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THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

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St. Margaret's Bay–La Panne 420-Circuit Submarine-Cable System with Transistor-Type Submerged Repeaters

R. J. W. MYERSON, C.Eng., M.I.E.E.†

U.D.C. 621.315.28: 621.375.4: (422.3 & 493.3)

The insertion of transistor-type submerged repeaters into an existing submarine cable between St. Margaret's Bay and La Panne (Belgium) increased the capacity of the cable from 216 to 420 telephone circuits. This was the first use of transistor repeaters in an international submarine cable, and, on completion, the capacity was the largest of any submarine-cable system in existence.

INTRODUCTION

A PROGRAM of increasing the number of communication circuits carried by submarine cables in the North Sea was embarked upon as a result of an international conference held in London in 1961 and referred to as the North Sea Cable Conference. Agreement was reached on the provision of a number of new 120-circuit cable systems between the United Kingdom and the continent of Europe; these systems have already been described in this Journal.[1]

The Conference also decided to increase the circuit capacity of an existing cable between St. Margaret's Bay, Kent, and La Panne in Belgium by the addition of submerged repeaters. This project, described here, was completed towards the end of 1964. The system was thoroughly re-tested in January 1966 at the end of the guarantee period, and its performance was found to be unchanged compared with the results of the commissioning tests.

As the submerged repeaters and terminal equipment are transistor-operated the successful completion of the project marked an important step by British industry in the history of communications. It was the first international submarine-cable system to employ transistor repeaters, and its capacity of 420 4 kHz-spaced telephone channels was the largest of any submarine-cable system in existence.

The Original System

The submarine-cable was laid in 1948 originally to provide 216 4 kHz-spaced telephone circuits between London and Brussels. The frequencies transmitted over the cable were 60–956 kHz in the direction St. Margaret's Bay to La Panne and 1,152–2,048 kHz in the reverse direction, and no submerged repeaters were required. The links between London and St. Margaret's Bay, and between La Panne and Brussels, were provided by coaxial-cable systems.

Submarine-Cable Design

The submarine cable is of unusual construction[2] in that, over the main sea section, the polythene dielectric incorporates an air-space obtained by laying a helix of polythene cord over the inner conductor and applying an extrusion of polythene over the helix to an overall diameter of 1·7 in.

The outer conductor consists of six copper tapes overlaid by two copper binder tapes. The inner conductor of the coaxial pair is formed over a core of polythene of 0·443 in. diameter and consists of a helical copper tape enclosed by a longitudinal tape. There is a strand of copper wires at the centre of the polythene core, but it has no electrical function in the system.

The land cable and the shore-end sections of the sea cable employ solid polythene as the insulant, i.e. an air-space is not included, and the diameter of the polythene core within the inner conductor is reduced to 0·348 in. to preserve a uniform cable-impedance.

The overall attenuation of the cable has increased since it was originally laid. During the first 3 years after the cable was laid its attenuation increased by 3 per cent, but after this it settled down to a lower average increase of about 0·3 per cent per annum. The increase of attenuation in the early life of the cable was attributed to pressure effects and the ingress of water vapour through the polythene into the air-space. It was thought that the further increase might be due to an increase in contact resistance between tapes of the outer conductor and possibly, although less likely, some mechanical deterioration of inner and outer conductors. It was, therefore, considered prudent to assume for the purpose of the present system design that the cable-attenuation rise would continue until 1971 at a rate of about 0·2 per cent per annum.

SYSTEM PLANNING

From a consideration of the performance of commercially-available transistors it was clear that the useful working frequency range of the cable could be increased

†Main Lines Development and Maintenance Branch, E.-in-C.'s Office.

to about 4 MHz by the insertion of two submerged repeaters. It was, therefore, decided to invite tenders from British manufacturers for the overall engineering of such a system, including the manufacture of the terminal equipment and submerged repeaters, and the installation and testing work at the terminal stations. At the same time a testing program was instituted to assess the reliability of the transistors to be used in the repeaters.

The specification for the system was in terms of the required performance, and allowed the tenderers some latitude in formulating their solution at the tender stage. Basically, the requirement was for a broadband system suitable for the simultaneous transmission of about 420 telephony channels in both directions, complying with the transmission standards recommended by the C.C.I.T.T.* and employing transistor-type terminal equipment and not more than two transistor-type submerged repeaters.

The maximum deviation in the system gain over the band, compared with that at a mid-band frequency, was specified at 1 dB. The maximum psophometrically-weighted noise power, in an unloaded test channel of 3·1 kHz bandwidth, was specified as 3 pW/km of route-length plus 70 pW for each frequency translation, with the system conventionally loaded with white noise.

The C.C.I.T.T. recommend that for 2-wire systems having common amplifiers for the two directions of transmission the mean power loading be assumed to be given by

$$n(\bar{P}) = -12 + 10 \log_{10} N \text{ dB, for } N \geqslant 240,$$

where $n(\bar{P})$ is the absolute power level at a zero relative-level point of a uniform-spectrum signal, and N is the number of channels in each direction of transmission. This formula assumes the use of one multi-channel voice-frequency telegraph system per supergroup. However, to allow for five telegraph systems per supergroup the quoted conventional loading for the system was increased to +15 dBm0.

In proposing a system of the capacity of 420 circuits, which constituted a major advance in the technique, it was considered necessary to call for a high standard of reliability and stability with regard to both the performance of individual components and the system as a whole. But, at the same time, a competitive price was required. Therefore, as a guide to the manufacturer, it was stated that the repeater failure rate should be not worse than one fault in 5 years, this being a reasonable figure for such a short system in shallow waters.

Regarding the locations for the submerged repeaters it was deemed advisable to avoid laying them in shipping lanes or on the Outer Ruytingen Bank at the Belgium end of the route. It was found possible to specify two sections of the route where repeaters might be placed: from 3 to 25 and from 29 to 32 nautical miles from St. Margaret's Bay.

The contract was awarded to Submarine Cables, Ltd., and the remainder of this article describes the system supplied.

*C.C.I.T.T.—International Telephone and Telegraph Consultative Committee.

SUBMERGED REPEATERS

The two repeaters are bi-directional, and have a maximum gain of approximately 45 dB, a single-tone overload point† of +18 dBm, and a noise criterion* of 7·5 dB,—all measured at 4·3 MHz.

Following conventional practice, the bands of frequencies associated with the two directions of transmission are separated by directional filters and are amplified simultaneously by a common amplifier. In this design the common amplifier was developed in the

†Single-tone overload point—the output power at which the gain has fallen by 0·2 dB.

*Noise criterion—the extent to which the noise referred to the amplifier input exceeds that from a terminated line.

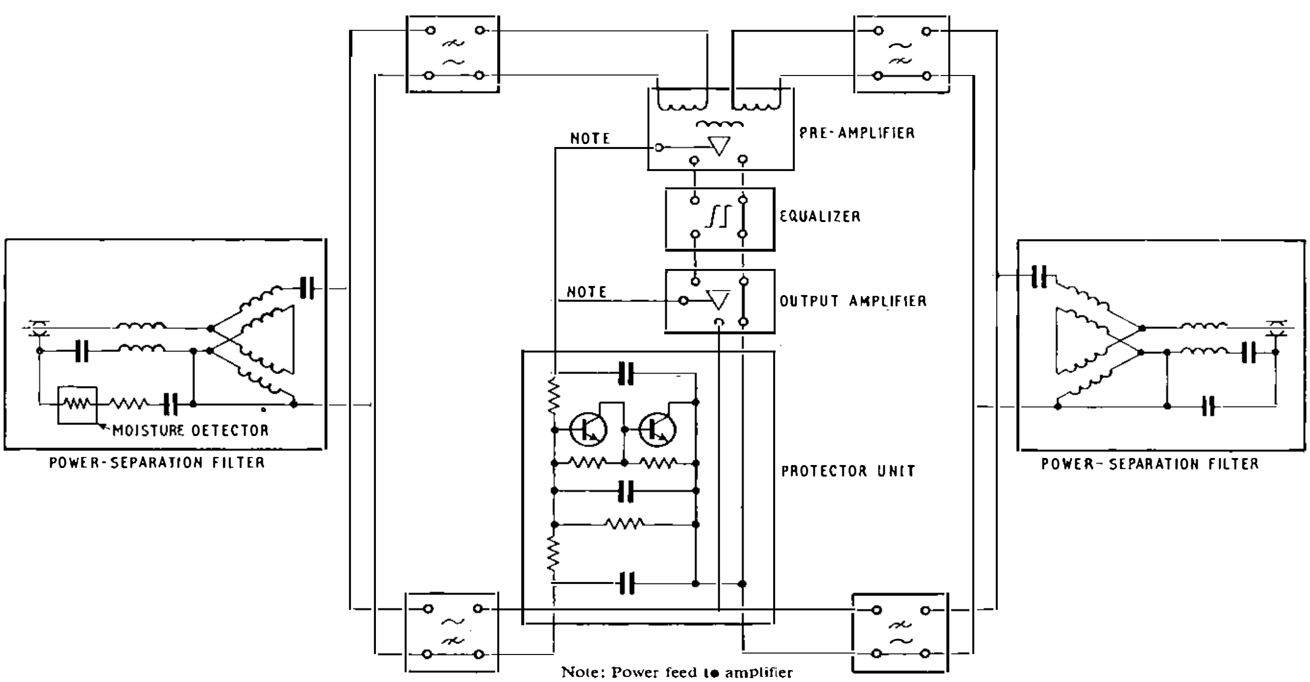


FIG. 1—BLOCK SCHEMATIC DIAGRAM OF SUBMERGED REPEATER

form of two 3-stage amplifier units, namely, a pre-amplifier and an output amplifier, which are connected in cascade via an equalizer. A block schematic diagram of the arrangement is shown in Fig. 1. The gain of the repeater is designed to compensate for the cable attenuation of a repeater section at all signal frequencies, the desired characteristic being realized partly by the equalizer and partly by employing frequency-dependent feedback in the output amplifier.

The power-separating filters, which separate the transmission circuits from the d.c. supply to the amplifiers, are of interesting construction. They each incorporate a coaxial choke to suppress any longitudinal signals, followed by two air-cored bifilar coils which function as a transformer of indefinite bandwidth.[3] The first of these air-cored coils is connected as an auto-transformer having a 2:1 turns ratio (4:1 impedance ratio) to match the cable impedance of approximately 60 ohms to a more convenient value for the design of the directional filters and amplifier circuits. The second coil is identical to the first and acts as a phase-shifting transmission line, improving the frequency response of the network at the higher frequencies. By the inclusion of suitable capacitors in the circuit the power-feeding current (140 mA) is diverted within the repeater to energize the amplifiers.

There was a requirement for a capacitor of fairly large value (0·2 μF) for decoupling the d.c. supply and the transistor-emitter circuits. The capacitor was required to have a residual inductance of only a few millimicrohenries and an impedance free of unwanted resonances up to 150 MHz, in order to achieve a very close control of the feedback characteristics and ensure complete stability in the amplifiers. The solution adopted[3] was a design employing polystyrene film as the dielectric, and, to achieve a low series inductance, single-end multiple connexions to the aluminium foils were made by gold-plated copper-strips; the capacitor then behaves as an electrically-short open-circuit transmission line of very low characteristic-impedance.

Considerable attention was given to the use of reliable components, much of the necessary experience of component reliability having been accumulated by the Post Office and the contractor over a number of years. Where practicable, metal parts and the copper wire used for wiring between components were gold plated, and materials, such as pure tin, cadmium or zinc, which produce metal filaments ("whiskers") were avoided. The repeaters were manufactured in special premises where the temperature, humidity and dust content were controlled, and the operators wore nylon suits, hats and gloves.

Amplifier Units

The amplifier units were constructed on gold-plated brass base-plates; the majority of the components are embedded in channels cut into the underside of the base-plates, while the large components are mounted on the top of the plates. The transistors are electrically insulated from the base-plates by clamping between two silvered sintered-beryllia washers. Beryllia, having a thermal conductivity similar to that of aluminium, ensures that the transistors are provided with a heat sink of low thermal resistance. Full details of the amplifier design and construction have been given elsewhere.[4]

Transistors

One type of transistor was used throughout the amplifiers, and the device chosen was a commercially-available silicon planar transistor[5] of American manufacture, purchased to tightened limits of h_{FE} and h_{fe} (100 MHz). The long-term reliability of the device was assessed by a program of accelerated aging of a large number of samples in the laboratories of Submarine Cables, Ltd., under the direction of the Post Office Research Station. From mechanical and thermal step-stress and steady over-stress aging data it was possible to estimate the probable failure rate of the devices under normal working conditions. This work has already been recorded in this Journal.[6]

The probability of failure of the device for the system was required to be better than 0·06 in any period of 5 years. This conclusion may be arrived at as follows. Let q_s be the probability of survival of one transistor over the given period; then, in a repeater containing six transistors with no redundancy, the probability Q of the repeater surviving (neglecting other components) over the period is given by q_s^6, and the probability of a system containing N repeaters surviving is Q^N. Thus, in the Anglo-Belgian system, assuming even chances of survival, $Q^2 = q_s^{12} = 0{\cdot}5$, and $q_s = 0{\cdot}94$. The probability of failure, p, of one transistor is therefore given by $p = 1 - q_s$, i.e. 0·06.

It was concluded from the reliability-assessment program that this level of reliability would be very comfortably met by the devices. Their reliability was, in fact, considered to be adequate for a route being planned that would need up to 60 repeaters, each containing a single-path 3-stage amplifier and requiring a probability of survival of the system of 0·75 in 5 years, i.e. with $q_s = 0{\cdot}998$.

