L. R.	H.C. Reg.	20.7.59
			Bryant, K. J.	H.C. Reg.	7.7.59
			White, W. J.	H.C. Reg.	7.7.59

Promotions—continued

Name	Region	Date	Name	Region	Date
<i>Technical Officer to Assistant Engineer—continued</i>			<i>Experimental Officer to Senior Experimental Officer</i>		
Govan, J. G.	L.T. Reg.	7.7.59	Brook, H. D.	E.-in-C.O.	24.6.59
Thompson, D. A.	L.T. Reg.	7.7.59	Sheppard, N. F.	E.-in-C.O.	24.6.59
Robinson, W. H.	L.T. Reg.	7.7.59	<i>Assistant Experimental Officer to Experimental Officer</i>		
Blackwell, D.	L.T. Reg.	7.7.59	Howard, J. B. (Miss)	E.-in-C.O.	26.5.59
Hill, A. F.	L.T. Reg.	7.7.59	Nye, D. A.	E.-in-C.O.	26.5.59
Lea, E. J.	N.E. Reg.	20.7.59	James, D. T.	E.-in-C.O.	26.5.59
Bear, L.	N.E. Reg.	20.7.59	Schroder, C. R.	E.-in-C.O.	26.5.59
Booth, E.	N.E. Reg.	20.7.59	<i>Scientific Officer (Open Competition)</i>		
Lawson, J. I.	N.E. Reg.	20.7.59	Jones, J. I. (Miss)	E.-in-C.O.	7.5.59
Bulmer, E.	N.W. Reg.	20.7.59	<i>Assistant Experimental Officer (Open Competition)</i>		
<i>Technical Officer to Inspector</i>			Fudge, A. D.	E.-in-C.O.	3.6.59
Hopkinson, R. R.	N.E. Reg.	15.4.59	Birkby, J. W.	E.-in-C.O.	22.6.59
Wheeler, H. C. B.	L.T. Reg.	13.5.59	<i>Assistant (Scientific) (Open Competition)</i>		
Levesley, L. C.	N.W. Reg.	21.5.59	Smith, A. F.	E.-in-C.O.	3.6.59
Basey, G. W.	H.C. Reg.	15.6.59	<i>Workshop Supervisor I to Technical Assistant II</i>		
<i>Technician I to Inspector</i>			Reynolds, W. B.	H.C. Reg. to London Reg.	5.6.59
Pearson, J. B.	N.E. Reg.	15.4.59	<i>Leading Draughtsman to Senior Draughtsman</i>		
McMahon, T.	N.E. Reg.	29.4.59	Edwards, H. G.	W.B.C.	9.6.59
Goode, D. W.	N.E. Reg.	26.4.59	<i>Draughtsman to Leading Draughtsman</i>		
Taylor, F. W.	L.T. Reg.	1.5.59	Jones, R. G.	E.-in-C.O.	18.6.59
Green, H. E.	L.T. Reg.	13.5.59	<i>Higher Executive Officer to Senior Executive Officer</i>		
Scott, S. H. A.	L.T. Reg.	14.6.59	Duncan, W. B.	E.-in-C.O.	10.7.59
Ironsides, T. J.	L.T. Reg.	13.5.59	<i>Executive Officer to Higher Executive Officer</i>		
Bumpus, S. W.	H.C. Reg.	15.6.59	Tucker, F. Y. (Miss)	E.-in-C.O.	10.7.59
Jestico, R. E.	H.C. Reg.	7.7.59			
Johnson, H.	Mid. Reg.	30.6.59			
Dawkes, H. E.	L.T. Reg.	7.7.59			
Higgins, A. J.	L.T. Reg.	7.7.59			
Hirst, A. E.	N.E. Reg.	18.6.59			
Moorhouse, J.	N.W. Reg.	14.7.59			
Fish, J.	N.W. Reg.	14.7.59			
Harrison, K. R.	N.W. Reg.	22.7.59			

Retirements and Resignations

Name	Region	Date	Name	Region	Date
<i>Assistant Engineer-in-Chief</i>			<i>Assistant Engineer—continued</i>		
Warren, A. C.	E.-in-C.O.	31.8.59	Grimmitt, T. W.	Mid. Reg.	31.5.59
<i>Chief Regional Engineer</i>			Titmarsh, G.	H.C. Reg.	31.5.59
Davis, H. G.	N.W. Reg.	31.7.59	Jago, R. T.	L.T. Reg.	6.6.59
<i>Senior Executive Engineer</i>			Graham, J. M.	Scot.	8.6.59
Stone, M. C.	E.-in-C.O.	21.7.59	Rumary, F. J.	S.W. Reg.	25.6.59
<i>Executive Engineer</i>			Harrison, H. G.	S.W. Reg.	28.6.59
Sharps, C.	E.T.E.	19.4.59	Singleton, W. H.	E.T.E.	16.6.59
Pyman, F. A. M.	L.T. Reg.	30.4.59	Rawlinson, W.	N.E. Reg.	2.7.59
Williams, J. E.	S.W. Reg.	1.5.59	Webb, C. D.	S.W. Reg.	7.7.59
Sawyer, R. H. W.	H.C. Reg.	9.5.59	Wyatt, E. J. R.	L.T. Reg.	31.7.59
Bogg, A.	E.-in-C.O.	11.5.59	Johnson, C. W.	N.E. Reg.	31.7.59
Clayton, W.	N.E. Reg.	21.5.59	Cudmore, T. W.	H.C. Reg.	28.8.59
Biggers, P. S. S.	Scot.	8.6.59	Cooper, H. L.	H.C. Reg.	31.8.59
Watt, J.	E.-in-C.O.	15.6.59	<i>Inspector</i>		
Ross, J. D. (Resigned)	E.-in-C.O.	8.5.59	Penington, W. I.	N.W. Reg.	31.12.58
Iles, S. B.	N.W. Reg.	30.6.59	Bollard, C.	L.T. Reg.	17.2.59
Fox, W. H.	E.-in-C.O.	19.7.59	Campbell, J.	Scot.	7.2.59
<i>Assistant Engineer</i>			Nunn, N. E.	H.C. Reg.	8.3.59
Pitt, R. F.	E.-in-C.O.	9.4.59	Guile, F. J.	H.C. Reg.	2.4.59
Boyes, T.	Mid. Reg.	9.4.59	Mercer, H. H.	N.W. Reg.	28.2.59
Anson, T. A.	N.E. Reg.	13.4.59	Longbottom, G. R.	N.E. Reg.	9.4.59
Henson, F. B.	Mid. Reg.	24.4.59	Alexander, L.	L.T. Reg.	18.4.59
Nall, W. A.	Mid. Reg.	30.4.59	Jewes, F. T.	N.E. Reg.	25.4.59
Christopher, F. J.	H.C. Reg.	5.5.59	Cowell, F. H.	N.E. Reg.	28.4.59
Green, D.	N.E. Reg.	2.5.59	Hubble, B.	L.T. Reg.	7.5.59
Massey, G. O.	Scot.	2.5.59	Juden, L. J.	L.T. Reg.	10.5.59
Searle, E. L.	L.T. Reg.	5.5.59	Greaves, H. C.	N.E. Reg.	14.5.59
Downs, A. E.	L.T. Reg.	11.5.59	Pringle, C.	H.C. Reg.	31.5.59
Smith, J. P.	N.E. Reg.	15.5.59	Sansom, W. S.	S.W. Reg.	1.6.59
White, H. S.	E.-in-C.O.	18.5.59	Lines, F. W. G.	L.T. Reg.	8.6.59
Adams, W.	N.E. Reg.	22.5.59	Cross, J. W.	L.T. Reg.	13.6.59
			Clewer, R. W. H.	Mid. Reg.	18.6.59
			Palmer, R. C.	L.T. Reg.	30.4.59
			Cross, F. C.	W.B.C.	31.7.59

Retirements and Resignations—continued

Name	Region	Date	Name	Region	Date
<i>Experimental Officer</i>			<i>Assistant Regional Motor Transport Officer</i>		
Warren, R. E... (Resigned)	E.-in-C.O.	30.6.59	Waterfield, A. J. B. ..	London Reg.	9.4.59
			Mathewson, F. J. ..	N.E. Reg.	15.5.59
<i>Assistant Experimental Officer</i>			<i>Senior Draughtsman</i>		
Little, D. J. (Resigned)	E.-in-C.O.	30.1.59	Brown, J. F. ..	W.B.C.	8.4.59
<i>Assistant (Scientific)</i>			<i>Leading Draughtsman</i>		
Garrett, B. V. (Resigned)	E.-in-C.O.	29.5.59	Clipsone, H. G. ..	E.-in-C.O.	31.5.59
Guthrie, A. G. A. ..	E.-in-C.O.	30.6.59	Storry, S. C. ..	Scot.	10.6.59
(Resigned)			<i>Higher Executive Officer</i>		
			Lyndoe, H. G. ..	E.-in-C.O.	23.1.59