Surge Protection

As the cable was only about 48 nautical miles in length and only two repeaters would be employed in the system, the power-feeding voltages were quite low (82 volts when power-feeding from one terminal). It was, therefore, decided that a very simple surge-protection circuit in each repeater would be adequate. The arrangement is shown in Fig. 1, and consists of a resistor-

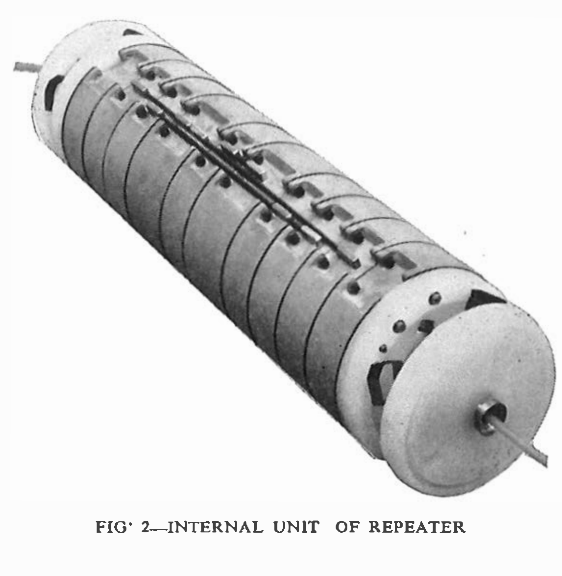


FIG. 2—INTERNAL UNIT OF REPEATER

capacitor combination with two diodes connected in series across the d.c. feed to the amplifiers. To avoid a further reliability-assessment exercise on another device, the silicon planar transistor of the type employed in the amplifiers was used as a diode (base–collector connexion) for this purpose.

Mechanical Construction

The mechanical construction of the repeater contains some interesting novel features.

The electrical assemblies of the repeater are mounted in die-cast sections which are bolted together with set-screws to form a rigid cylindrical unit (Fig. 2), the electrical connexions between the sections being made with coaxial cable. This unit is then totally encapsulated in a 0·27 in.-thick polythene tube which is welded to polythene end-disks (Fig. 3), and the completed unit is flushed with dry nitrogen. A moisture-detector is included in the power-separation filter circuit at one end of the repeater to enable the relative humidity of the interior to be monitored electrically during processing. A desiccating unit containing silica gel is fitted in the unit to absorb any residual moisture.

Although polythene is not impervious to water, it has been estimated that, if the capsule were surrounded by an environment of 100 per cent relative humidity continuously, the action of the desiccator would ensure that the operation of the repeater would be unaffected for a minimum of 60 years. The capsule is, however, housed in a tubular steel casing of 8 in. internal diameter and $10\frac{1}{2}$ in. external diameter (Fig. 4), which is designed to work at 1,200 lb/in^2 (84 kg/cm^2), and is tested during production at 2,000 lb/in^2 (140 kg/cm^2) for 5 days. At each end of this casing is a demountable bulkhead through which a cable passes and connects to the internal unit. This cable is moulded to the bulkhead prior to assembly, and each gland is tested at a hydrostatic pressure of 5 tons/in^2 (787 kg/cm^2). The pressure seal between the bulkhead and the casting is made by a soft

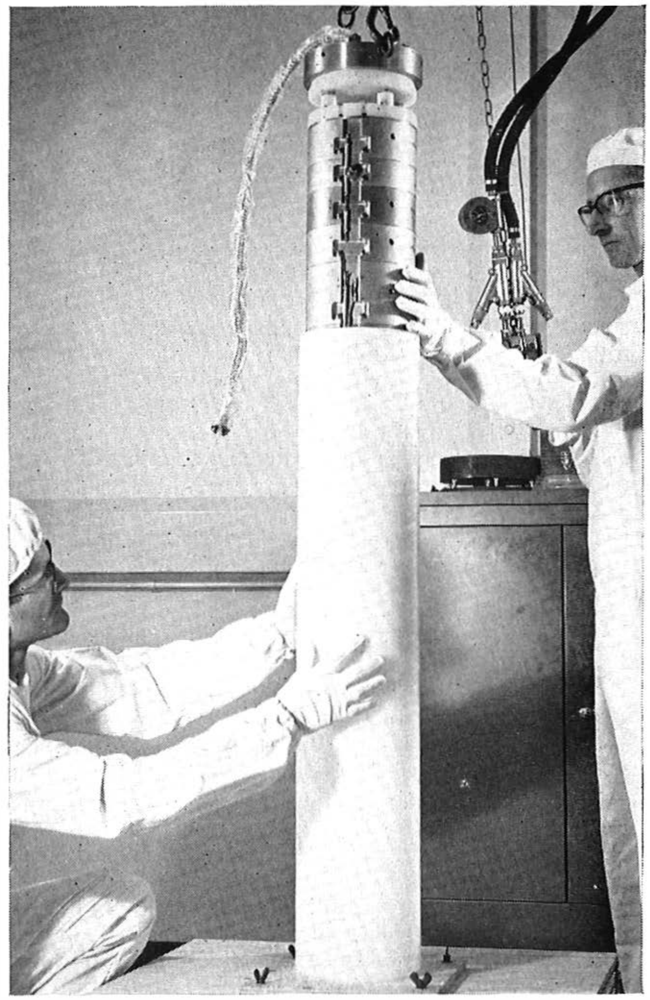


FIG. 3—INTERNAL UNIT BEING INSERTED INTO POLYTHENE TUBE

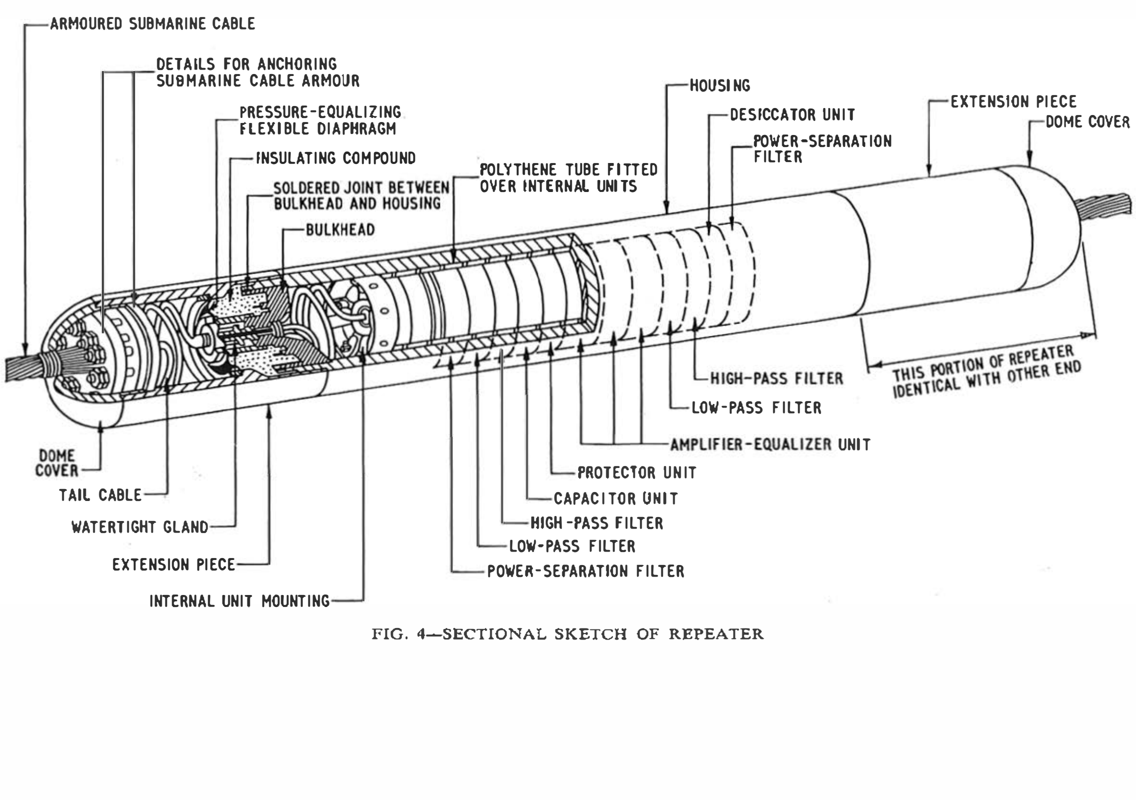


FIG. 4—SECTIONAL SKETCH OF REPEATER

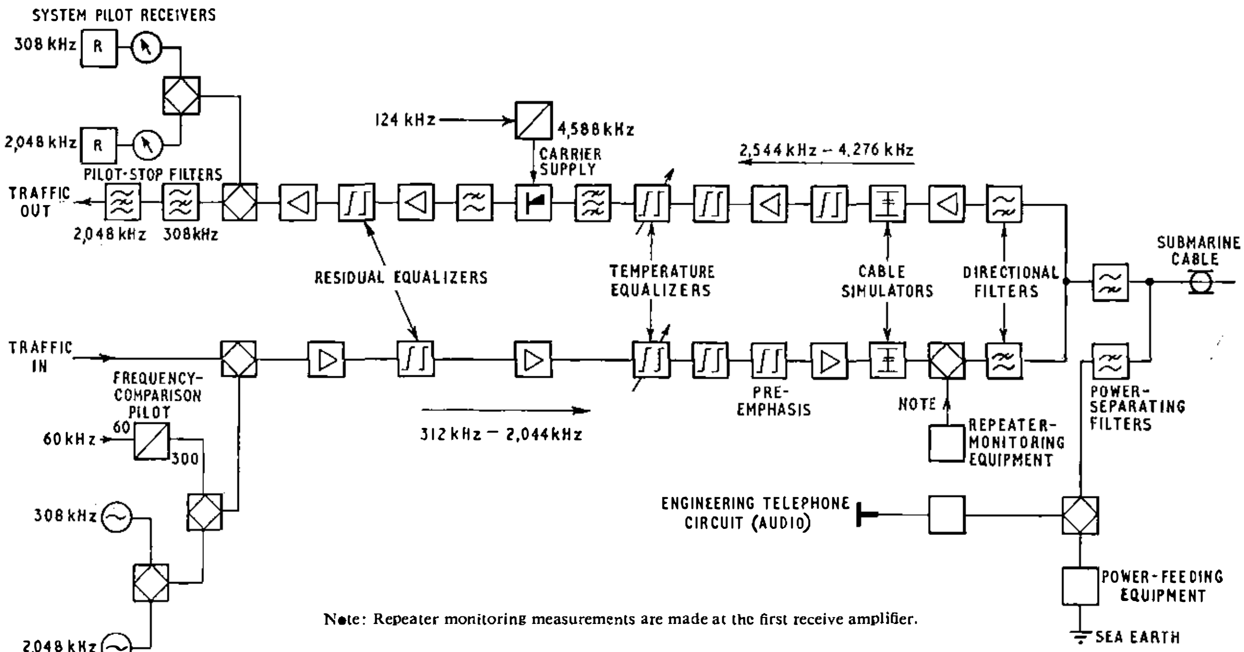


FIG. 5—BLOCK SCHEMATIC DIAGRAM OF ST. MARGARET'S BAY TERMINAL

metal eutectic alloy, which is run into an annular cavity between the casing and the bulkhead.

The remainder of the construction follows well-established techniques for a rigid repeater. A steel extension tube is screwed on to the end of the casing and contains a pressure-equalizing diaphragm assembly which is designed to exclude sea water from the face of the bulkhead and, thus, inhibit corrosion. The space between the bulkhead and the pressure-equalizing diaphragm is filled with polyisobutylene, injected under pressure via an orifice in the extension.

The repeaters were provided with cable tails of 0·935 in. diameter armoured sea-cable of conventional construction except that the inner conductor was reduced in size so that the impedance of the tails would match that of the 1·7 in. diameter cable. The dielectric used was grade-2 polythene with an admixture of 5 per cent butyl rubber and 0·1 per cent santanox antioxidant. A special taper joint was designed by the Post Office Research Station for the joint between the tails and the main sea cable.

TERMINAL EQUIPMENT

The terminal equipment[7] was developed, manufactured and installed on behalf of Submarine Cables, Ltd., by one of its parent companies, the Telecommunications Division of Associated Electrical Industries, Ltd.

The equipment accepts seven supergroups, which are assembled conventionally by supergroup translating equipment, in the band 312–2,044 kHz, and these frequencies pass over the cable in the direction from St. Margaret's Bay to La Panne. In the opposite direction the signals are translated using a carrier frequency of 4,588 kHz to the range 2,544–4,276 kHz for transmission by the submarine link.

The apparatus at each terminal station comprises cable-terminating and power-separating equipment, power-feeding equipment to supply the submerged repeaters, a pair of directional filters to separate the two directions of transmission, a frequency modulator (or demodulator), amplifiers, equalizers, pilot-generation and pilot-monitoring equipment, carrier-supply equipment and engineering-speaker equipment. A block schematic diagram of the St. Margaret's Bay terminal equipment is shown in Fig. 5. The La Panne terminal equipment is similar except that the frequency translation takes place in the send path.

Two system pilot frequencies of 308 kHz and 2,048 kHz are generated by crystal-controlled oscillators, and these pilot signals are combined with the traffic signals entering the submarine-terminal equipment. The 308 kHz oscillator contains a CT-cut crystal operating in a miniature oven, kept within the range of 74°C to 77°C. The 2,048 kHz crystal is AT-cut and is not temperature controlled. The frequency stability of these oscillators is better than ± 10 parts in 10^6, and, by means of a Zener-diode stabilizer, the level variation of each oscillator is maintained at better than $\pm 0{\cdot}1$ dB for normal variations of power supply and ambient temperature.

These pilots are filtered out at the end of the receive path at the distant terminal, and are monitored by meters and recording decibelmeters from which the behaviour of the system is kept under continual surveillance. Thus, it is possible to determine when adjustments of the variable temperature-equalizers are necessary to compensate for variations in the cable characteristics due to seasonal changes in the sea temperature.

Amplifiers

A single type of wide-band amplifier is used throughout the terminal equipment and was designed to the following requirements.

(*a*) Gain: 23 dB $\pm$ 0·2 dB, over the range 60–4,776 kHz.

(*b*) Single-tone power output: at least +24·5 dBm.

(*c*) Harmonic performance: better than 90 dB for

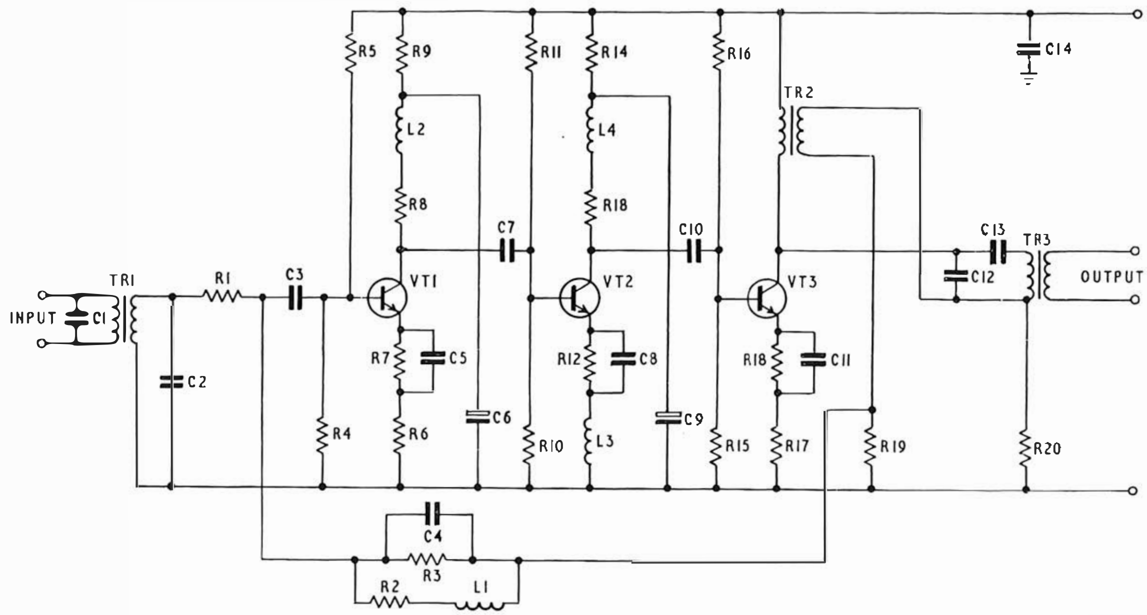
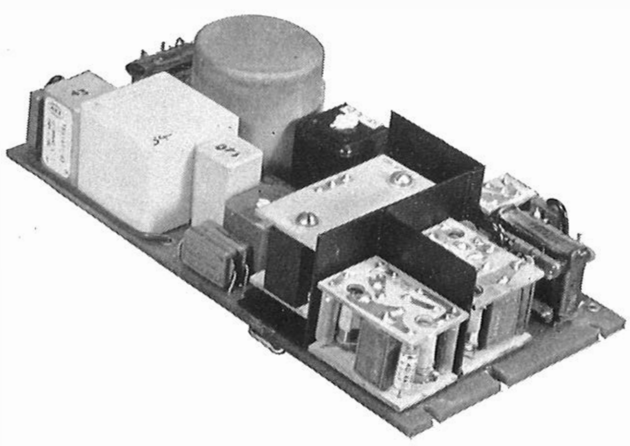


FIG. 6—SCHEMATIC DIAGRAM OF AMPLIFIER

second harmonic and 105 dB for third harmonic, at a fundamental output level of 0 dBm.

(*d*) Noise factor: 7 dB or less when used as a low-level receive amplifier.

The circuit, consisting of a 3-stage amplifier employing silicon planar epitaxial transistors in the common-emitter configuration, is shown in Fig. 6. A modular construction was adopted for each stage to minimize the length of leads to components; Fig. 7 shows the inside of the amplifier unit.



The amplifier is approximately 15 cm long
FIG. 7—AMPLIFIER ASSEMBLED ON PRINTED-WIRING BOARD

The output transformer is shunt-fed; this avoids the instability difficulties due to common leakage-inductance that can occur between the output and voltage-feedback windings when a 3-winding transformer is used. The blocking capacitor forms a high-pass filter with the primary shunt-inductance of the output transformer. The leakage-inductance is overcome by capacitor C12, which gives a low-pass filter effect at high frequencies.

In the collector circuit of transistor VT3, the primary of transformer TR2 forms the coupling inductor, and voltage feedback is taken from the secondary to avoid the common-leakage difficulty. Current feed-back is taken from resistor R20, which is in series with the primary of the output transformer TR3.

It was not found possible to meet the harmonic and noise requirements simultaneously, but a small change in two resistor values enabled the noise performance to be met at a slight expense to the overload performance in the two first receive amplifiers.

Directional Filters

The remainder of the submarine-terminal transmission equipment follows well-established practice, but one of the most critical parts of any submarine terminal is the directional-filter combination. In this system the filters have a cross-over in their attenuation characteristics in the region of 2,294 kHz (Fig. 8). The stop-band attenu-

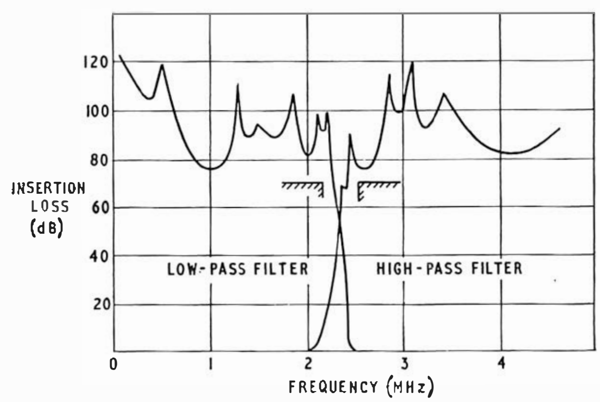


FIG. 8—ATTENUATION/FREQUENCY RESPONSE OF DIRECTIONAL FILTERS

ation of each filter of the pair is at least 70 dB, and, at the normal operating levels, the combination has an intermodulation performance of 130 dB for second-order products and 150 dB to 180 dB for third-order products.

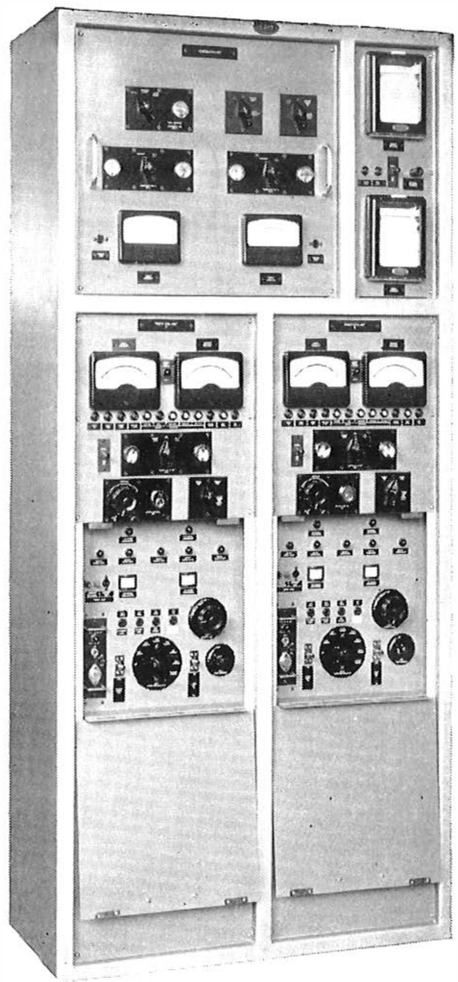


FIG. 9—POWER-FEEDING EQUIPMENT

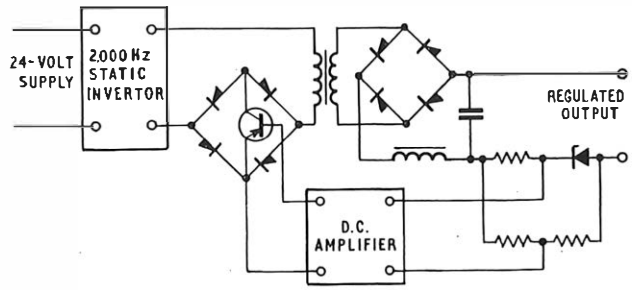


FIG. 10—PRINCIPLE OF CONSTANT-CURRENT POWER-FEEDING EQUIPMENT

This high standard of performance is dictated by the wide level-differences between the sent and received signals at the junction of the two filters.

Power-Feeding Equipment

Power is fed to the submerged repeaters by maintaining a constant direct-current of 140 mA through the centre conductor of the coaxial cable. The sea is used as the return path, and the electrodes and cables for the sea earths were laid off St. Margaret's Bay and La Panne by the Netherlands cable ship *Poolster* in advance of the operation of inserting the repeaters.

The power-feeding equipment is illustrated in Fig. 9. It is powered from the nominal 24-volt station batteries. Basically, the equipment consists of a static invertor, the output of which is connected via a variable-impedance device, to a step-up transformer and then to a rectifier bridge (see Fig. 10). The output from the rectifier bridge is smoothed and passed via an error-detector to the low-pass section of the power-separating filter and, thence, to the sea-cable. In the differential error-detector a convenient potential is derived from the cable current, and this potential is compared with a standard reference voltage from a Zener diode. The resulting difference voltage is amplified and applied to the variable-impedance control element, which consists of a bridge of four silicon diodes having a transistor across the bridge. A rapid regulative action is achieved by operating the invertor at a frequency of 2,000 Hz.

There is an identical unit at each terminal station, and the output current of each unit is arranged to vary uniformly by $\pm 1 \cdot 5$ per cent of the nominal value from short-circuit to maximum-load conditions. Under normal conditions the two units operate together in series, sharing the total voltage equally at a current 1·5 per cent less than the short-circuit value. If one unit fails the output voltage of the other rises and the line current falls to 3 per cent less than the short-circuit value.

INSERTION OF REPEATERS

The repeaters were laid by H.M.T.S. *Iris* in October 1964. The ship took on a supply of 1·7 in. stock cable before sailing, and jointed a length of this cable to the first repeater to be laid. This repeater was inserted at a position 16·76 nautical miles from La Panne on 29–30

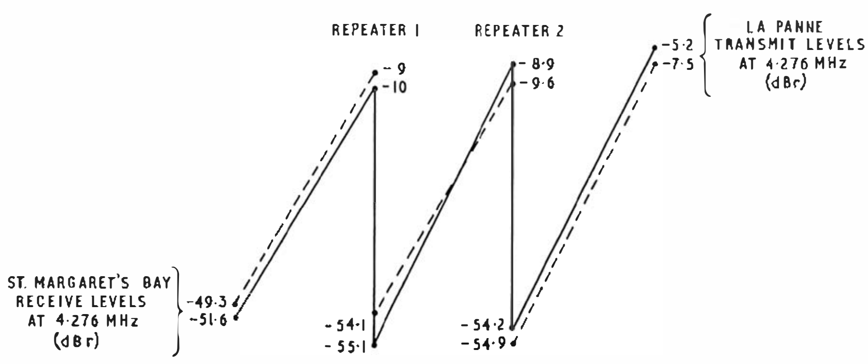
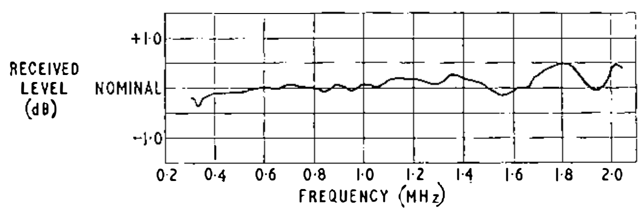


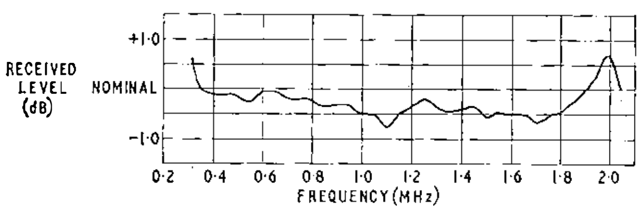
FIG. 11—SYSTEM LEVEL DIAGRAM

October. Before the repeater was finally jointed to the cable, harmonic tests were made from this position towards La Panne and towards St. Margaret's Bay to ensure that there was no defect in the cable that would significantly degrade the non-linearity performance of the system. Stock cable was paid out towards St. Margaret's Bay after the repeater had been laid, and the cable was jointed and tested overall with the one repeater in circuit.

It was found that the cable attenuation from La Panne to the first repeater was rather higher than that predicted by an increase of 0·2 per cent per annum on figures taken in 1961, but that there had been no increase in attenuation since that date over the remainder of the cable. It was concluded that the attenuation was unlikely to increase further, and the system planning was reviewed to take account of temperature variations only. Since the pre-emphasis characteristic was chosen to give an equal signal-to-noise performance on all channels in the high band and in the higher-frequency end of the low band, it was simply necessary to consider the levels at the highest frequency: it was decided that the required distance between repeaters was 16·58 nautical miles. The separation actually achieved was 16·708 nautical miles, which



(a) St. Margaret's Bay to La Panne



(b) La Panne to St. Margaret's Bay

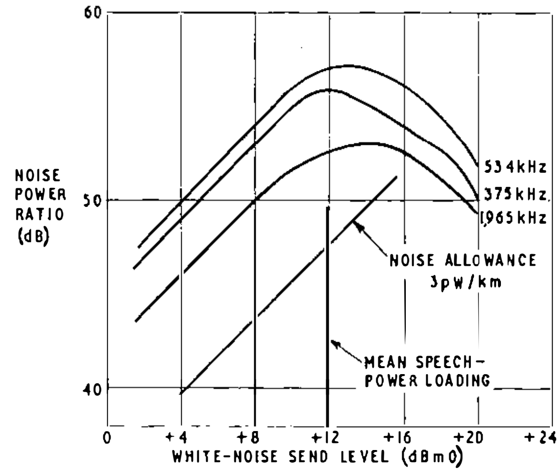
FIG. 12—SYSTEM ATTENUATION/FREQUENCY RESPONSE

was within the tolerance for the system. Fig. 11 shows the expected level excursions on the system at the top frequency for the specified extremes of temperature.