Transfers

Name	Region	Date	Name	Region	Date
<i>Assistant Staff Engineer</i>			<i>Assistant Engineer</i>		
Jackman, A. J. ..	E.-in-C.O. to L.T. Reg.	1.6.59	Foster, G. J. ..	E.-in-C.O. to Foreign Office	2.2.59
<i>Regional Engineer</i>			King, F. A. ..	E.-in-C.O. to L.T. Reg.	23.3.59
Greening, F. C. G. ..	L.T. Reg. to E.-in-C.O.	1.6.59	Morgan, E. P. ..	W.B.C. to Foreign Office	1.2.59
<i>Senior Executive Engineer</i>			Feltham, D. R. ..	E.-in-C.O. to H.C. Reg.	20.4.59
Rattue, P. J. ..	H.C. Reg. to War Office	20.5.59	Barker, A. L. ..	E.-in-C.O. to Foreign Office	27.4.59
Harris, D. J. ..	E.-in-C.O. to H.C. Reg.	6.7.59	Sheldon, W. ..	Pakistan to E.-in-C.O.	6.5.59
<i>Executive Engineer</i>			Adcock, D. P. ..	E.-in-C.O. to L.T. Reg.	23.6.59
Adams, L. J. ..	E.-in-C.O. to L.T. Reg.	1.5.59	Kerry, W. C. ..	E.-in-C.O. to L.T. Reg.	23.6.59
Robinson, J. T. ..	L.P. Reg. to War Office	19.5.59	Millard, C. N. ..	E.-in-C.O. to H.C. Reg.	4.8.59
Greenall, J. ..	E.-in-C.O. to L.P. Reg.	6.7.59	<i>Assistant Experimental Officer</i>		
Kyme, R. C. ..	Nigeria to E.-in-C.O.	1.7.59	Biggs, K. J. ..	E.-in-C.O. to Min. of Supply	9.3.59
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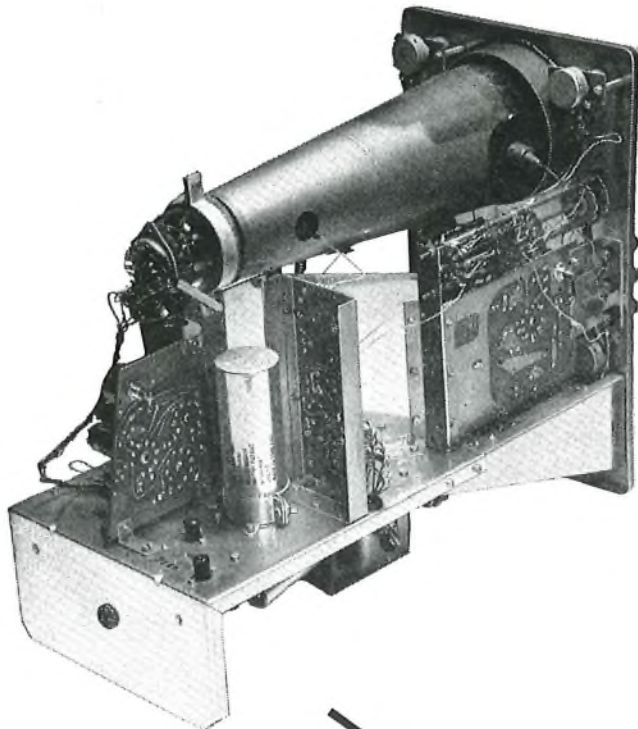
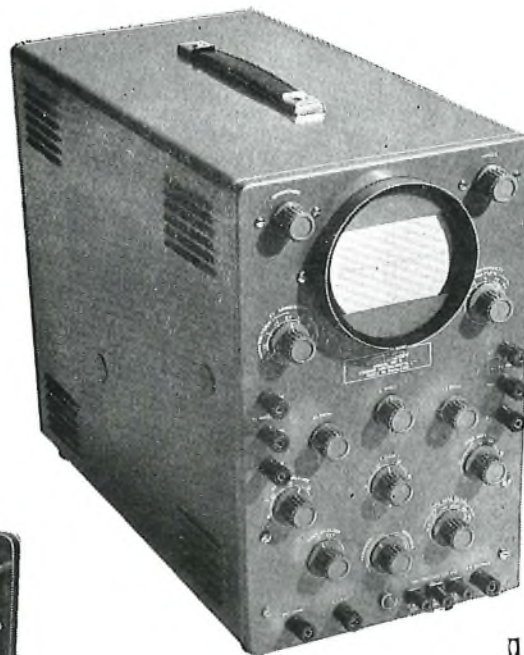
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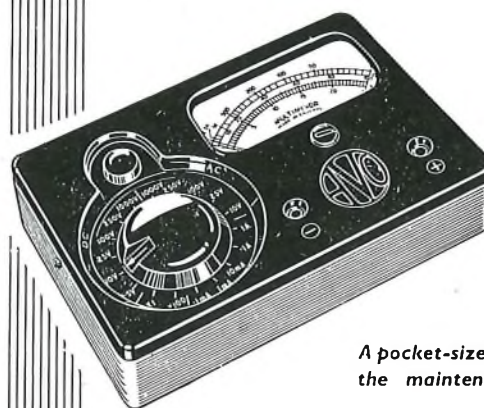
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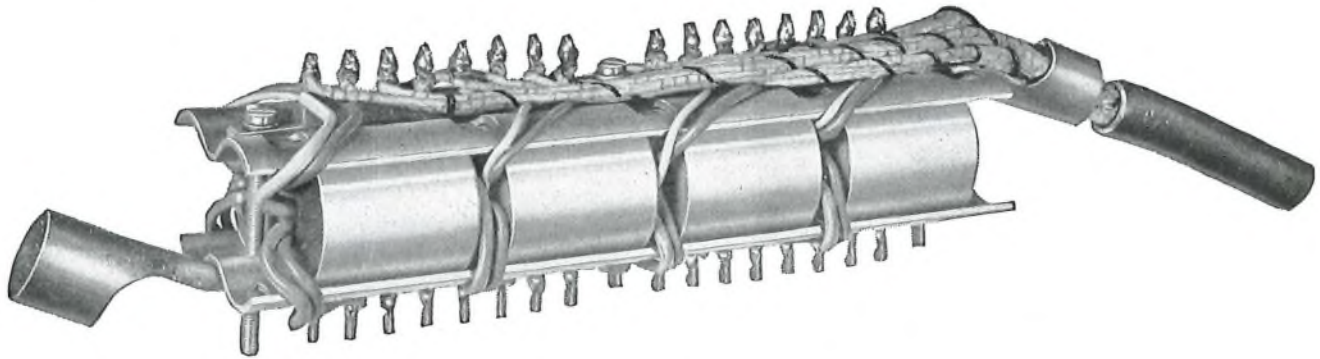
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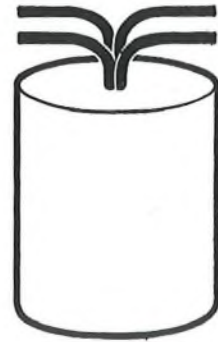


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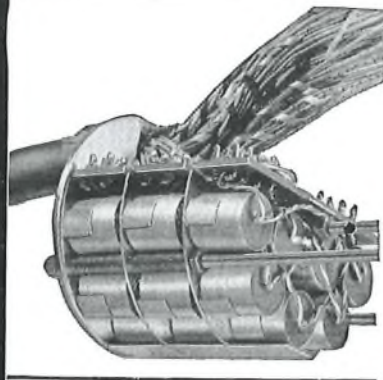
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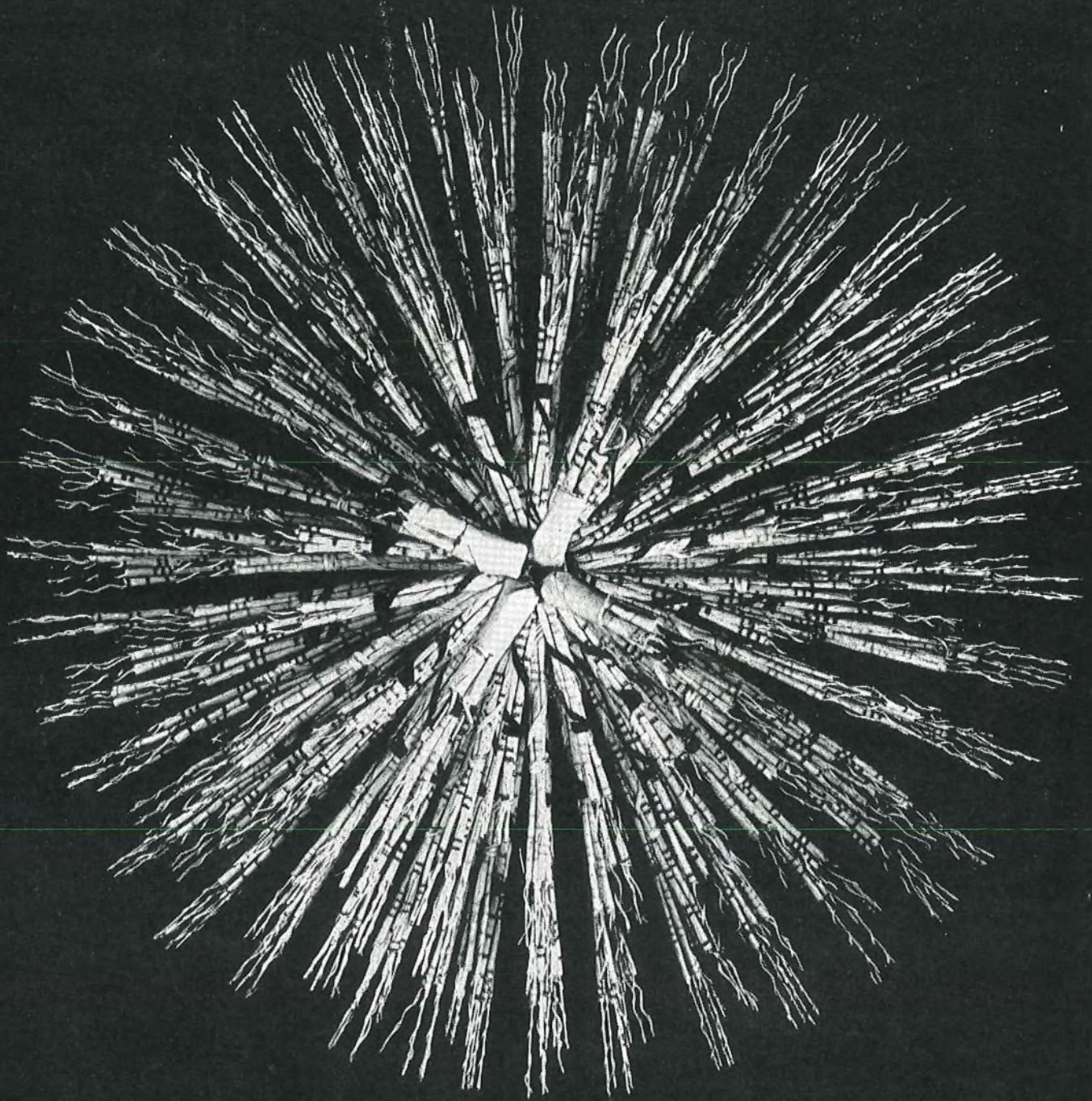
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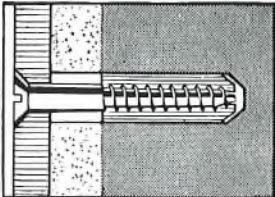
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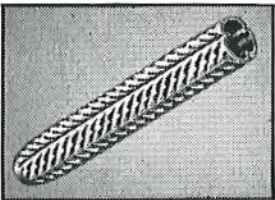
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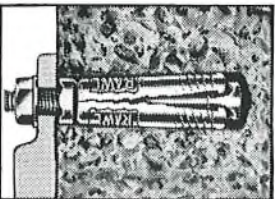
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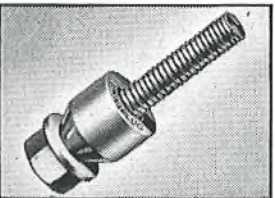
For firm Screw Fixings. The specially treated fibrous construction of the Rawlplug provides the most effective stronghold for wood-screws in any masonry. The simple method of making the hole, inserting the Rawlplug and driving home the screw enables firm fixings to be made quickly without mess or damage to walls or decorations. Sizes are from the tiny No. 3 to the 1" diameter No. 30.



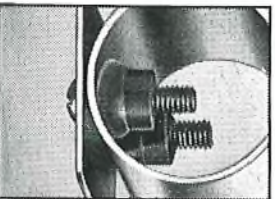
On the occasions where a metal plug is preferred or advised, such as for wet or acid situations, there is the choice of Rawlplug Screw Anchors or White Bronze Plugs, but for these Cadmium plated screws should be used.



Heavy Duty Fixings. RAWLBOLTS are expansion bolts which only require a hole in the masonry in the same way as a Rawlplug. By turning the bolt the metal segments are locked within the hole and the fixing will take very heavy loads with complete safety. Sizes are from 3/16" to 1" diameter.

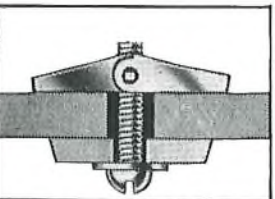


Wet or Acid Situations. Rawlplug Bolt Anchors and Rawltamps are made for heavy duty bolt fixings in places where the exposure to corrosion is extremely high. The Bolt Anchor can be set deep down in thick concrete whereas the Rawltamp enables a threaded insert to be fixed in shallow concrete.



Thin or Cavity Walls. Proprietary building materials often present fixing problems because of being either hard and thin or thick and soft. The Rawlplug Company have devised several clever devices for making firm fixings to such materials including lath and plaster ceilings, hollow pot, panel doors, etc.

The upper illustration shows how one of the devices will make the almost impossible fixing of a metal plate to a pipe and the bottom illustration shows how the wings of a Spring Toggle spread the load over a plasterboard ceiling.



Rawlplug Fixing Devices and Hole Boring Tools are sold by Ironmongers, Hardware Dealers, Builders Merchants and Stores. If you experience any difficulty in obtaining the type and size you require please send details to the following address.

Rawldrills. Standard sizes for Rawlplugs Nos. 3 to 30 and Rawlbolts A. B. C. D. E. and G. Adaptable Rawldrills need only three holders for the 10 sizes Nos. 3 to 22. There is also a very useful Universal Tool-set with a knurled holder to take Universal Rawldrills Nos. 6 to 20.

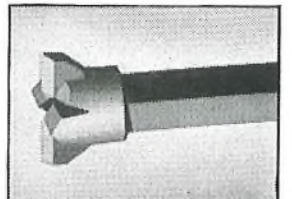
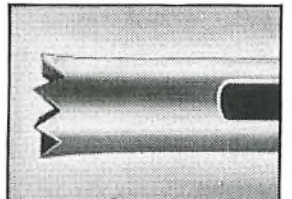
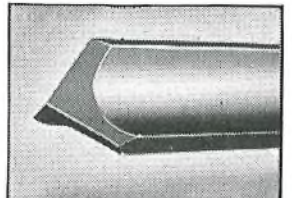
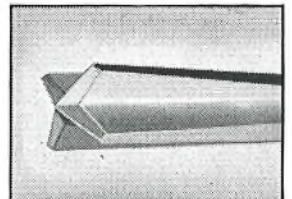
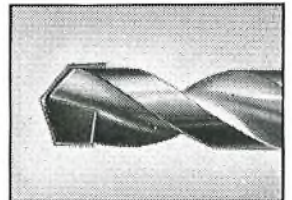
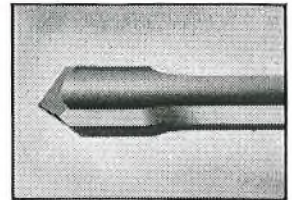
Durium tipped Drills. For faster, silent penetration of masonry and tiles Durium drills are the answer. They can be used in hand or suitable electric drills. Sizes for Rawlplugs Nos. 6 to 30; for C. D. E. and G. Rawlbolts, and a long series for drilling right through walls. Free resharpening Voucher given with every Durium drill.

Rawlplug Stardrills. An inexpensive one piece tool for use on jobs needing a small number of holes. Twenty sizes from 1 1/32" to 2 1/8" are made, of which eight are for Rawlbolts "A" to "K", and it is only necessary to quote the reference letters of the Rawlbolts when ordering Stardrills to use with them.

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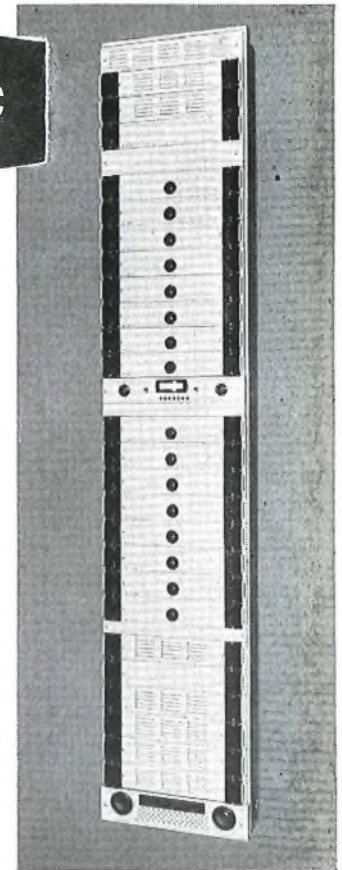
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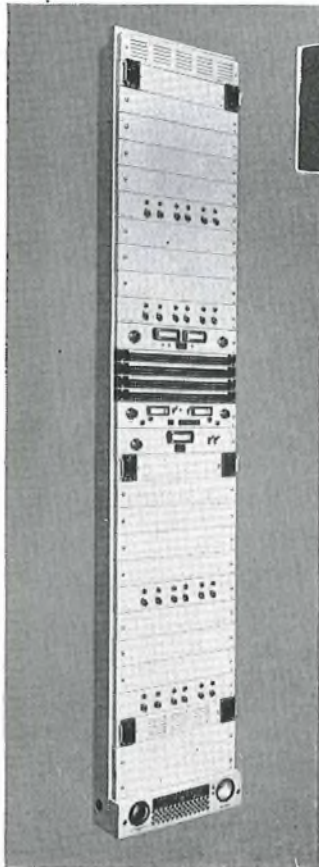
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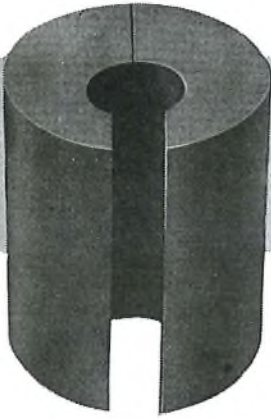
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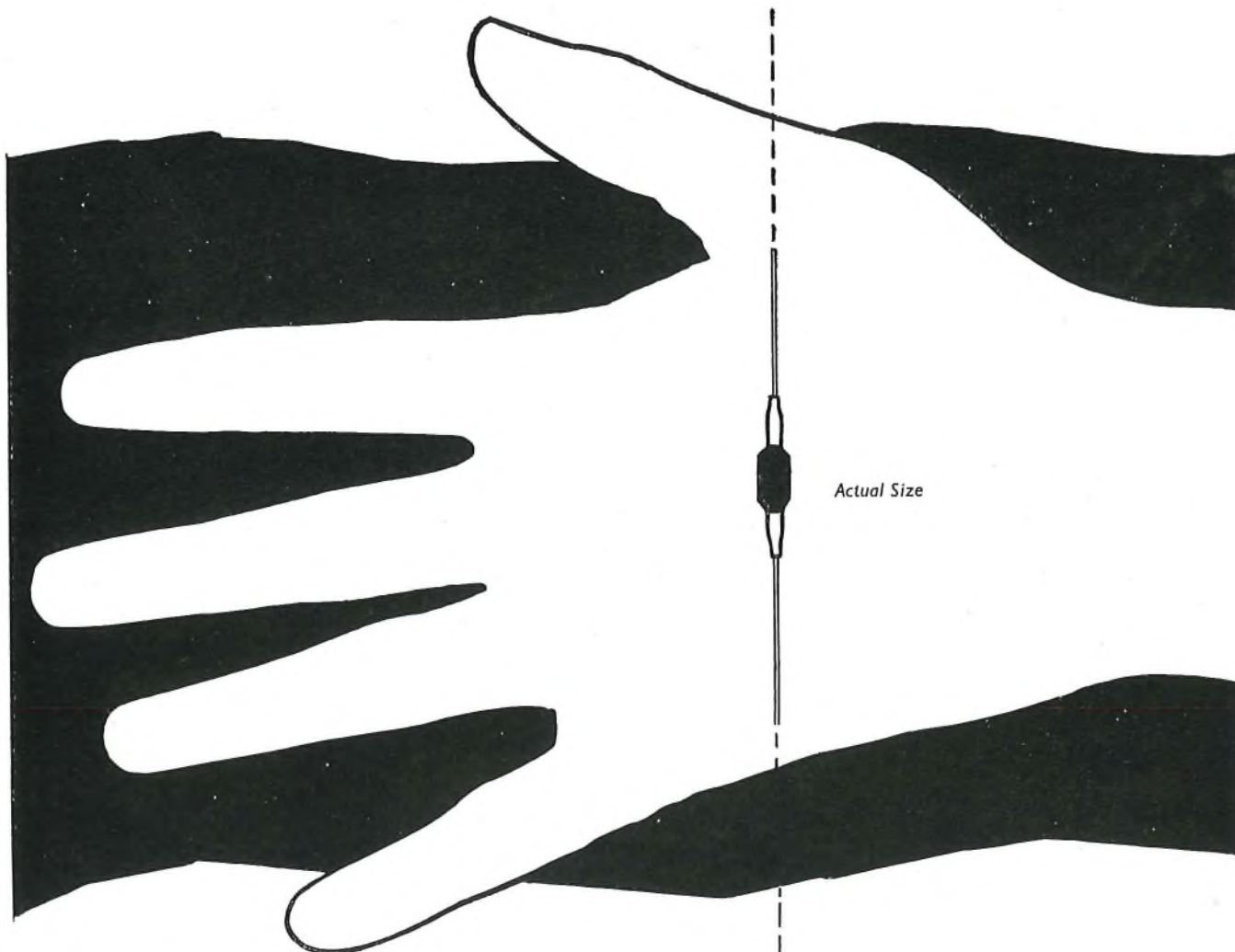
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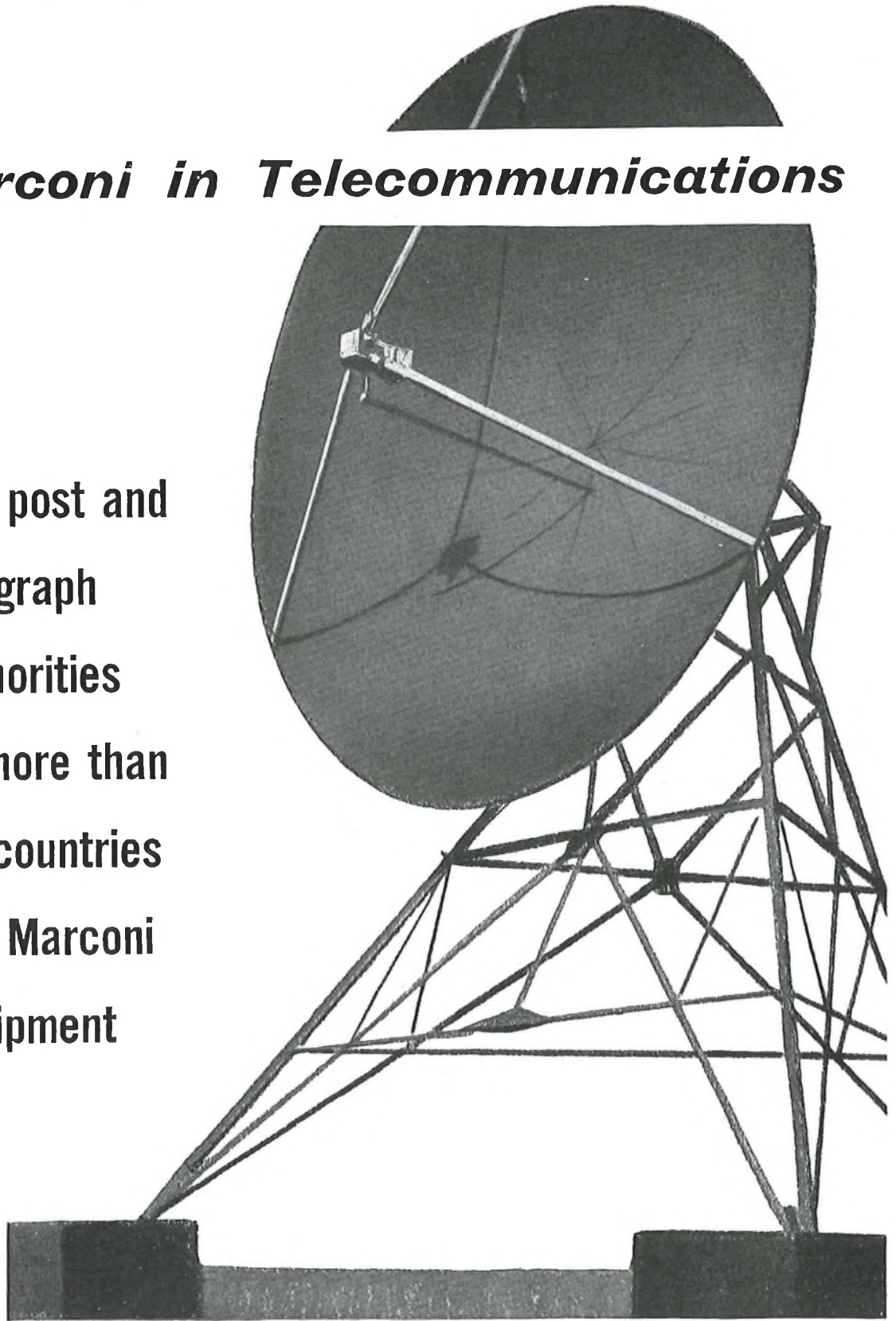
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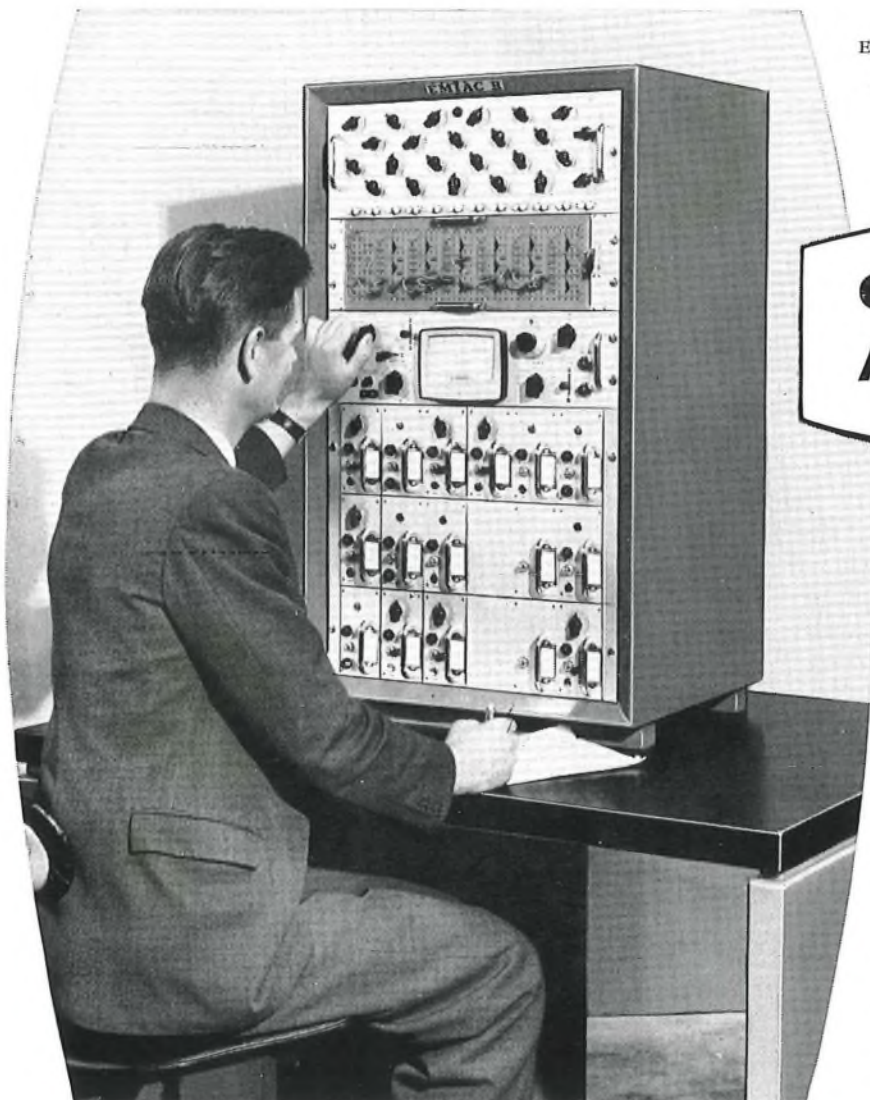
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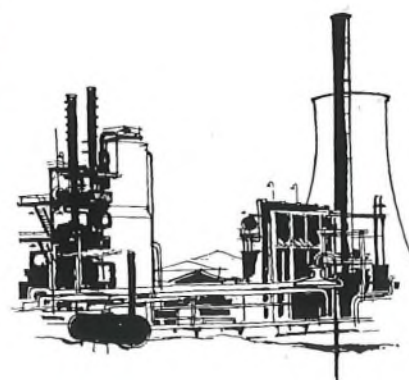
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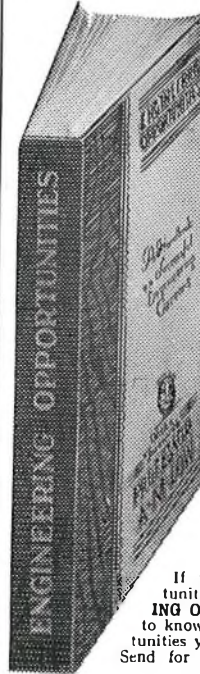
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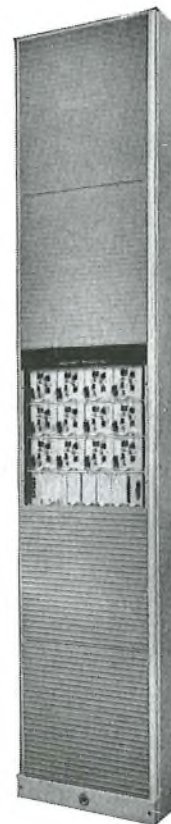
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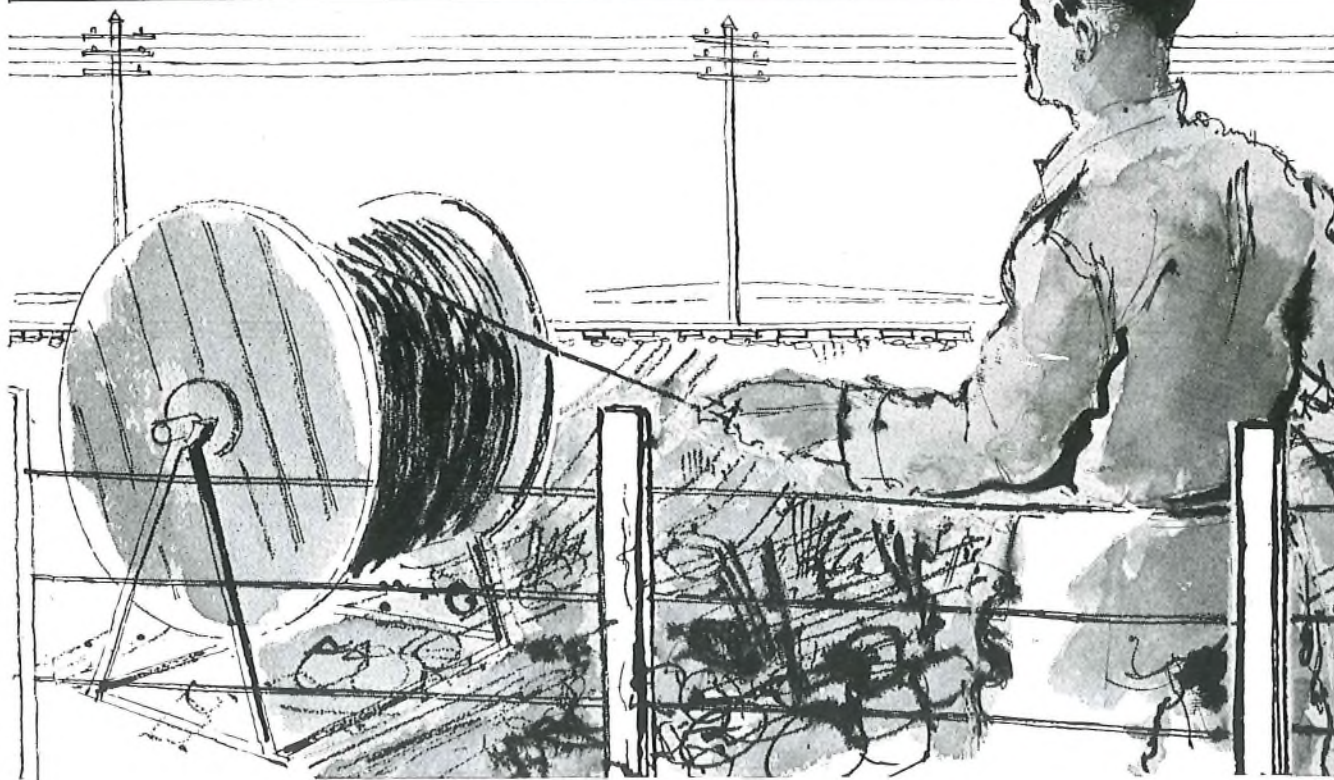
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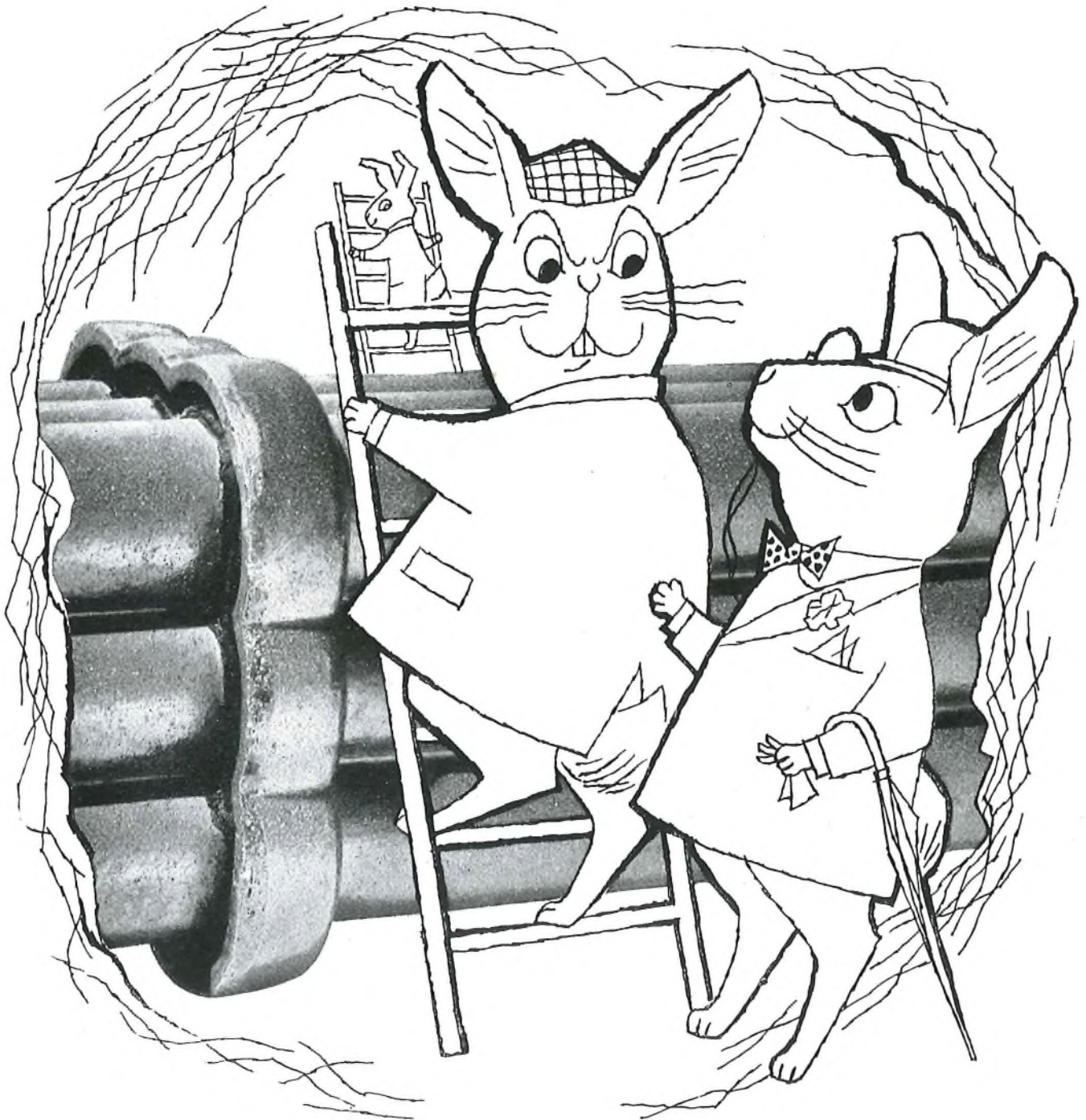
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'Progress!' said the oldest rabbit. 'Pah! When I was a young bunny they only 'ad single Salt Glazed Pipes down 'ere. Now they got 'em in blooming great bundles and you 'ave to climb up and down blinking ladders to get across the road. Where's it going to end, eh?'