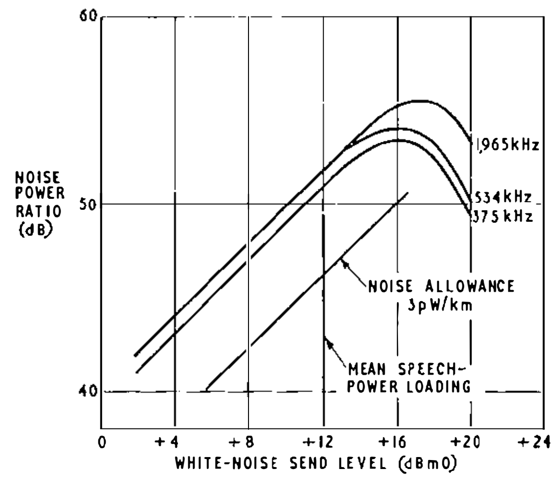
SYSTEM PERFORMANCE

The overall adjustments and the performance of the system were the responsibility of the contractor, but the commissioning tests were carried out as a joint operation between the contractor, the British Post Office and representatives of the Belgian Administration.

Extracts of the more interesting results are given graphically in Fig. 12, 13 and 14, which show, respectively, the system attenuation/frequency responses for the two directions of transmission, the white-noise loading test results for the two directions of transmission, and the second-order intermodulation test results. The difference-frequency intermodulation products falling into the low-frequency end of the spectrum, due to two test frequencies at the high-frequency end of the spectrum, exhibit maxima and minima when measured at La Panne.



(a) St. Margaret's Bay to La Panne



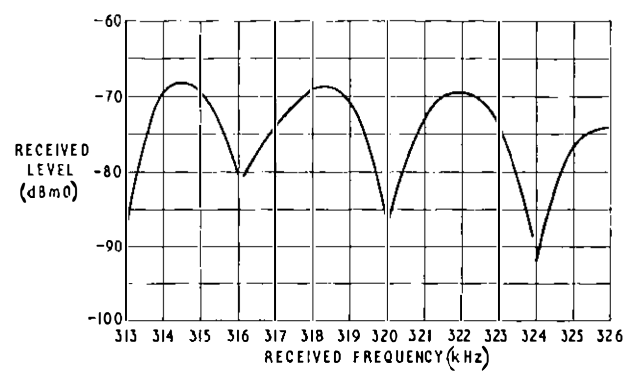
(b) La Panne to St. Margaret's Bay

FIG. 13—WHITE-NOISE LOADING TESTS

The phase of the addition and subtraction of the products is a function of the propagation time in the send and receive directions and, therefore, a function of the spacing between repeaters.

Repeater Monitoring

An existing design of repeater-monitoring equipment[8] was modified by the Post Office to make it suitable for this system, and was installed at St. Margaret's Bay.



Difference products, high band to low band, measured at La Panne

FIG. 14—RESULTS OF INTERMODULATION TESTS

The second and third harmonics of pulses sent from this equipment are returned from each repeater, and are displayed and measured separately on a time-division basis by a cathode-ray oscilloscope. Apart from the test of second-order and third-order intermodulation products already described, no repeater-monitoring tests were performed at La Panne.

FURTHER DEVELOPMENT

Development of transistor-type submerged-repeater systems is continuing, and several new 480-circuit systems are on order for completion in 1967. These include new cables from Covehithe (near Lowestoft) to Katwijk in the Netherlands, from Scarborough to Kristiansand in Norway, and from Bournemouth to Jersey.

CONCLUSIONS

Two transistor-type repeaters have been inserted in an existing submarine cable between St. Margaret's Bay and La Panne, and new equipment has been installed at the terminal stations to provide a system of 420-circuit capacity. The system has proved to be entirely satisfactory.

ACKNOWLEDGEMENT

The author thanks the Directors of Submarine Cables, Ltd., and Associated Electrical Industries, Ltd., for assistance and information supplied in connexion with this article, and for the photographs of Fig. 2, 3, 7 and 9.

Acknowledgement is also due to all who by their efforts contributed towards the successful completion of this project: in particular, the two manufacturers, the Regie des Télégraphes et des Téléphones of Belgium, the master and crew of H.M.T.S. *Iris,* the staffs at the terminal stations, the Home Counties Region Engineering Branch and the author's colleagues in the Engineering Department.

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Books Received

"Pulse Generators." Edited by G. N. Glasse and J. V. Lebacqz. Constable and Company, Ltd. xiv+741 pp. 502 ill. 24s.

"Klystrons and Microwave Triodes." D. R. Hamilton, J. K. Knipp and J. B. H. Kuper. Constable and Company, Ltd. xiv+533 pp. 227 ill. 24s.

"Vacuum Tube Amplifiers." Edited by G. E. Valley, Jr., and H. Wallman. Constable and Company, Ltd. xvii+743 pp. 392 ill. 24s.

"Waveforms." Edited by B. Chance, V. Hughes, E. F. MacNichol, D. Sayre and F. C. Williams. Constable and Company, Ltd. xxii+785 pp. 758 ill. 26s.

The above four books were originally published by McGraw-Hill Book Co., Inc., in the Massachusetts Institute of Technology Radiation Laboratory Series as Volume 5 (1948), Volume 7 (1948), Volume 18 (1948) and Volume 19 (1949), respectively. By the co-operation of MacGraw-Hill with Dover Publications, Inc., the books, unabridged and unaltered, have now been reproduced in Dover paperback editions on a paper which, the publishers claim, gives minmum show-through and will not discolour or become brittle with age; the pages are sewn in signatures, and the books may be opened flat without fear of pages dropping out.

Between 1940 and the end of the second world war the development of pulse generators for microwave radar proceeded space. The purpose of the authors of "Pulse Generators" was to record those developments which they considered would be by no means limited to radar applications but would be of use in tackling many problems in physics and engineering. This they achieved by giving, in full, both the theoretical and practical aspects of pulse-generator design, and dividing the book into three parts: hard-valve pulsers, line-type pulsers and pulse transformers.

In "Klystons and Microwave Triodes" the authors attempted to cover the development of microwave receiving valves, local oscillators and signal amplifiers. The book is divided into three parts: four introductory chapters covering valve types and functions, and basic electronic and circuit phenomena common to all types of valves, are followed by a part on planar grid valves and a part on klystrons.

The last two books form a pair: "Vacuum Tube Amplifiers" and "Waveforms" cover the principles of circuit design, respectively, for circuits that are essentially linear (amplifiers) and for circuits that are essentially nonlinear (oscillators, electronic switches, etc.).

"Elements of Mathematical Statistics." 2nd Edition. J. F. Ratcliffe, M.Sc. Oxford University Press. x+224 pp. 24 ill. 18s.

The first edition of "Elements of Mathematical Statistics" was reviewed in this Journal in January, 1964 (Vol. 56, p.236). For this second edition the chapter on regression and correlation (Chapter 16) has been enlarged to deal with curvilinear and multiple regression. The author points out in his preface that these were formerly embarked upon with reluctance because of the heavy computation involved, but the computation and analysis can now be left to a standard program on a computer. He has, therefore, included them to help the student to use, with understanding, such programs and the results they provide. Another chapter has also been added, and includes probability density and moment-generating functions, and the question of one-tailed and two-tailed tests.

At the end of his preface the author indicates the standard and scope of his book thus: "Readers may like to know that the title of this book was chosen (statistics covering such a wide field, from the purely descriptive to the strictly mathematical) to indicate that it provides the basis or elements of a mathematical treatment. A knowledge of A-level mathematics, and certainly a feeling for mathematical reasoning required at that level, is essential to the understanding of most of it."

A Wideband Multi-Channel Voice-Frequency Telegraph System

C. S. HUNT †

U.D.C. 621.394.441

A transistor-type frequency-shift modulation multi-channel voice-frequency equipment is described that has particular application for radio-telegraph traffic as a link between telegraph terminals and radio stations. The equipment can be used to provide six or 12 480 c/s-spaced channels, depending on the line bandwidth available.

INTRODUCTION

HIGH-SPEED unidirectional multi-channel voice-frequency telegraph (m.c.v.f.t.) systems are used as links between the London international telegraph terminals and the Post Office radio stations. Valve-operated m.c.v.f.t. equipment of the type used in the network between the Electra House overseas telegraph terminal and the radio stations has been described in a previous article in this Journal.[1] This article describes a re-designed equipment, using transistors, provided for a complementary network between the Fleet Building (London) international telex centre and some of the Post Office radio stations.

The aim of the re-design, apart from the use of transistors, with consequent saving in space and in power consumption, was to obtain a more effective use of the bearer-circuit bandwidth and an improved performance.

The system provides six unidirectional 480 c/s-spaced channels with mean frequencies in the series $600+(n-1)$ 480 c/s, where n is the channel number, and requires a bearer circuit bandwidth of 360–3,240 c/s. Many bearer circuits to the radio stations, however, have a bandwidth of 300–6,000 c/s or more, two 300–3,000 c/s telephony channels being assembled in a bandwidth of 300–6,000 c/s in London and used as a bearer circuit to the i.s.b. radio-telephony transmitter at the radio station (and, conversely, from the radio receiving station to London). This type of circuit is frequently used to carry m.c.v.f.t. systems, and to utilize the available bandwidth the new type of m.c.v.f.t. system can, if required, operate with line frequencies in the range 3,240–6,120 c/s. Combining two 6-channel systems, one with normal line frequencies and the other with the higher line frequencies, enables the maximum use to be made of the available bearer circuits by assembling a 12-channel system with 480 c/s-spaced channels in the bandwidth 360–6,120 c/s.

An improvement in performance has been obtained by attention to the method of generating the channel carrier frequencies. The three lowest-frequency carriers are generated at the same basic frequencies as those of the higher-frequency channels, and are modulated by the telegraph signal before being translated to the lower frequencies for transmission to line. Maintaining a high ratio between the carrier frequency and the modulating frequency produces a smooth change of frequency with little amplitude or phase discontinuity, thus avoiding the "jitter" that takes place on transitions when the ratio is low.

†Telegraph and Data Systems Branch, E.-in-C.'s Office.

[1]HUNT, C. S. Frequency-Modulated Voice-Frequency Telegraph Systems for Radio-Telegraph Services. *P.O.E.E.J.*, Vol. 53, p. 21, Apr. 1960.

DESCRIPTION OF EQUIPMENT

Send Terminal

A block schematic diagram of a send terminal is shown in Fig. 1.

The initial generation of all channel frequencies is at one of the mean frequencies of 2,040, 2,520 or 3,000 c/s, and telegraph modulation takes place at this stage, for the reasons previously given. The signal frequencies of the appropriate channels are then translated to their line frequencies by a group modulator, and the following table shows the basic mean frequency, group modulator carrier frequency (where appropriate), and mean line frequency for each channel.

Basic Mean Frequencies, Group-Modulator Carrier Frequencies, and Mean-Line Frequencies

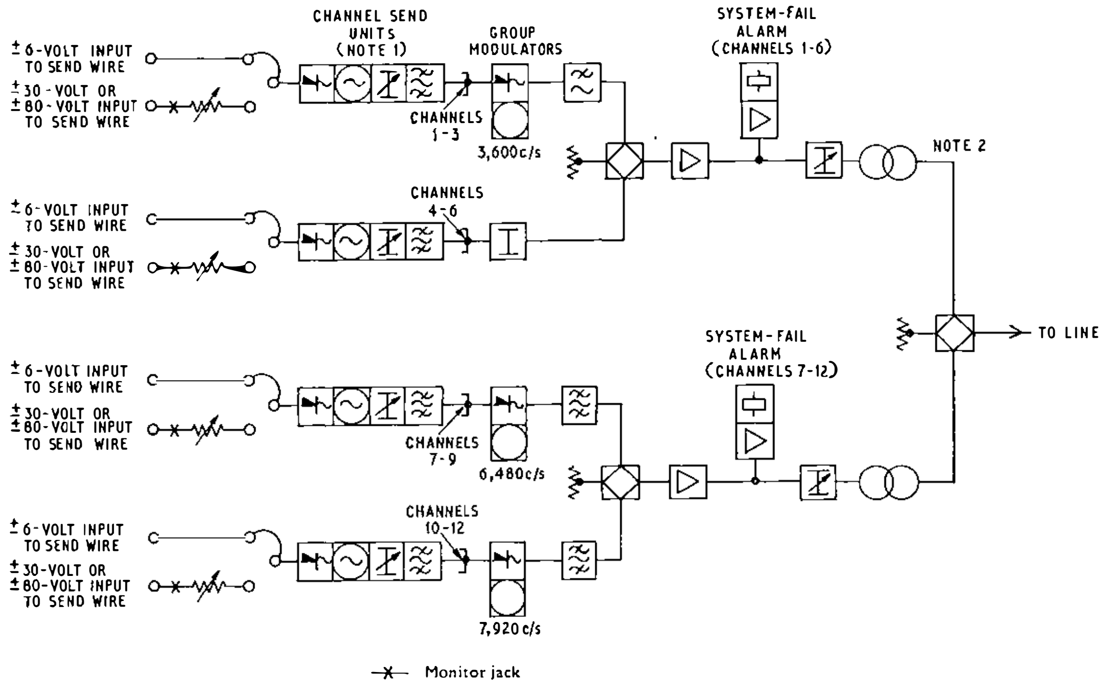
Channel No.	Basic Mean Frequency (c/s)	Group-Modulator Carrier Frequency (c/s)	Mean Frequency to Line (c/s)
1	3,000	3,600	600
2	2,520	3,600	1,080
3	2,040	3,600	1,560
4	2,040		2,040
5	2,520		2,520
6	3,000		3,000
7	3,000	6,480	3,480
8	2,520	6,480	3,960
9	2,040	6,480	4,440
10	3,000	7,920	4,920
11	2,520	7,920	5,400
12	2,040	7,920	5,880

With the process of telegraph modulation the carrier frequency is shifted 240 c/s, i.e. it is deviated about the mean carrier frequency by ± 120 c/s to produce two characteristic frequencies: the upper frequency f_A, corresponds to signalling condition A and the lower frequency, f_Z, corresponds to condition Z. The maximum permissible tolerance for the difference between the two characteristic frequencies is ± 6 c/s, as specified by C.C.I.T.T. Recommendation R38A,[2] and that for the mean frequency f_M, which corresponds to $(f_A + f_Z)/2$, is ± 4 c/s. To accord with the same C.C.I.T.T. recommendation, the frequencies in the bearer circuit correspond to f_Z for a stop-polarity telegraph signal input, and to f_A for a start-polarity signal.

For channels 4–6, which are not group translated, the above convention directly applies to the channel modulator, but the remaining channels all undergo frequency inversion during translation, and the channel modulators have to be arranged to give the reverse condition, which is again reversed by the group-translation process.

A further requirement is that with input-signal failure, i.e. with no input voltage to the modulator, the channel frequency to line should automatically go to f_A. The send units for channels 4–6 are, therefore, arranged

[2]Recommendation R38A, Blue Book, Vol. VII, International Telegraph and Telephone Consultative Committee.



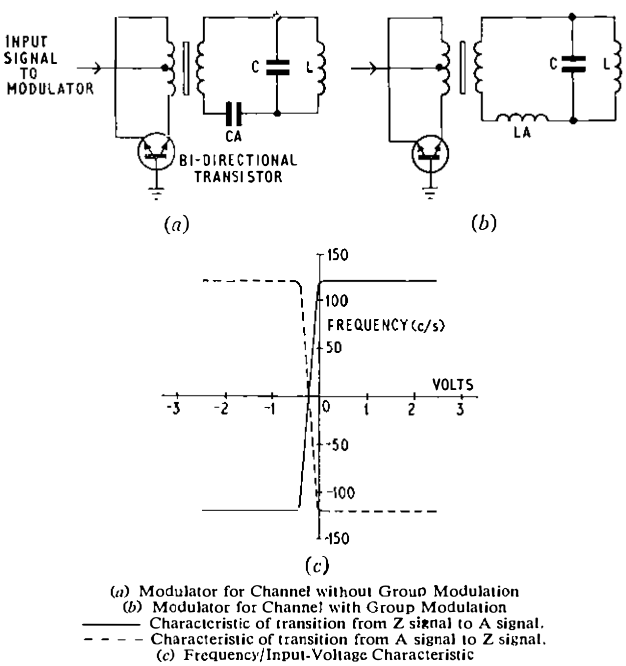
Notes: 1. The basic mean frequency of each channel is shown in the table.
2. The line is connected at this point if only six channels are required.

FIG. 1—BLOCK SCHEMATIC DIAGRAM OF SEND TERMINAL

to do this, but those for the translated channels are arranged to give the opposite effect.

The required conditions are selected by the appropriate connexion of soldered straps in the sender unit. Each channel sender unit comprises an *LC* oscillator, telegraph-signal modulator and band-pass filter.

Fig. 2 shows in simplified form the action of the channel modulator. A negative-potential input signal causes the bi-directional transistor connected across the transformer primary to conduct, causing a low resistance to be reflected into the transformer secondary, which then acts as a low-resistance connexion. Conversely, with a positive-potential input signal, the primary is open-circuited and the secondary acts as a disconnexion. For untranslated channels, network LC is set to produce the upper characteristic frequency, f_A, with a positive input voltage, and when the input voltage is made negative an additional capacitor, CA, is connected in parallel with the network LC, thus lowering the frequency. The value of capacitor CA can be adjusted to give a frequency shift of exactly 240 c/s. For translated channels the opposite conditions must apply, and with a positive-potential input signal network LC is adjusted to give the lower characteristic frequency, f_Z. When the input voltage is made negative, an inductor LA is switched into circuit, and, by adjusting the value of LA, the frequency of oscillation is raised by 240 c/s.



(*a*) Modulator for Channel without Group Modulation
(*b*) Modulator for Channel with Group Modulation
——— Characteristic of transition from Z signal to A signal.
- - - - Characteristic of transition from A signal to Z signal.
(*c*) Frequency/Input-Voltage Characteristic

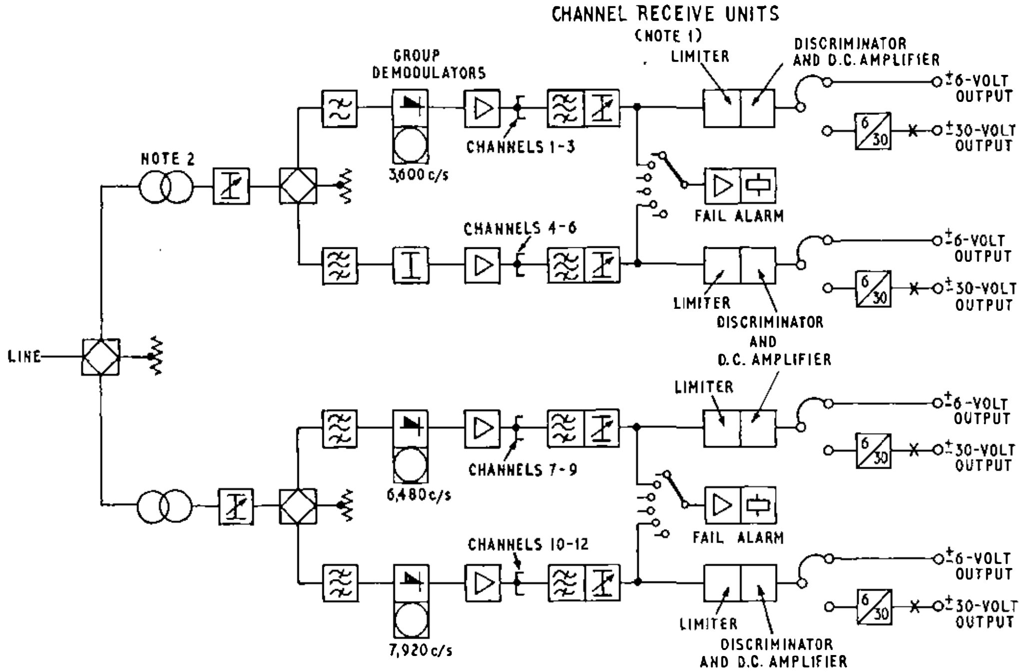
FIG. 2—MODULATOR ACTION

In a 6-channel system, the two groups of three channels, one group-translated, the other not, are combined by a hybrid coil, which is followed by a system amplifier and level-adjusting attenuator, and then connected to line. For a 12-channel system two further groups of three channels, both group translated as indicated in the table, are connected via group filters, combining hybrid coils, system amplifier and attenuator to another hybrid coil that combines channels 1–6 with 7–12 (see Fig. 1).

Receive Terminal

At the receive terminal the received tones are passed by the appropriate group filters to each group of three channel receive units, the arrangement being shown in block schematic form in Fig. 3.

Each receive unit comprises a channel band-pass filter, limiter stage, discriminator and d.c. amplifier output stage. The limiter maintains the level of tone to the discriminator materially constant despite level changes



—✕— Monitor jack

Notes: 1. The basic mean frequency of each channel is shown in the table.
2. The line is connected at this point if only six channels are required.

FIG. 3—BLOCK SCHEMATIC DIAGRAM OF RECEIVE TERMINAL

about nominal of +10 to −15 db, and a square-wave signal is produced at its output.

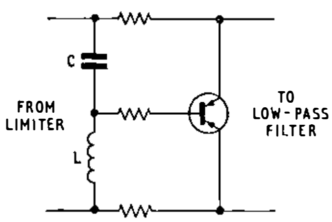
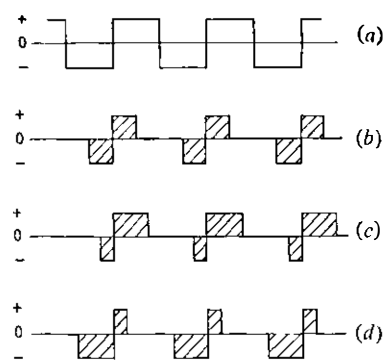


FIG. 4—DISCRIMINATOR CIRCUIT

The discriminator (Fig. 4) is of rather unusual design. Circuit LC is tuned to the channel mean frequency f_M, and the bi-directional transistor short-circuits the input to a low-pass filter for half a cycle of every cycle of channel frequency. Network LC delays the switching action by 90°, exactly a quarter of a cycle of the channel mean frequency, and, as will be seen in Fig. 5, the two quarter-cycles of conduction (shown as shaded areas in Fig. 5(*b*)) into the filter are then equal and opposite, hence the filter output is zero. For higher frequencies the switching action occurs later in the cycle (Fig. 5(*c*)), and the overall difference in conducting areas results in a positive-potential output signal. Conversely, with lower frequencies, the width of the negative-potential areas of conduction increases at the expense of the positive, thus producing a negative-potential output (Fig. 5(*d*)). The output from the post-discriminator filter is therefore the difference between the shaded areas, the resulting p.d. driving the d.c. amplifier stage, which includes a bias control and is arranged to give an output of nominally ±6 volts into a 1,000-ohm load. The polarity of the discriminator output can be reversed by means of soldered straps, a facility necessary to give the correct output polarity for both translated and untranslated channels.



(*a*) Square Waveform of Signal at Output of Limiter
(*b*) Effect of Switching Action at Output of Discriminator at Channel Mean Frequency, f_M
(*c*) Effect of Switching Action at Upper Signal Frequency, f_A
(*d*) Effect of Switching Action at Lower Signal Frequency, f_Z

FIG. 5—DISCRIMINATOR ACTION

Output-Signal Voltage Converter. Where the receiving m.c.v.f.t. terminal is at a radio-transmitting station, it is sometimes necessary to generate ±30-volt signals to control the radio-transmitter drive unit. This is effected by a solid-state device that transforms a ±6-volt input to a ±30-volt output. It combines the functions of a ±30-volt supply and a polarized relay, and is powered only from the −12-volt supply.

Power is provided by an oscillator of approximately 20 kc/s; its output is fed to two switched power-amplifiers, the feed to one being via a phase-changing circuit controlled by the input signal. The output signal is derived from a transformer with two identical secondary windings, one for either condition of the output signal. Each winding provides rectangular-wave pulses to the output terminals via a pair of switching transistors controlled in antiphase by the input signal. One pair allows only positive half-cycles from the oscillator to pass to the output, the other pair allowing only negative half-cycles to pass. After the signal has traversed a smoothing network only a very small percentage of the original oscillator frequency remains.

The distortion introduced by the converter does not exceed 2 per cent at 250 bauds.

Full d.c. isolation is provided between the power supply and the input and output circuits.

Physical Design

At the Fleet Building terminal, 9 ft rack-sides are used, each accommodating four sending or four receiving 6-channel equipments together with the necessary power-units, which are mounted at the top of the rack-side. A jackfield is provided for testing purposes for the ±30-volt or ±80-volt channel ends, and a U-link panel for testing at ±6-volts. The receive rack-side can also accommodate the requisite number of signal-voltage converters if they are required, but with the general trend to more transistor-type equipment there is less demand for interface-signal voltages other than ±6-volts except where the output signals have to be transmitted via the external line network.

At the radio stations rack-sides 6 ft 6 in. in height were chosen to line up with existing racks. These rack-sides (Fig. 6) accommodate either three sending or three receiving equipments; otherwise the arrangement is the same as on the 9 ft rack-side. Two rack-sides can be bolted back-to-back, thus accommodating either eight or six equipments in one rack space.

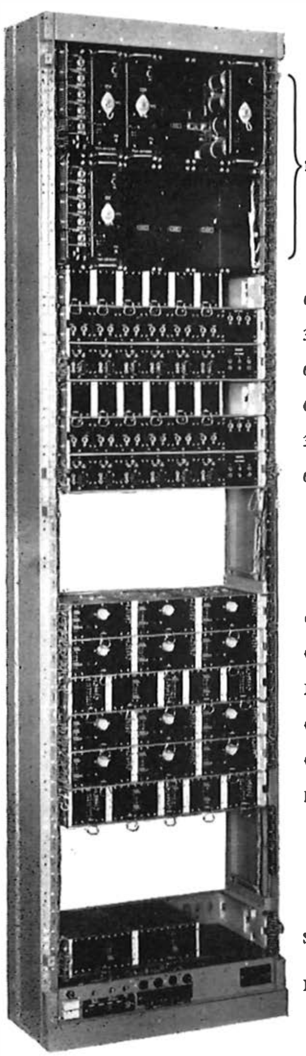


FIG. 6—A 6 ft 6 in. RACK-SIDE EQUIPPED AS TWO RECEIVE TERMINALS

Power Supply

Each rack-side is served by a number of a.c. mains-operated power units which, as already mentioned, are accommodated at the top of the rack-side. Each unit provides a regulated 12-volt output, unaffected by changes in mains supply of ±10 per cent and loads of up to 1 amp d.c.

The transistor circuits are designed to operate from +12-volt and −12-volt supplies, and one pole of each 12-volt supply is earthed as required, to provide one of the two required polarities.

Alarm Facilities

Since the equipment carries high-revenue-earning circuits, immediate recognition is required of an equipment failure, and an alarm signal is, therefore, given for: (*a*) failure of either of the ±12-volt stabilized supplies, (*b*) a reduction from normal of 15–20 db in the line level of the aggregate tones of six channels at the send terminal, and (*c*) a reduction from normal of 9–14 db in tone level at the band-pass filter output of any one selected receive channel at the receive terminal.

Performance

The voice-frequency channels are the land-line connexions to long-distance h.f. radio channels, and they have to cater for a variety of telegraph systems with a wide range of modulation rates. It is important, therefore, that they should perform with a minimum of distortion at comparatively-high modulation rates, as this will avoid the added complication of signal regeneration at radio transmitting stations.

The performance is such that the isochronous distortion on any channel does not exceed 7 per cent at modulation rates up to 240 bauds, when all other channels are signalling and with signal-level variations between +10 and −15 db about normal. Under normal conditions the majority of channels perform with appreciably less distortion than this, and a similar performance is obtained when two systems are combined into a 12-channel system.

CONCLUSIONS

A re-designed, wideband frequency-shift-modulation voice-frequency telegraph equipment has been described which has particular application for carrying radio-telegraph traffic. Apart from the considerable saving in space and power consumption obtained by the use of transistors, greater use is made of available bearer-circuit bandwidth, and an improved performance is obtained.