'Where indeed?' said Baron Rabbit. 'Those over there are in bundles of nine, and, by the way, they are conduits, not pipes. They make

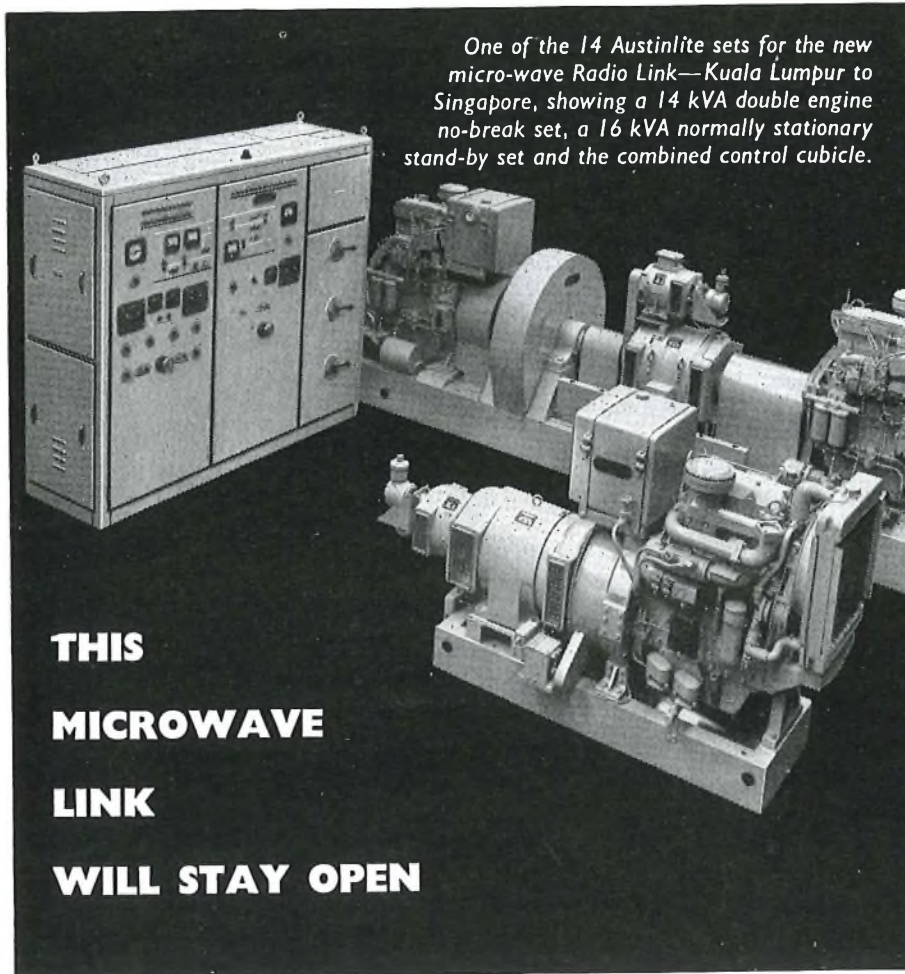
them like that to save time and labour in the laying. And the fact that you can get Salt Glazed Conduits in multiples is only one of their advantages. They're glassy smooth inside to prevent abrasion of the cable, they're impermeable, resistant to soil acids, durable —'

'Ho yes? That's all very int'resting', said the oldest rabbit. 'Now give us a shove up this perishing ladder, will yer?'