ACKNOWLEDGEMENT

The photograph reproduced in Fig. 6 was supplied by Associated Electrical Industries, Ltd.

Trench-Cutting Machines

E. W. CHARLTON, C.Eng., A.M.I.Mech.E.†

U.D.C. 621.315.233.002.5

This article gives a brief description of the various trench-cutting machines employed by the British Post Office since they were first introduced in 1948.

INTRODUCTION

PRIOR to 1948 the trench-excavating machinery available in this country had been much too large and heavy for successful application to the cutting of the narrow and shallow trenches needed for British Post Office underground duct work.

Many of the machines employed by contractors were very much over-designed for Post Office work. Some were capable of digging trenches 3 ft wide and 12 ft deep: their capital cost was high, they were heavy and difficult to transport from place to place, and they were generally unsuitable for use on narrow grass verges, where much of the Post Office duct is laid.

It was not until the Aveling-Barford trench-cutting machine, described below, became available that the Post Office, seeing in this machine the nearest approach so far to its requirements, decided to place a number of these machines on trial.

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

FIG. 1—AVELING-BARFORD TRENCH CUTTER

EARLY TRIAL MACHINES

Aveling-Barford Trench-Cutting Machine

The Aveling-Barford trench-cutting machine (Fig. 1) was driven by an 8 h.p. petrol engine and was self-hauling, using a ground anchor and 300 ft of $\frac{3}{8}$ in. diameter wire rope. The rope passed round a pulley at the anchor and over a winch drum on the machine, giving an effective travel of 140 ft with each anchor setting. Forward motion of the machine was effected by a crank-operated variable-ratchet drive on the winding drum. The rear wheels were adjustable in a vertical direction, allowing the machine to be used on sloping ground. Stellite-tipped steel tines and scraper plates on an endless chain, moving over the digging boom, loosened and carried soil forward and upwards to a transverse conveyor-chain belt. This belt deposited the soil in a continuous bank on one side or the other of the machine. Trenches could be cut within 2 ft of a boundary line.

The machine weighed about 3 tons, and digging speeds of about 30 yd/hour could be achieved in good average conditions, but this was liable to be reduced to 15–20 yd/hour in difficult terrain.

The results of the trial were considered satisfactory, and 10 machines were purchased in 1948. They were a valuable acquisition at a time when contract labour available to the Post Office had been greatly reduced, and considerable savings, compared with contract prices, were reported.

There were, however, a number of criticisms of the machine: it was said that the trencher was cumbersome and difficult to manoeuvre into position during trenching operations, that it had difficulty in dealing with clay

FIG. 2—ALLEN 12/21 TRENCHER

soil, and that it was not easy to keep the machine on a straight course. Complaints were also made about the time taken to change the soil conveyor from one side to the other.

Allen 12/21 *Trenchers*

The only other trenching machine on the market that looked as if it might be suitable for Post Office work, taking account of the above criticisms of the Aveling-Barford Trencher, was the Allen 12/21 Trencher (Fig. 2). This machine was the smallest of the range of Allen Trenchers. It was powered by a hydraulically started diesel engine, developing 40 b.h.p. at 1,000 rev/min. The engine provided power for the road tracks, main digging boom and the hydraulic rams that raised and lowered the boom. A 2-speed gear-box was incorporated to drive the excavating buckets, which were arranged to tip the soil on to a flat transverse conveyor belt. The conveyor was 18 in. wide, and could be pushed by hand to project either side of the machine to suit whichever position in which it was desired to dump the excavated material. Operation of the machine was controlled from the side, thus enabling the operator to observe the digging system and the guide marker at the front, and so keep the trencher on its course.

Four digging speeds covering a range of 2 ft 6½ in. to 7 ft 6 in. per minute, together with reverse, were provided. The complete machine, capable of road speeds of 2½ mile/hour and 4 miles/hour, weighed 7¼ tons and could cut trenches 12 in. or 18 in. in width and up to 6 ft deep.

The machines were of rugged design, and their digging performance was excellent even in the most difficult terrain. Digging speeds of approximately twice that of the Aveling-Barford Trencher were achieved. Difficulty was experienced, however, in providing suitable work for these machines in sufficient quantity to keep them fully occupied. The majority of the large duct-laying jobs were undertaken by contractors, and it was found that, due to the difficulty of transporting the machine from site to site, it could only be used economically on large works, and comparatively few of these were being undertaken by direct labour.

A few of these trenching machines still exist, but their employment is limited to special jobs where the digging is particularly difficult and the cost of transporting the machine to site can be justified.

Astell-Watts Trencher

In 1956 a trial was made of a tractor-mounted trench excavator. This excavator, the Astell-Watts Trencher (Fig. 3), was designed to be mounted at the rear of an industrial tractor. The digging chain was fitted with transverse spade-plates on an adjustable boom; the chain was driven from the tractor engine through the back axle of the tractor, the road wheels being disconnected, by the removal of a locking pin on the hub unit, whilst the excavator was being driven. The digging boom was raised and lowered by means of the tractor 3-point hydraulic linkage.

A ratchet-operated winch fitted to the front of the tractor, and operated by an arm fixed to a crank on the chain drive, provided forward motion to the unit through the medium of a winch rope and a ground anchor in advance of the tractor.

Originally, a transverse spoil-conveyor belt, driven from the power take-off of the tractor, disposed of the spoil to the side of the trench. This was later abandoned in favour of two dish-type scraper plates (see Fig. 3).

FIG. 3—ASTELL-WATTS TRENCHER

Trials of this excavator proved that it had decided advantages over the Aveling-Barford and Allen excavators previously employed. It was self-mobile, easily manoeuvred into position, and it could be used where the others would be impracticable. Furthermore, its low running cost and its speed of operation made it an economical proposition even for laying short lengths of duct.

The Astell-Watts Trencher did, of course, require a tractor, and, whilst it was claimed that the excavator could be removed from the tractor in about an hour, the re-fitting of the normal winch to enable the tractor to be used for moledraining purposes took the best part of half a day. Later, a special winch was designed that could be fitted to the excavator by merely removing the digging boom, but the performance of this winch did not equal that of the winch normally provided for moledraining operations. Whilst the unit was self-mobile over short distances, transporting it over long distances meant employing a low-loading trailer, and, unfortunately, the width over the tractor wheels, when increased to accommodate the drive to the excavator, prevented it from being loaded on to the Post Office's standard 4-ton low-loading trailer.

Although it might be said that the design of this trench excavator had been a step in the right direction, it did not completely meet Post Office requirements.

FIG. 4—TRENCH EXCAVATOR No. 1

Therefore, following the Astell-Watts Trencher trials, attempts were made to interest a number of manufacturers of agricultural-type machinery in producing a small compact trench-excavator to dig trenches from 3–12 in. in width and up to 3 ft deep for Post Office work; but these attempts were without success. Outside the Post Office there seemed to be little demand at that time for this type of excavator and, as no guaranteed demand could be given, the firms approached were unwilling to accept a development contract to produce a prototype trench-excavator for trial.

FIG. 5—TRENCH EXCAVATOR No. 2

American Trenching Machines

There had always been a number of medium-weight and light-weight trenchers available in the U.S.A., and, eventually, one or two British firms took agencies for the sale of this plant in the United Kingdom. The trenching machines in which the Post Office were interested were manufactured by three American companies: A.R.P.S. Corporation, Wisconsin, U.S.A.; Charles Machine Works, Oklahoma, U.S.A.; Davis Manufacturing Inc., Kansas, U.S.A.

Trenching machines from each of these companies were given a field trial in 1961. The outcome of these trials was the introduction of the three machines described below, which go a long way to meet the present requirements of the British Post Office for laying single-way duct and polythene cable directly in the ground.

PRESENT TRENCHING MACHINES

Excavator, Trench, No. 1

The Excavator, Trench, No. 1, is provided for cutting trenches 3 in. wide and to a depth of 2 ft for polythene cable and small-diameter duct. The machine (Fig. 4), of the chain type and mounted on three wheels with semi-pneumatic tyres, is powered by a 6 h.p. air-cooled petrol engine with recoil start. It is 78 in. long, 31 in. wide and weighs $2\frac{1}{2}$ cwt.

The machine is drawn forward by means of a wire rope from the excavator winch to a ground anchor in advance of the machine. A 6-speed self-winding mechanism enables the trenching speed to be adjusted to suit soil conditions, with engine stall due to shock loads being prevented by a torque-limiter unit. A V-belt tightener acts as an engine clutch.

The digging boom is raised and lowered by a cranked self-locking handle. An earth-disposal auger conveys the spoil to one side of the machine, the excavated soil being finely chopped and ideal for reinstatement. Typical performance figures for a trench 12 in. deep are 75 yd/

hour under favourable digging conditions and 15 yd/hour under difficult digging conditions.

Excavator, Trench, No. 2

The Excavator, Trench, No. 2 (A.R.P.S.), is for excavating trenches from 4–12 in. wide and up to a depth of 3 ft 6 in. The machine (Fig. 5), which is for use on surfaces where a track-laying vehicle would not be permitted, is a pedestrian-operated self-propelled machine mounted on four pneumatic-tyred wheels. Power is provided by a 12½ h.p. air-cooled petrol engine with electric starter, and road speeds of 3 miles/hour are possible.

The boom is fitted with a chain-type digging line that can be raised and lowered hydraulically. Digging speeds are infinitely variable, control knobs being provided on each side of the machine to enable digging speeds to be easily adjusted to suit conditions. Excavated material can be deposited to either one side of the machine or the other, as desired, by means of a transverse conveyor belt. An adjustable crumber attachment is also provided to remove loose soil from the bottom of the trench. The excavated soil is finely chopped and ideal for reinstatement. Digging speeds vary considerably depending on soil conditions and trench dimensions. Typical performance figures are given in the following table.

Digging Conditions	Trench Width (in.)	Trench Depth (in.)	Cutting Speed (yd/hour)
Favourable	12	24	60
	4	12	180
Difficult	12	24	30
	4	12	60

The excavator, which weighs 14 cwt and measures 61 in. in length with the digging boom raised and 38 in. in width with the soil conveyor removed, has front wheels which are steerable and provide excellent directional control. The machine can be loaded with ease under its own power into a vehicle or on to a low-loading trailer.

Excavator, Trench, No. 3

The Excavator, Trench, No. 3 (Ditchwitch) is for excavating trenches 4–12 in. wide and up to 3 ft in depth.

The machine (Fig. 6) is suitable for use on soft ground and on sloping verges. It is not intended for use on asphalt surfaces; such surfaces may be damaged by the tracks, especially in warm weather.

The excavator is of the chain-type, self-propelled, and mounted on caterpillar tracks. The operator stands on a platform at the rear of the machine and steers with a long vertical lever that actuates a steering-clutch mechanism on the tracks. Power is provided from a 12½ h.p. air-cooled petrol engine with electric starter.

A gear-box and planetary reduction unit provides three forward speeds and one reverse speed for transport and digging: road speeds of up to 3 miles/hour are possible.

The digging boom is raised and lowered hydraulically, and soil from the trench is deposited to one side of the machine only by means of an earth auger. The digging speeds are similar to those obtained with Excavator, Trench, No. 2. A crumber attachment is also provided with this machine for removing loose soil from the bottom of the trench.

The machine, which weighs 14 cwt and measures 96 in. in length with the boom up and 48 in. in width, can be loaded under its own power into a vehicle or on to a low-loading trailer.

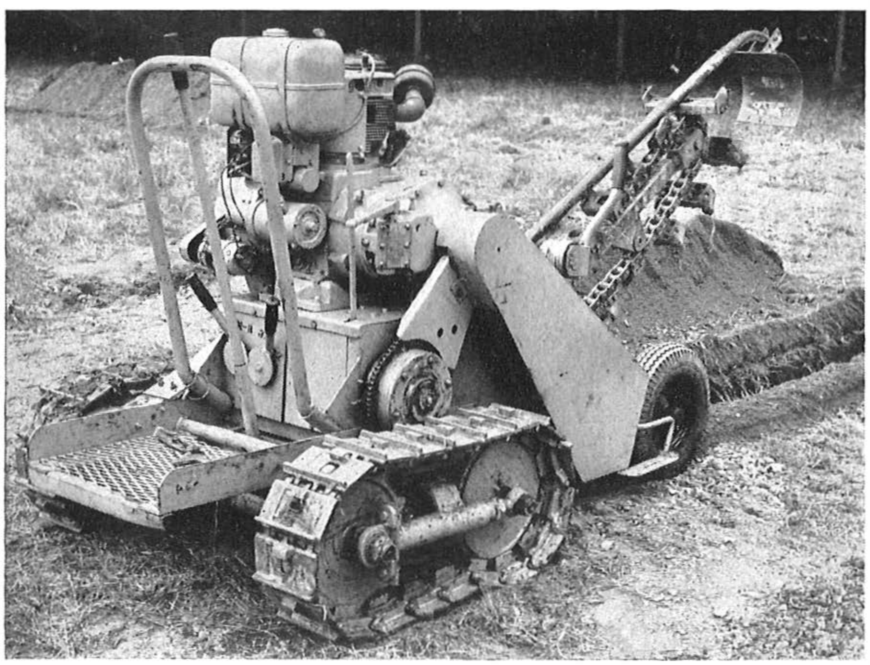
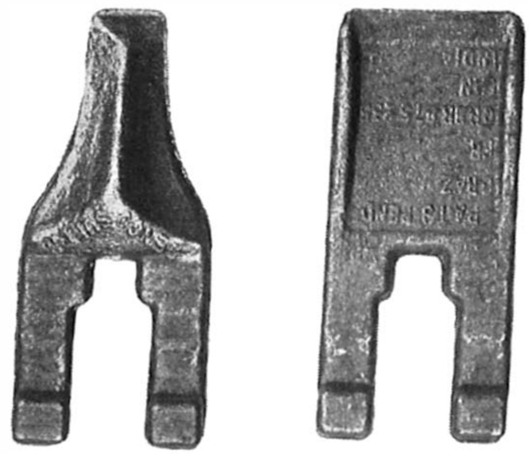


FIG. 6—TRENCH EXCAVATOR No. 3



(a) Super Tooth (b) Wisdom Tooth

FIG. 7—TEETH USED IN TRENCH EXCAVATORS No. 2 AND 3

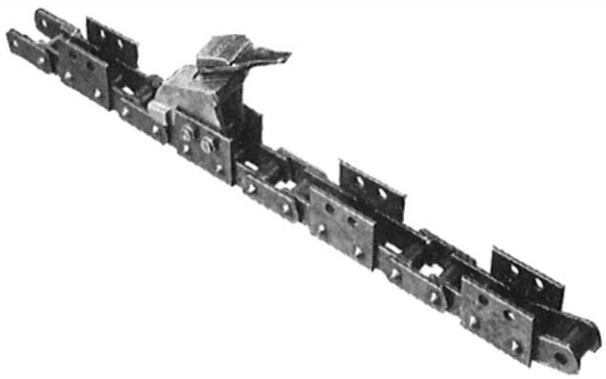


FIG. 8—SUPER TOOTH MOUNTED ON DIGGING CHAIN

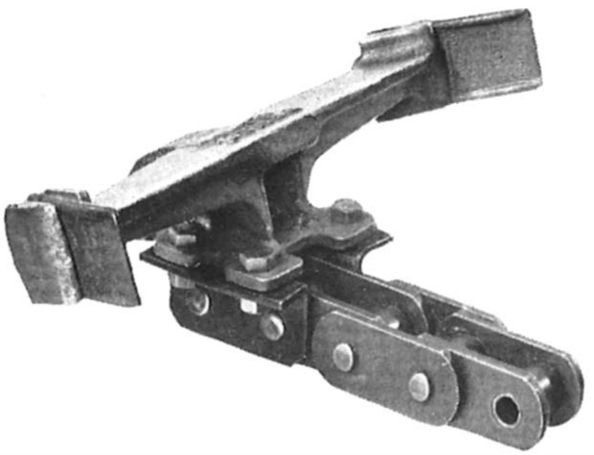


FIG. 9—WISDOM TEETH MOUNTED ON DIGGING CHAIN

Digging Teeth

Excavators, Trench, No. 2 and 3, are both now fitted with Pengo digging teeth. These teeth are forged from alloy steel, and are held in position by specially designed holders which enable them to be easily replaced when they become worn or broken. Fig. 7 shows the two types of teeth used, the Super Tooth and the Wisdom Tooth, and Fig. 8 and 9 show these teeth mounted on the digging chain.

Wisdom Teeth are suitable for digging in normal conditions. They should always be fitted in the widest holder positions, as they clean-up the sides of the trench: they may be reversed when the outside corner wears. Super Teeth are designed to break up hard ground, and should be used when the Wisdom Teeth have difficulty in doing this. Super Teeth should be fitted with the ridge along the tooth facing upwards.

The method of fitting and removing teeth is identical for both types. Each tooth is held firmly in its holder by a short length of $\frac{1}{8}$ in. diameter solid rubber known as Rubber Lock. To fit a tooth, a length of Rubber Lock is cut equal in length to the width of the tooth. This is inserted through a hole in the tooth holder (Fig. 10). The tooth is then pushed on to the holder and lightly driven home with a hammer. The rubber is compressed between the edges of the holder and the inside of the tooth, thus locking the tooth in position. To remove the tooth it is driven off in the reverse direction using a tapered punch. The same piece of Rubber Lock may be used for several changes of teeth.

CONCLUSIONS

The results obtained from Excavators, Trench, No. 1, 2 and 3, have been very satisfactory. Their compact design and light weight has enabled them to be easily manoeuvred into position in the field, and transportation from site to site has presented no problems as the machines can be loaded with ease into vehicles or on to low-loading trailers of standard Post Office pattern.

The three types of excavator cater for most of the trenching undertaken by direct labour for duct-laying or burying cable directly in the ground. Trenching on housing estates does still, however, present a problem where made-up ground is encountered: the digging in these conditions can be extremely tough going. In an attempt to combat these conditions, two British firms are now producing designs of machines equivalent to Excavators, Trench, No. 1 and 3, but with more digging power.

There is also need for an excavator with an offset digging line which will enable trenches to be cut to one side of the machine. Some development work of an exploratory nature has already been done in this direction, but there remain a number of problems to be overcome.

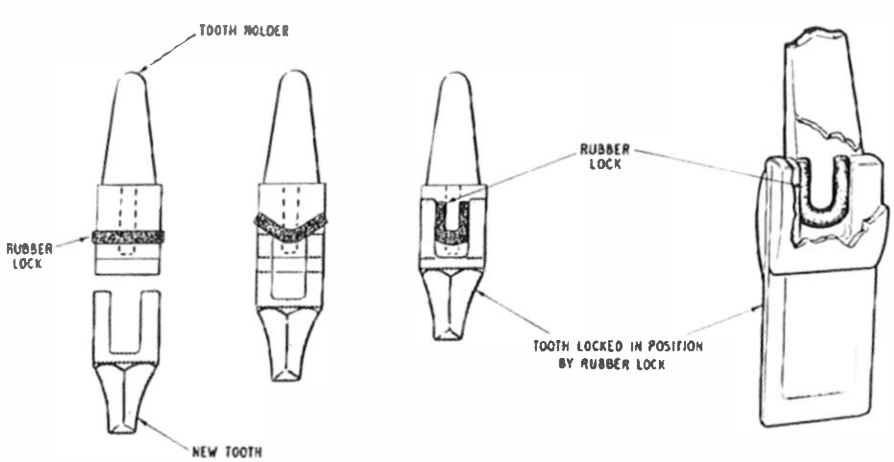


FIG. 10—METHOD OF FITTING TOOTH

The Public Utility Street Works Act, 1950: Calculation of Benefit by Deferment of Renewal Allowance

U.D.C. 351.712

The Public Utility Street Works Act, 1950, lays down that, where a public utility undertaker's existing plant has to be replaced in a new position in conjunction with road-works operations, the cost to the promoter of the works has to be offset by an amount equal to the benefit accruing to the utility undertaker by virtue of the deferment of the subsequent renewal of the plant. An agreed method for the calculation of benefit by deferment of renewal is discussed.

THE British Post Office, like other public utility undertakers, is often called upon to remove items of plant on the public highway to a new position to enable the highway authority to carry out alterations to the line or level of the existing footway or carriageway. Much of the work of this nature is carried out under Part II of the Public Utility Street Works Act, 1950,* which lays down the principle on which charges for this work are to be based. In general, and with certain well-defined exceptions, the principle laid down is that the undertaker is permitted to charge the highway authority for the reasonable cost involved in recovering existing plant and providing new plant (or for shifting the existing plant) to give facilities equal to those previously enjoyed. If, however, it is decided to take the opportunity to provide plant which gives better facilities than those existing, the excess cost for this "betterment" must be borne by the undertaker.

A feature of the Act is the recognition of the fact that when new plant is provided in replacement of the existing, the subsequent renewal of the plant in the normal course is deferred. The circumstances are shown diagrammatically in the illustration. If plant

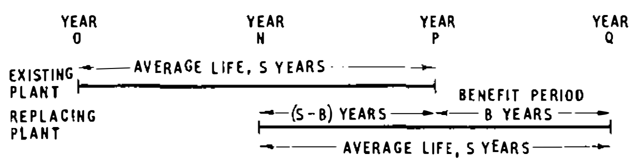


DIAGRAM SHOWING RELATIONSHIP OF BENEFIT PERIOD TO AVERAGE LIFE OF PLANT

having an average life of S years was provided in year O it would normally be renewed in year P. If, however, in year N the plant has to be replaced by new plant because of roadworks, the renewal for the new plant is not now necessary until the year Q. The period of time between year P and year Q, B years, is the period of time for which the renewal is deferred; it is termed the "benefit period," and the Act stipulates that credit should be allowed to the highway authority equal to the financial benefit derived by the undertaker in consequence of the deferment of renewal by this period.

The Act is not precise as to the calculation of the financial benefit and, hence, different methods have been adopted by the various utility undertakers and highway authorities. This position was not satisfactory and, resulting from a series of meetings between representatives of all parties concerned, a formula acceptable to all has now been agreed. The new formula is based on the concept of lump-sum commitment charges. Referring again to the illustration, the considerations are as follows.

Under the original situation the existing plant has to be replaced at year P at a cost of, say, £G. Under the new situation this commitment does not arise until the year Q. The benefit to the undertaker in deferring the commitment from year P to year Q is represented by the difference in the present value, i.e. at year N, between these two charges.

If an interest rate, for present value purposes, of r is assumed, the allowance becomes

$$\pounds\frac{G}{(1+r)^{S-B}} - \frac{G}{(1+r)^{S}},$$

$$\text{i.e. } \pounds\frac{G\{(1+r)^{B}-1\}}{(1+r)^{S}}$$

For ease of application it has also been agreed that as far as Post Office plant is concerned, for this purpose only, the average life for all plant will be taken as 60 years and the residual value of all plant will be zero. Thus, the new formula requires no modification for different residual values, and the final formula to be used will be,

$$\pounds\frac{G\{1+r)^{B}-1\}}{(1+r)^{60}}.$$

It has been further agreed that an interest rate of 5 per cent, subject to review after an interval of not less than 3 years, should be used for the formula.

The agreement has been ratified by 20 bodies representing all the Highway Authority interests, including the Ministry of Transport, and the Electricity Supply Industry, Gas Council, British Waterworks Association and the Post Office.

C.R.G.H.

*PAGE, E. A. The Public Utility Street Works Act, 1950. *P.O.E.E.J.*, Vol. 45, p. 8, Apr. 1952.

Semiconductor Device Developments: Integrated Circuits

Part 1—Construction, Properties and Applications

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U.D.C. 621.38.049.75

Integrated circuits offer the possibility of greater reliability in less space and at a lower cost than is possible with discrete components. This article is intended as a general introduction to integrated circuits: Part 1 contains a brief description of the construction and properties of the main types of circuit currently available, together with some indications of their advantages, applications and possible future developments; Part 2 will describe the standard logic circuits available in the form of semiconductor integrated circuits.

INTRODUCTION

INTEGRATED circuits have been developed from laboratory prototypes to production items in a remarkably short space of time, and they seem likely to cause a revolution in the electronics industry far greater than that brought about by the introduction of the transistor. Many different circuits are now available in integrated form, and some may eventually find wide application in Post Office equipment. This article is intended as a general introduction to the types of integrated circuit available at the present time, and gives a very brief review of their construction and properties.

Conventional electronic circuits are constructed from individual discrete components such as resistors, transistors, etc., each of which is an indivisible unit having specific properties. The components are interconnected to form the circuit required, and, in the event of a fault, the faulty component can be replaced by another similar unit. An integrated circuit is a complex component which may perform a similar function to a complete conventional circuit but which is itself produced and tested as an indivisible unit; in the event of a fault the whole unit has to be replaced. The early development of integrated circuits was almost solely concerned with military and satellite requirements, the result being that most of the circuits available are highly miniaturized devices and the term "integrated circuit" has become generally associated with microelectronics. An integrated circuit is not necessarily small however: its essential feature is that it is, physically, an indivisible unit, and it is this property that differentiates an integrated circuit from a miniaturized assembly of discrete components.

There is as yet no standard nomenclature in use for integrated circuits, but those available at the present time are generally classified into the following four types.

(*i*) Thin-film integrated circuits.
(*ii*) Thick-film integrated circuits.
(*iii*) Semiconductor integrated circuits.
(*iv*) Hybrid integrated circuits.

In the thin-film integrated circuit the passive elements are produced by the deposition of thin films on an insulating substrate. Circuits which also include discrete active devices attached to the substrate are generally included under this heading although they would be more correctly classified as thin-film hybrid circuits. The thick-film integrated circuits are similar except for the nature of the films used for the passive elements. In the semiconductor integrated circuit all the circuit elements are produced by diffusion techniques similar to those used for planar transistors. The whole circuit may be constructed in a single piece, or "chip," of semiconductor material; it is then known as a "single-chip" or "monolithic" circuit, while two or more separate chips may be interconnected inside a single package to produce a "multi-chip" circuit. Only the monolithic type of circuit is considered here in any detail, and, unless otherwise stated, all future references to semiconductor integrated circuits refer to this type of circuit. The term hybrid integrated circuit is used to describe a circuit which is constructed using a combination of different techniques.

Although rapid advances have been made over the last few years, and highly complex circuits can now be obtained in integrated form, design has so far followed the well-established lines of conventional circuits. Most types of integrated circuit are the result of a discrete-components design that has been converted to integrated form, and it is generally possible to draw an equivalent circuit using conventional components and to allocate the function of each component to a particular part of the circuit. The integrated circuit lends itself to completely new design ideas, however, and it is possible that the design will eventually be in terms of operations which can conveniently be obtained in integrated form rather than in terms of those which are most convenient for discrete components. Although it will still be possible to draw an equivalent circuit in terms of conventional components, this circuit will be purely descriptive and may not have any direct relationship to the construction of the integrated circuit. An example of a completely integrated circuit is the quartz crystal: this performs the function of a highly-selective tuned circuit, but it is not possible to isolate the equivalent-circuit elements or to allocate them to physically-separate parts of the crystal.

THIN-FILM INTEGRATED CIRCUITS

There are many possible variations in the methods of production of thin-film circuits[1, 2, 3] and many different materials which can be used for the circuit elements. The brief account which follows is only intended as a general outline of the construction and properties of a typical circuit of this type.

The circuits are generally produced on substrates of borosilicate glass or of ceramic having a high alumina content. Glass has the advantage of being easily polished, giving a reliable and reproducible surface finish, but the ceramic has a better thermal conductivity, allowing a greater dissipation in the circuit. A typical substrate might have a surface area of $1 \times 0{\cdot}5$ in., and the passive elements of the circuit and the interconnexions may be formed by evaporating or sputtering the appropriate materials in a vacuum chamber. Either metal masks or photolithographic techniques are used to define the areas of the circuit elements.