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The new microwave Radio Link between Kuala Lumpur and Singapore, some 350 miles of jungle, humidity and pests, is assured of an uninterrupted power supply.

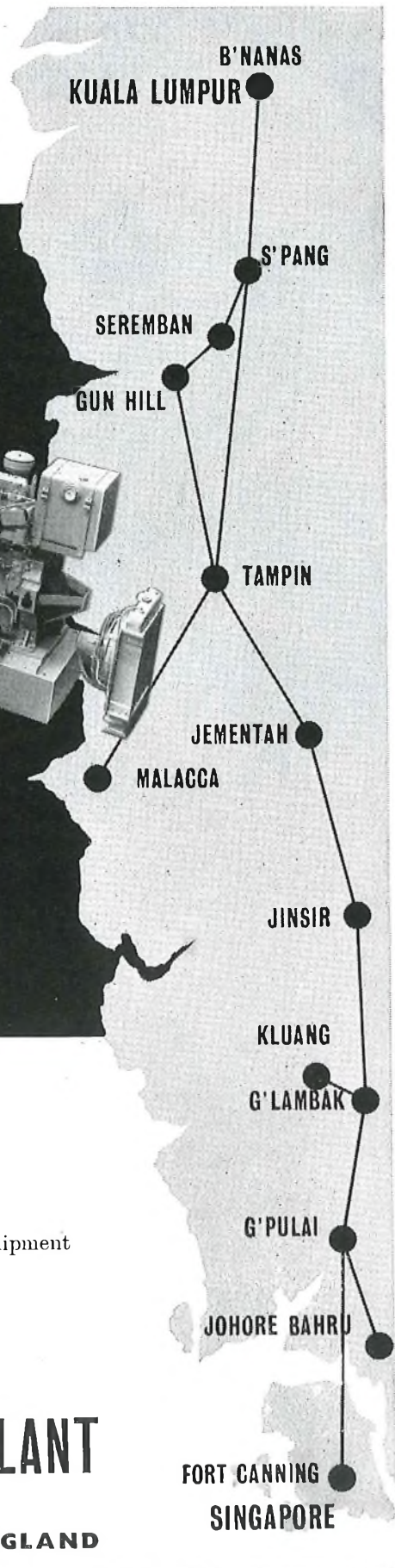
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... by a very simple system too. Very aptly we call it the SUBSCRIBERS' LINE CONCENTRATOR because it actually concentrates into 2 junctions from the exchange the full telephone service normally given to 10 subscribers using direct exchange lines.

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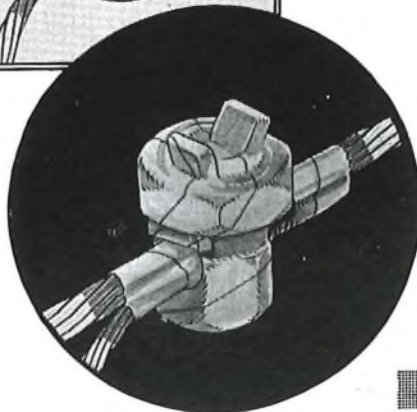
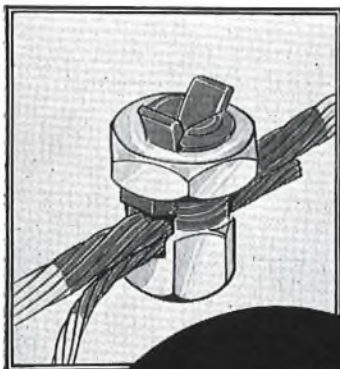
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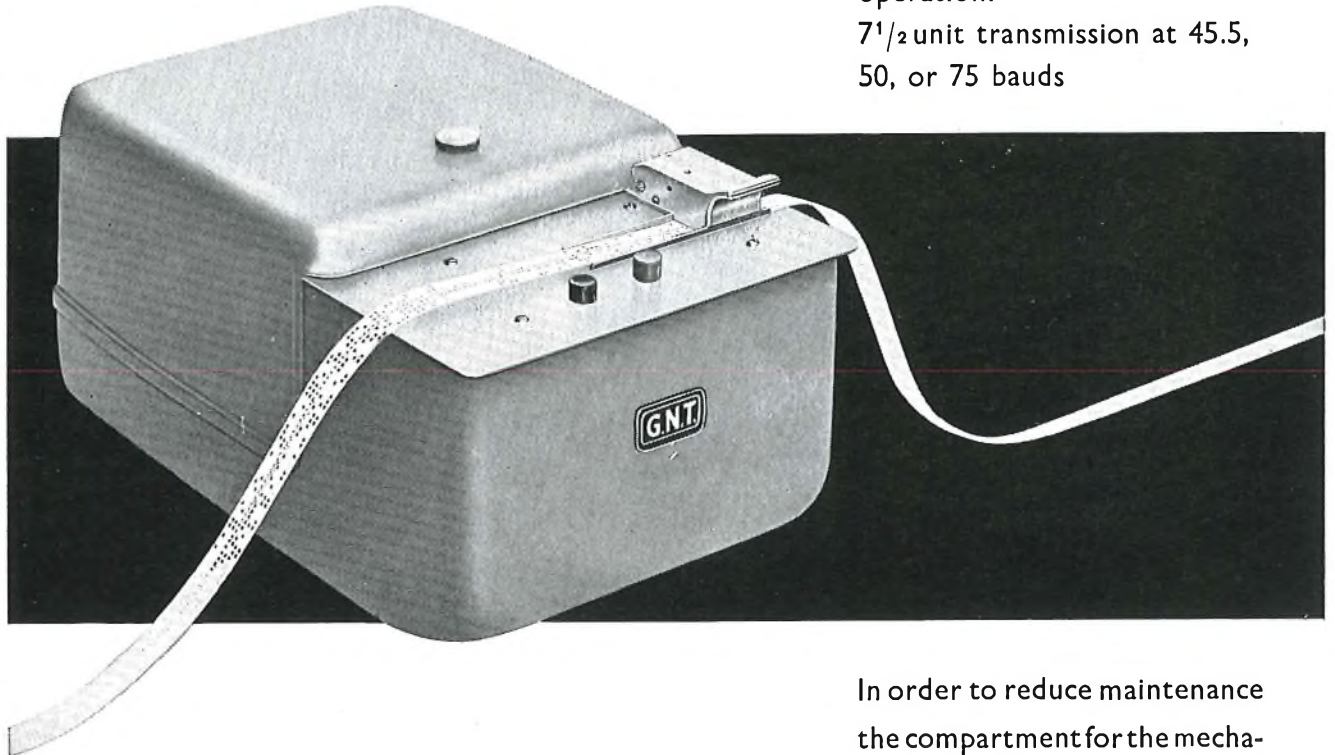
5-unit tape transmitter

model 20

Sequential type for single wire transmission.

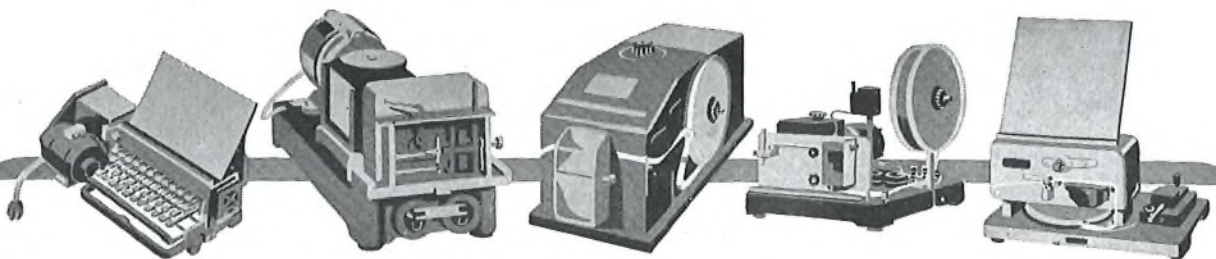
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*Meets all the requirements
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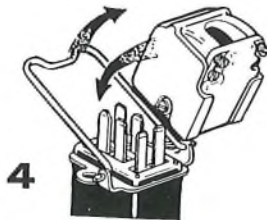
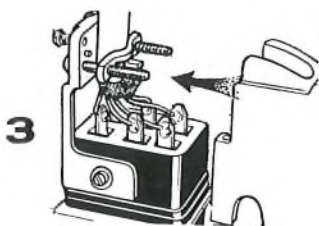
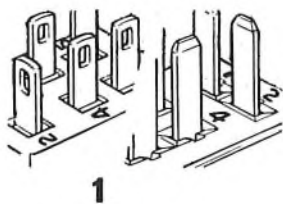
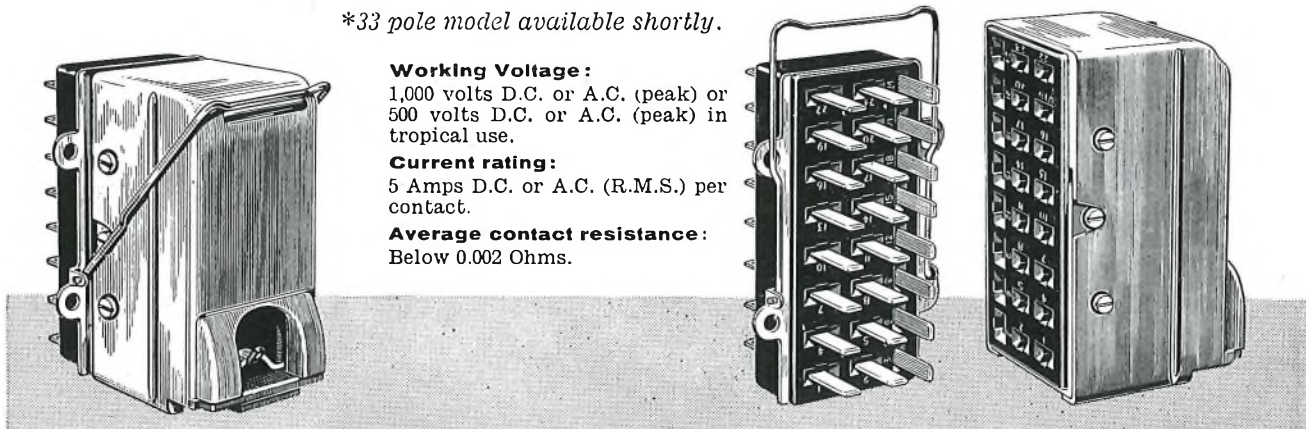
1,000 volts D.C. or A.C. (peak) or
500 volts D.C. or A.C. (peak) in
tropical use.

Current rating:

5 Amps D.C. or A.C. (R.M.S.) per
contact.

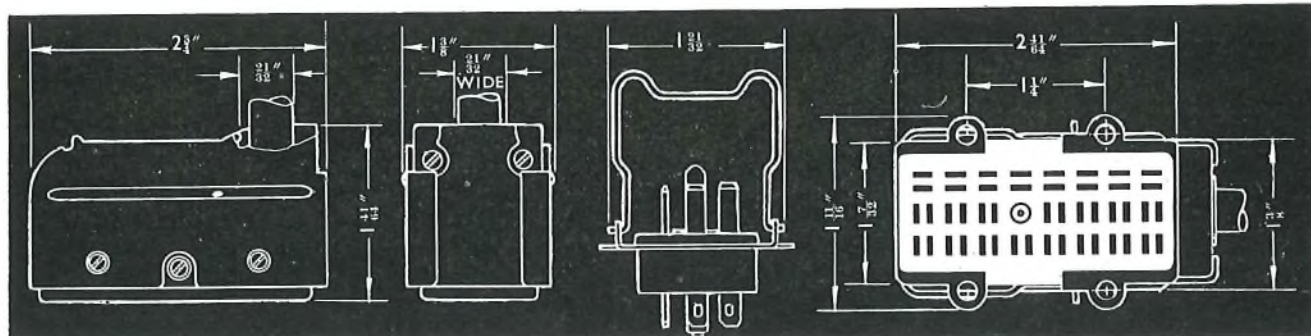
Average contact resistance:

Below 0.002 Ohms.



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British Patent 700999



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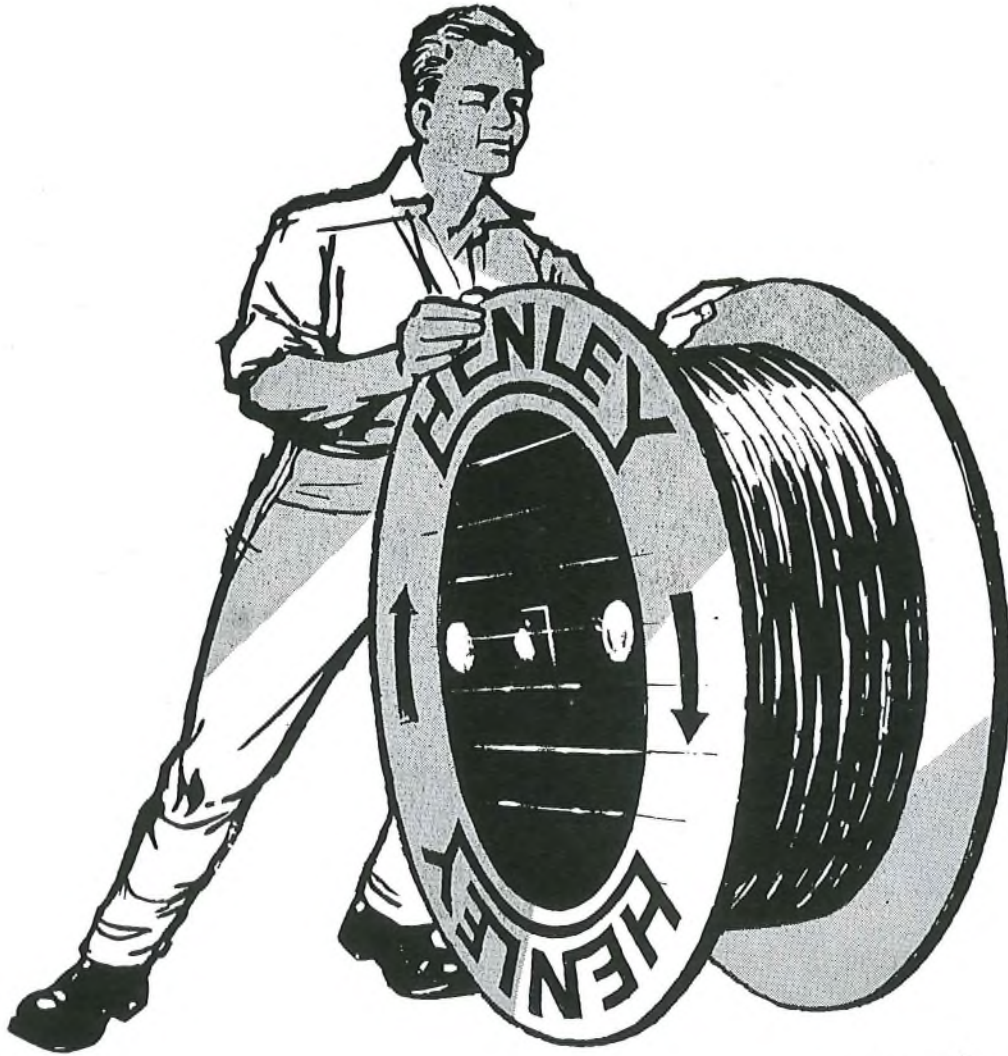


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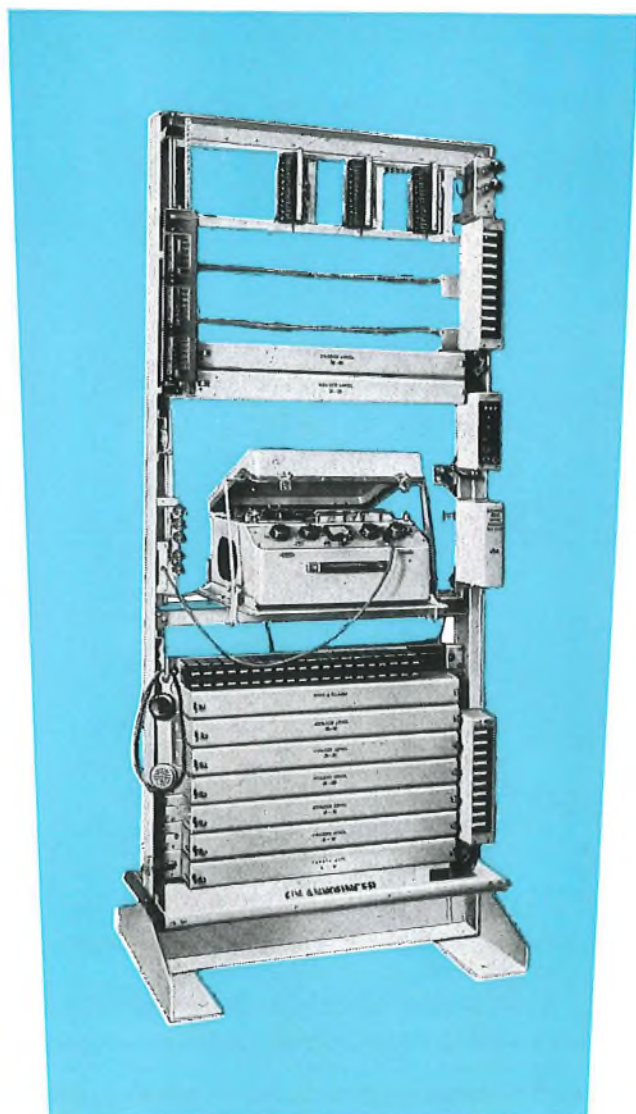
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Telephone, Radio and Television Works, Coventry, England



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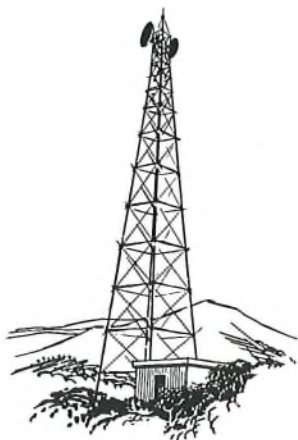


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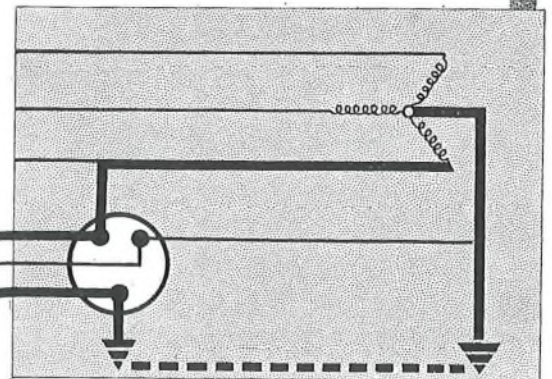
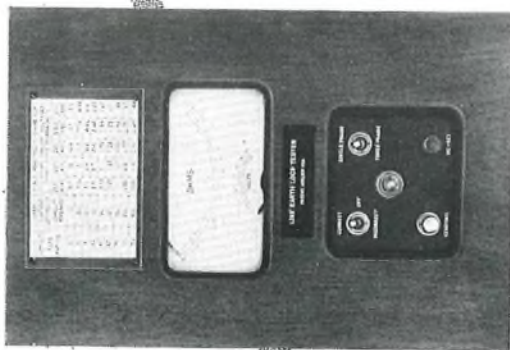
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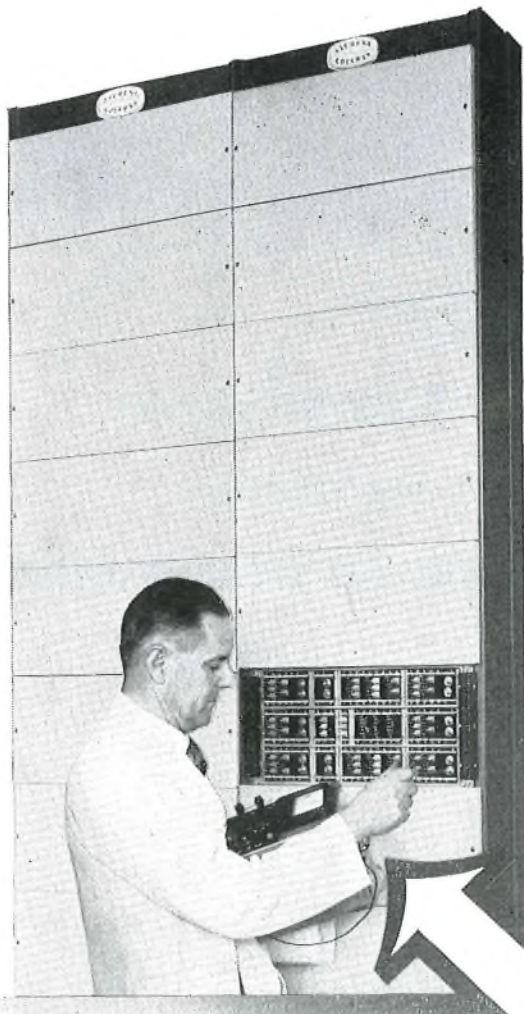


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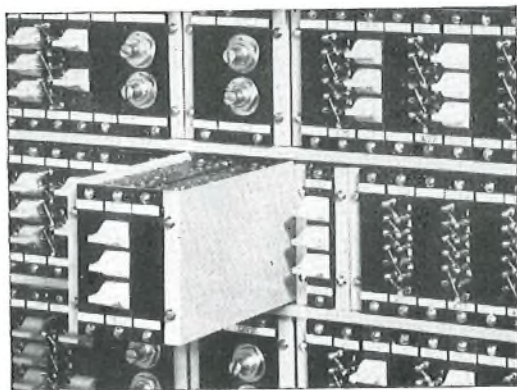


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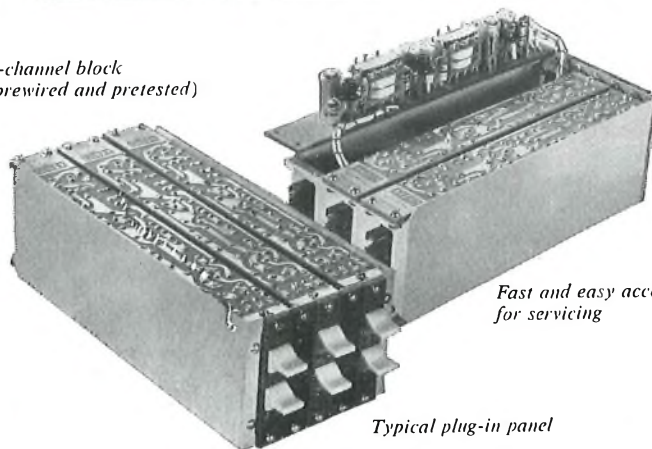
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- Uses standard 9 ft. by 20½ in. bays, allowing immediate incorporation into existing station arrangements
- Station cabling terminates at each 6-channel block



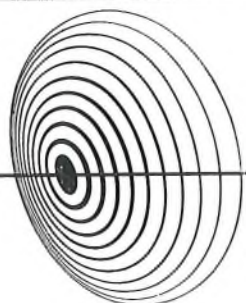
*6-channel block
(prewired and pretested)*



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carrier channelling equipment will thus once again play its part in helping the progress of the peoples of a distant land.

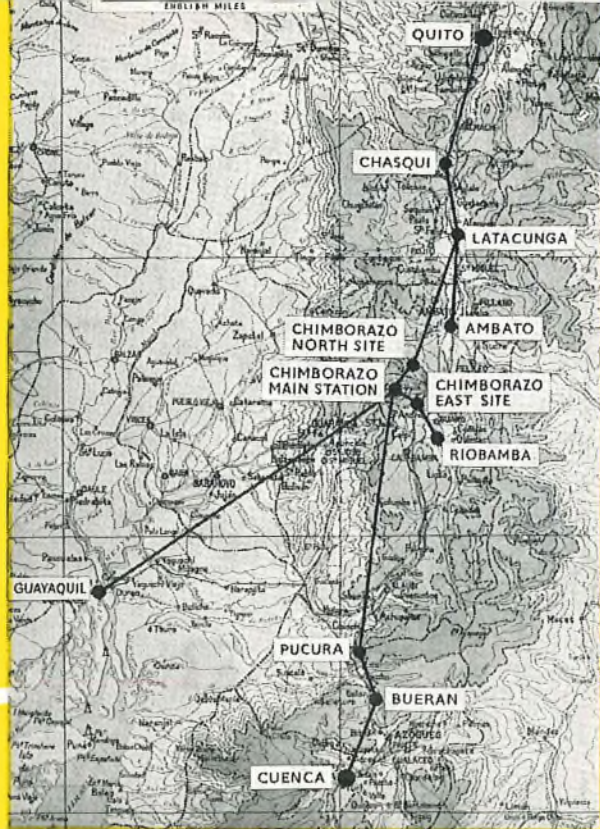
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MARCONI'S WIRELESS TELEGRAPH CO. LTD.

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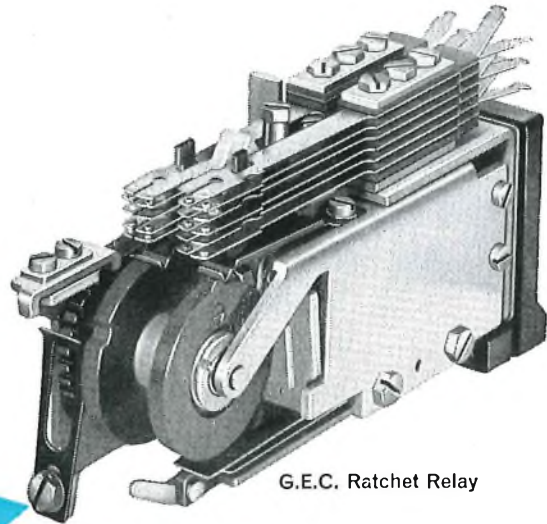
The equipment links two of the main centres, Quito and Guayaquil, and a number of smaller towns — Latacunga, Ambato, Riobamba and Cuenca. Between Quito and Guayaquil there are 12 bothway telephone channels. The terrain is mountainous and the maximum distance between stations is 300 kms.



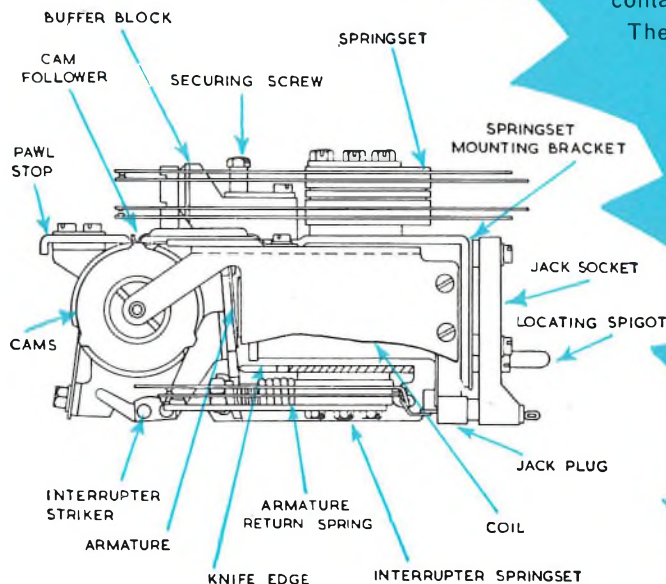
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G.E.C.**RATCHET RELAY**

The G.E.C. ratchet relay combines the smallness of the relay with the flexibility of the uniselector to provide an invaluable new tool for the designer of pulse-operated control circuits.



G.E.C. Ratchet Relay



It consists essentially of a reverse-drive uniselector mechanism from which the wipers have been removed and replaced by a cam and ratchet assembly, and the contact bank replaced by long-life relay-type springsets.

The ratchet relay can be fitted with one or two separate springsets as required, each of which can accommodate up to six contact springs in any combination of makes, breaks and changeovers. In practice, for reasons of mechanical stability, a minimum of four contact springs are used in each springset. Either springset is operated by a separate cam, and various types and combinations of cams can be fitted.

Auxiliary armature springs allow the relay to return to a "home" position by self-interruption (self-cycling).

All service adjustments can be carried out without removing the relay from its mounting.

The relay mounts in the same space that is occupied by a single P50 type (G.P.O. 3000 type) telephone relay.

The magnet coil power is restricted to approximately 10 watts to avoid overheating of either the relay itself or other components in close proximity.

G.E.C.**Ratchet Relays**

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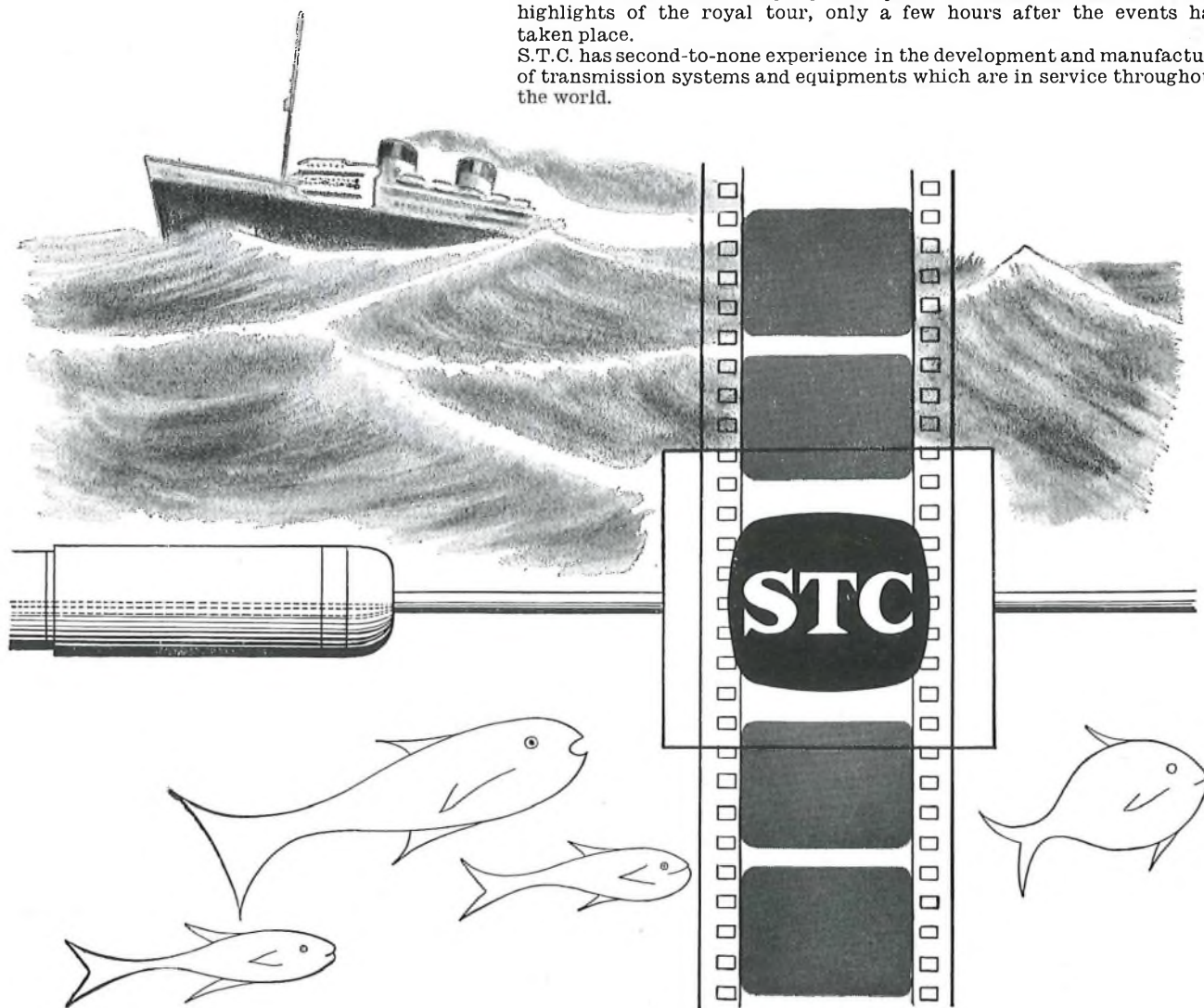
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SUBATLANTIC TELEFILMS

The skill and enterprise of the B.B.C. engineering staff, in successfully transmitting television news films via the Transatlantic Submarine Telephone cable, has achieved yet another advance in telecommunications techniques. B.B.C. slow speed telerecording equipment was designed to operate over the S.T.C. music transmission equipment which was specially developed for the transatlantic cable system and installed in Montreal, New York and Oban.

Other S.T.C. equipment, including the newly inaugurated microwave radio-relay system in Newfoundland, submerged telephone repeaters in the Newfoundland-Nova Scotia section of the transatlantic cable and coaxial cable equipment in the U.K. also played an important part in the transmissions which enabled B.B.C. television viewers to see filmed records of the arrival of Her Majesty the Queen in Newfoundland and other highlights of the royal tour, only a few hours after the events had taken place.

S.T.C. has second-to-none experience in the development and manufacture of transmission systems and equipments which are in service throughout the world.



Standard Telephones and Cables Limited

Registered Office : Connaught House, Aldwych, London, W.C.2

TRANSMISSION DIVISION : NORTH WOOLWICH · LONDON · E.16

When Space is restricted and high capacity cells required

TUNGSTONE Battery installations can now be supplied by using Faure type (pasted) plates instead of Standard Planté type cells—designed exactly to G.P.O. specification, ensuring maximum efficiency and length of working life.

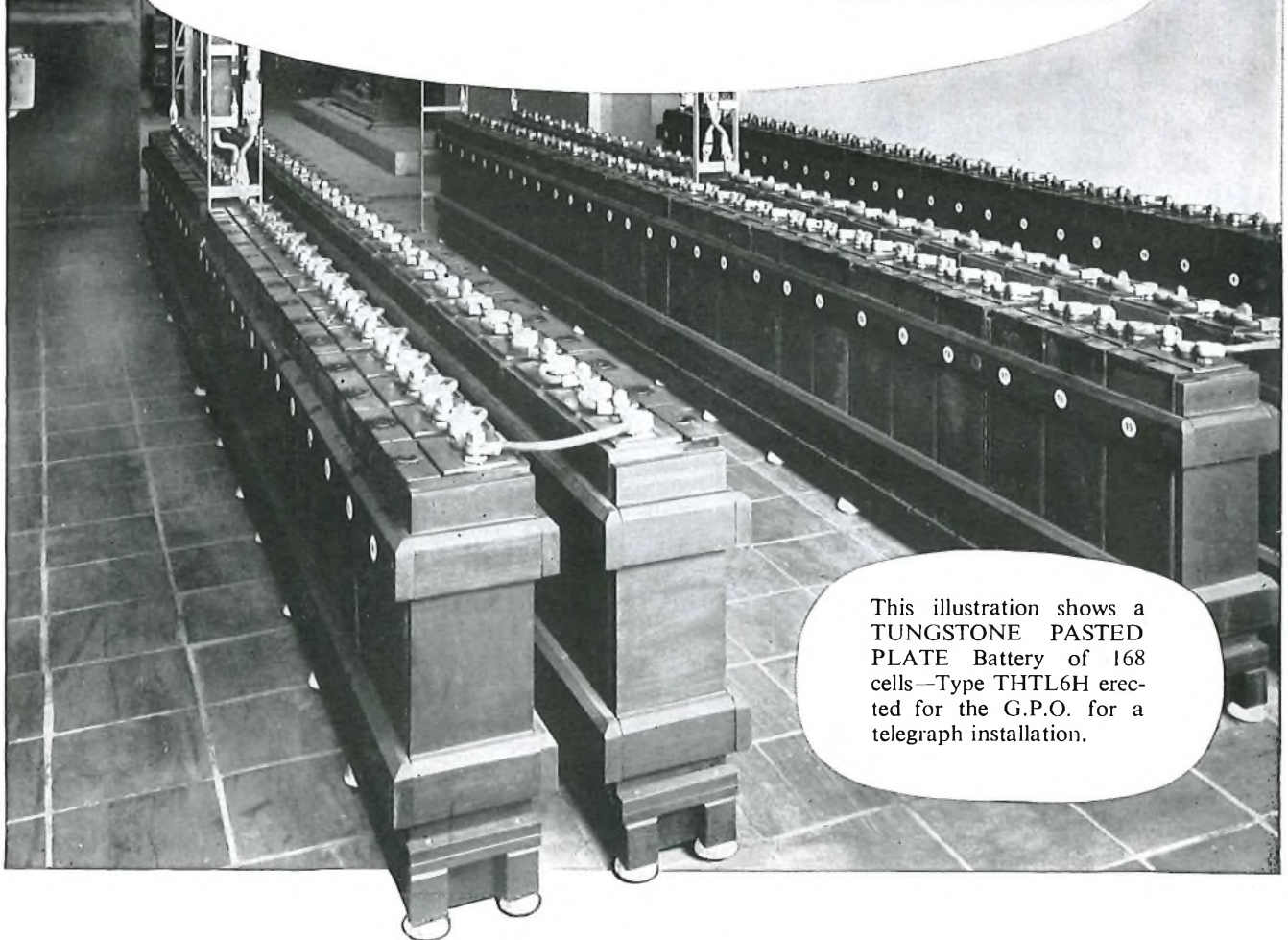
TUNGSTONE Storage Batteries are being regularly supplied to the British Post Office and Post and Telegraph Departments in many countries overseas.

OPEN TYPE CELLS

Available in glass or lead-lined wood boxes in a range of capacities from 100 a.h. to 5,000 a.h.

ENCLOSED TYPE CELLS

In moulded glass containers with sealed-in lid. Capacity range from 10 a.h. to 200 a.h.

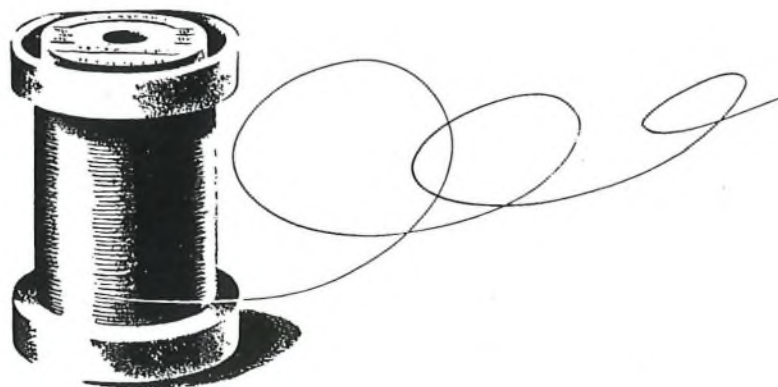


This illustration shows a TUNGSTONE PASTED PLATE Battery of 168 cells—Type THTL6H erected for the G.P.O. for a telegraph installation.

TUNGSTONE Batteries

TUNGSTONE PRODUCTS LIMITED

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polyester no 1

new Winding Wires & Strips

with these important characteristics:

HIGH THERMAL STABILITY

HIGH DIELECTRIC STRENGTH

GOOD ABRASION RESISTANCE

EXCELLENT FLEXIBILITY

Polyester No. 1 Winding Wires are a new development by BICC.

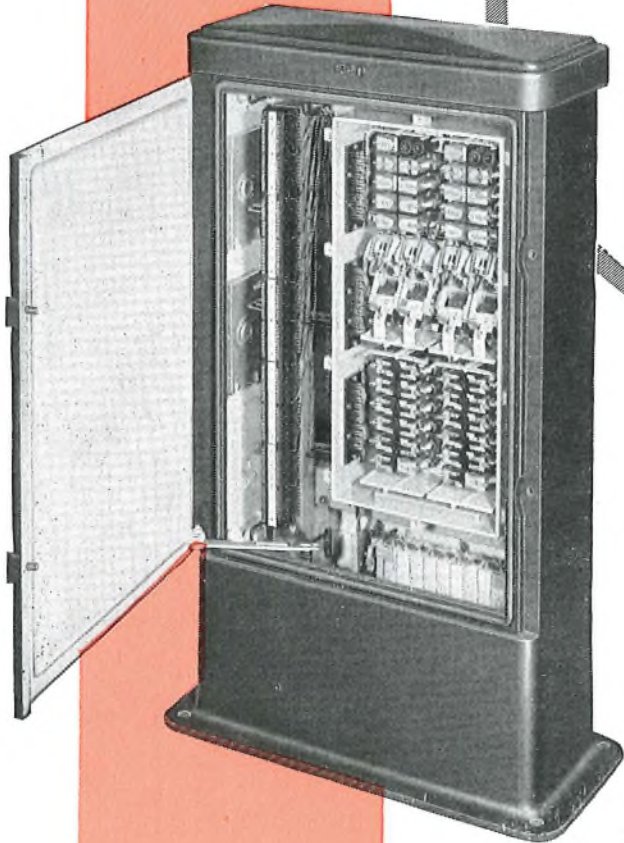
They are superior to, and supersede BICC Teramel Winding Wires, and have the additional advantage of improved flexibility on rectangular conductors.

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ERICSSON

LINE CONNECTORS

point the way . . .



22
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4



... to even greater economy
in line plant

- ◀ SERVICE FOR 22 SUBSCRIBERS
- ◀ 4 EXCHANGE LINES ONLY
- ◀ NO CONTROL LINES
- ◀ SAVING IN CALLING EQUIPMENT
- ◀ COMPLETE SECRECY
- ◀ EASE OF MAINTENANCE
- ◀ JACK-IN RELAY SETS
- ◀ INDIVIDUAL METERING
- ◀ STANDARD EQUIPMENT
- ◀ FULLY TROPICALIZED

The Ericsson Line Connector solves your cabling problems by providing service for 22 subscribers over 4 pairs only, as well as effecting a considerable saving in exchange equipment. Whilst being primarily of use in relieving external line plant shortages, it may also be used as an exchange in rural areas or as an alternative to a P.B.X. or P.A.B.X. Another application may be an economical service given to blocks of flats etc.

The remote unit and exchange equipment comprises telephone relays and uniselectors similar to those supplied to the British Post Office and no special maintenance problems are introduced. Equipment is not bridged across, nor left in series with, the line; thus, subscribers on the line connector enjoy

exactly the same facilities as those with normal direct lines. Intercommunication between subscribers is achieved by dialling the normal directory number, and all connections to and from subscribers are set up via one of the four pairs. Providing at least one of these pairs remains serviceable, connections between subscribers and the exchange can be maintained.

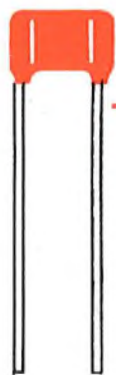
The remote equipment is sealed within a desiccated container which may be fitted into a standard B.P.O. cross connection cabinet as illustrated, or alternatively, arrangements can be made to meet customer's requirements.

The Ericsson Line Connector has been supplied to the B.P.O. and orders are in hand for overseas administrations. Full particulars are available on request.



ERICSSON TELEPHONES LIMITED
E TELCO LIMITED

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Catalogue sheets describing the complete range of JMC precision capacitors are available on request

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A gold-plated relay contact hermetically sealed
in inert gas for absolute reliability, high speed
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maximum resistive load	15 W
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minimum open resistance	$5 \times 10^{11} \Omega$

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operate time less than	2 mS
bounce time less than	0.5 mS
release time less than	0.5 mS

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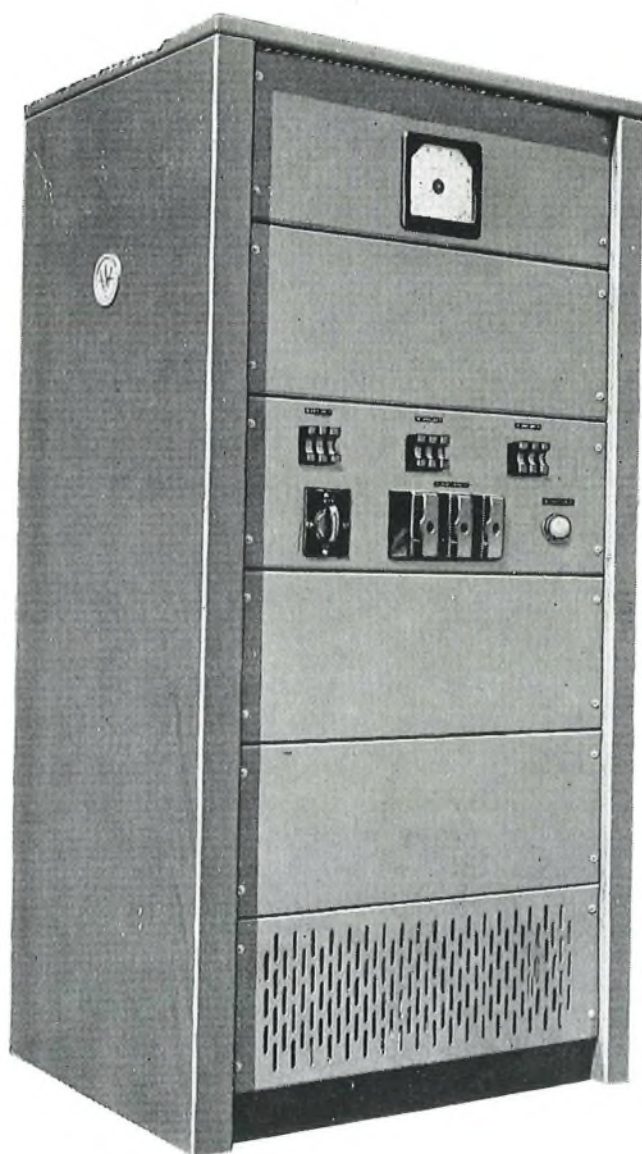
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are associated with the d.c. power supplies to
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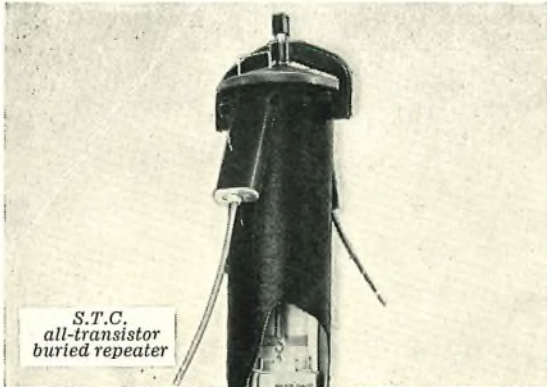


A Westinghouse transducer controlled rectifier set forms the basis of the power supply to the register translator in the new subscriber trunk dialling system. Equipments of this type are designed to stabilise the d.c. output voltage to less than $\pm 1\%$ over a load range of 10% full load to full load despite simultaneous mains input voltage variations of $\pm 6\%$ and frequency changes of $+1\%$ to -2% .

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The terminals will be equipped with S.T.C. terminal

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S.T.C., leaders in the industry, are fully equipped to undertake complete coaxial cable and systems planning, manufacture and installation.



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