Resistors are generally made in the form of films of

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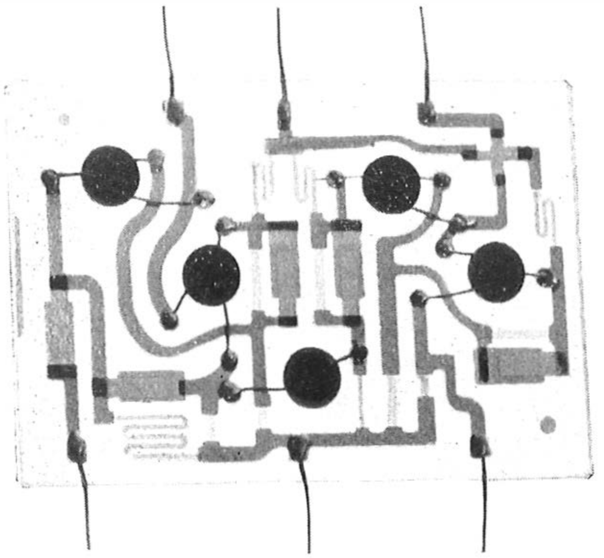
nickel-chromium alloy having a thickness of a few millionths of an inch. It is convenient to use a standard resistive film for all the resistors in a circuit, so that all can be deposited in one operation, and this generally has a sheet resistance of about 200 ohms/square.* Different values of resistance are then obtained by altering the length-to-width ratio of the film; high values of resistance require long narrow films, which are arranged in a meandering fashion in order to confine the resistor to a reasonable area of the substrate. Several resistors having different values can be seen in the typical thin-film circuit shown in Fig. 1. The width of the film is determined by the power dissipation and by the requirement



The circuit includes four transistors and one diode together with resistors and capacitors. The substrate measures 3 cm × 2 cm.
FIG. 1—TYPICAL THIN-FILM CIRCUIT

that the tolerances inherent in the masking operation should have only a small effect on the final resistance. A typical width would be about 0·02 in., and both the maximum and minimum values of resistance that can be obtained are limited by the area of substrate occupied. The range of values normally obtainable is from 50 ohms to 100,000 ohms. Normal tolerances are about 10 per cent, and the temperature coefficient is less than 50 in 10^6 per 1°C, but since all the resistors in a circuit are deposited at the same time their ratio tolerances can be much better than this, and they should all have similar temperature coefficients. It is possible (though more expensive) to adjust the values of resistors after deposition, and tolerances as low as 0·1 per cent have been quoted.

Capacitors are made in parallel-plate form by successive deposition of the lower electrode, dielectric, and top electrode. Aluminium is generally used for the electrodes and a silicon oxide for the dielectric. The range of capacitance values that can be obtained is limited by the area of substrate occupied, and by the maximum and minimum thickness of dielectric that can be used. A practical upper limit to this thickness is about 20×10^{-6} in., and the lower limit is determined by the breakdown voltage required. Capacitors having values from 50 pF to 25,000 pF can be obtained and normal tolerances are about 10 per cent, but values larger than a few thousand picofarads would normally be added as discrete components. The temperature coefficients are better than 100 in 10^6 per 1°C, Q-factors are in the region of several hundred from 1 kHz to 1 MHz, and voltage ratings of up to 50 volts can be obtained.

Normally, gold films are used for the conductors which interconnect the circuit elements, and these films may have a resistance of 0·5 ohms/square. This is an important fact to bear in mind when designing thin-film circuits, for a connexion having a length-to-width ratio of 20:1 would have a resistance of 10 ohms, and this could affect the performance of the circuit.

The use of tantalum in the construction of thin-film circuits is worth mentioning, for the sputtered-tantalum circuit enables resistors, capacitors and interconnexions to be produced by the same processes. Tantalum can be anodized to form an oxide layer which can be used as the dielectric of the capacitors, and resistors can be deposited to a value below that required and then anodized to adjust them to the required value.

Although values of inductance up to a few microhenries can be obtained in thin-film form by suitably laying-out conductor films, e.g. in the form of a spiral, these have very low Q values and occupy a relatively large area. It is generally preferable to avoid the use of inductors wherever possible and to use alternative techniques such as RC active devices, although inductors can, of course, be attached to the substrate in the form of miniature discrete components if necessary.

In a true thin-film integrated circuit the active elements would also be constructed in thin-film form at the same time as the passive components. Although many attempts are being made to produce thin-film transistors[4] they are not yet practicable for production purposes, and active devices have to be added to the circuit as discrete units. These may take the form of small encapsulated transistors which are soldered to the appropriate points of the circuit by means of flying leads. Alternatively, some specially-made transistor chips are available which are little larger than normal transistor chips and can be soldered directly to suitably-prepared areas on the circuit without using leads. This is often called the "flip-chip" technique.

The thin-film circuit is given a protective coating before any discrete components are added, and the whole assembly may be potted in resin before being mounted in a package. Package sizes depend on the size of the circuit and vary considerably: complete small circuits can be mounted in transistor-type cases, or several large substrates may be assembled together in a module.

THICK-FILM INTEGRATED CIRCUITS

Thick-film integrated circuits[5] are generally similar to the thin-film types of circuit except for the method of deposition of the passive components, which results in thicker films. The two terms are purely relative, however, for although the "thick" films are two or three orders thicker than the "thin" films, they are still only about 0·02 mm in thickness. For this type of circuit, ceramic substrates are used and conductors are defined by screen printing[6] a mixture of conducting and insulating materials on to the substrate through a suitable stencil. The mixture consists of noble metals and glass in an organic medium,

*For a uniform film the resistance between the opposite sides of an isolated square patch of the film is independent of the size of the square, and the resistivity is generally quoted in ohms/square.

and after deposition it is fired at about 800°C. Resistors are formed in a similar manner, and one of the advantages of the process is that a wide range of sheet resistances can be obtained by suitably altering the metal content of the glaze. Resistors of from 10 ohms to over 10 megohms can be deposited to tolerances of about 15 per cent and then adjusted, by sand blasting or edge cutting, to better than 1 per cent. Temperature coefficients are generally higher than for the thin-film elements, a typical value being 250 in 10^6 per 1°C.

Capacitors can be made by a similar process, but are generally added as discrete chips in the same way as the active elements. Such capacitors can be made by firing a conductive glaze to both sides of a wafer of a suitable titanate and then cutting it into chips.

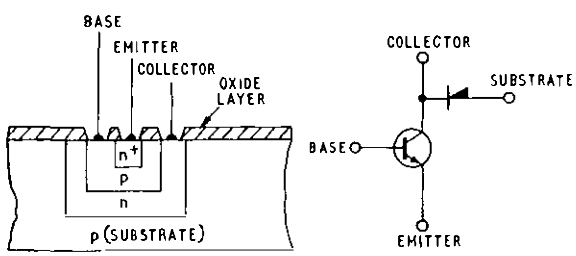
The main advantages quoted for the thick-film circuit are that it is cheaper to manufacture than the thin-film type and that it is more rugged and less likely to be damaged during assembly.

SEMICONDUCTOR INTEGRATED CIRCUITS

All semiconductor integrated circuits (s.i.c.)[1,2,7] are a present made from silicon, and both the active and the passive elements of such a circuit can be produced in a single chip of silicon about 1 mm square. The following description of the properties of the circuit elements is given in order to indicate how the integrated form differs from the corresponding discrete component. It should be borne in mind that the descriptions are simplified for explanatory purposes and several details of the construction, etc., are omitted. Most of the diffused elements are 4-layer distributed semiconductor devices, and their true equivalent circuits would be quite complex.

Transistors

The construction of an integrated transistor, illustrated in Fig. 2(*a*), is similar to that of a discrete planar transistor except for the substrate. In a discrete transistor the substrate is of a similar impurity doping to the collector, and its main purpose is to add physical bulk to make the transistor large enough to handle. In the integrated form other transistors may be constructed in the same substrate, so it is made of the opposite polarity to the collector in order to provide a means of isolating each transistor from the substrate and, hence, from any other. The introduction of this isolating junction is the cause of most of the parasitic effects in s.i.c.[8,9] A simplified equivalent circuit for the transistor is shown in Fig. 2(*b*), in which the diode represents the n–p junction to the substrate. There is also a shunt capacitance of about 5 pF associated with the diode, and a series resistance due to the resistance of the substrate. Similar unwanted capacitance and resistance occur for the other elements described below, although it is not always shown on the diagrams. As an indication of the simplification adopted in the equivalent circuit it will be seen from Fig. 2(*a*) that there is actually a parasitic p–n–p transistor having as its base the collector of the wanted transistor. The base region of the parasitic transistor is relatively wide and its gain is low, but under some conditions the current drain to the substrate could be appreciable.



(*a*) Construction (*b*) Equivalent Circuit

Note: n+ indicates a heavily-doped n region

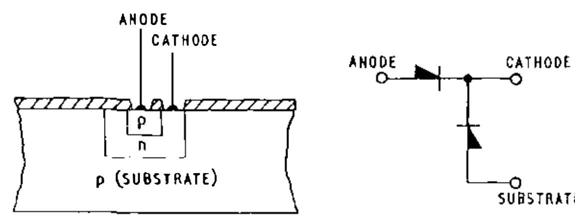
FIG. 2—INTEGRATED TRANSISTOR

In order to isolate the collector of the wanted transistor from the substrate the parasitic diode of Fig. 2(*b*) must be reversed biassed under all possible operating conditions, and this is normally achieved by arranging for the substrate to be permanently connected to the most negative point in the circuit.

In a discrete transistor the collector contact can be attached to the bottom of the substrate to provide a relatively low resistance path to the collector, but in the integrated form the contact has to be made to the upper surface of the chip; this results in a higher series resistance and, hence, a higher collector saturation resistance. This resistance, together with the capacitance of the parasitic diode, tended to limit the speed of operation of the transistors in early types of integrated circuits, but methods have now been developed which enable both these factors to be reducedand so bring the performance closer to that obtainable from a discrete component.

Diodes

An integrated diode is obtained from the junction corresponding to the base–collector or base–emitter junction of a transistor, the actual configuration depending on the characteristics required. The simplest form, which uses a base–collector junction, is shown in Fig. 3(*a*), and this type can be used provided the cathode is always positive with respect to the substrate. A simplified equivalent circuit for the diode is shown in Fig. 3(*b*). By diffusing several isolated p-type regions into the n-type region of Fig. 3(*a*) an array of common-cathode diodes can be obtained. In a similar way the base and emitter diffusion can be used to provide an array of common-anode diodes.

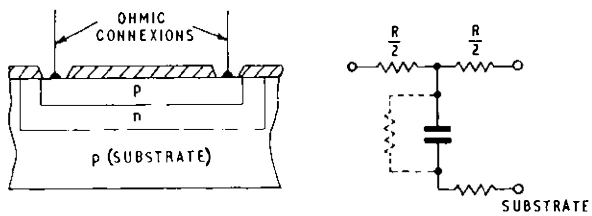


(*a*) Construction (*b*) Equivalent Circuit

FIG. 3—INTEGRATED DIODE

Resistors

In a true s.i.c. an integrated resistor is obtained by using the resistance of a diffused volume of silicon, and the diffusion which provides the base region of the transistors is normally used for this purpose. The construction is as indicated in Fig. 4(*a*), and this results in an isolating n-type region between the resistor and the substrate which must be taken to the most positive point in the circuit in order to prevent the p–n junction becoming forward biassed. The equivalent circuit can generally be simplified to that shown in Fig. 4(*b*); the shunt capacitance limits the frequency response of the resistor to about 10 MHz.



(*a*) Construction (*b*) Equivalent Circuit

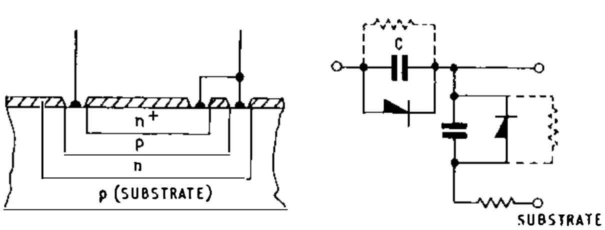
FIG. 4—INTEGRATED RESISTOR

The resistance of the base diffusion-layer is about 200 ohms/square; hence, high-value resistors will be long and narrow whilst low-value ones will be short and wide, and the value of resistance obtainable is limited at both ends of the range by the area of silicon required, the range of values being from about 20 ohms to 30,000 ohms. The width of a high-value resistor may be about 0·001 in., and close tolerances are not possible owing to masking difficulties. A typical tolerance would be about 20 per cent, but since all the resistors in a circuit are produced at the same time a ratio tolerance of better than 5 per cent can be obtained. The temperature coefficient may be as high as 0·2 per cent per 1°C, the maximum voltage is limited to about 20 volts by the breakdown voltage of the p–n junction, and the dissipation is limited to about 100 mW.

Thus, only a very limited range of poor-tolerance resistors, having very limited properties, can be obtained in integrated form. Where resistors having better properties are required a hybrid technique can be used in which the resistor is deposited on the silicon-dioxide layer on the surface of the chip by thin-film techniques.

Capacitors

An integrated capacitor is obtained by using a reversed biassed p–n junction, and one possible form is shown in Fig. 5(*a*), although a single junction or two junctions in



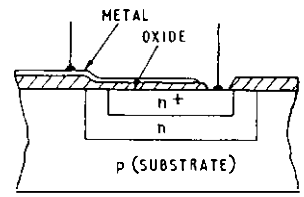
(*a*) Construction (*b*) Equivalent Circuit

Note: n+ indicates a heavily-doped n region

FIG. 5—INTEGRATED CAPACITOR

tandem could also be used. As with the other components, there is a parasitic diode to the substrate, and the wanted capacitor is accompanied by an unwanted capacitor to the substrate, as shown in Fig. 5(*b*). A relatively high series resistance is introduced by the diffused regions, which act as electrodes, and the *Q*-factor obtainable is generally less than 10. The capacitance is limited to a few hundred picofarads by area considerations, and its value varies with the applied voltage. Normal tolerances obtainable are about 20 per cent.

Because of its very poor properties the reversed-biassed junction is not often used as a capacitor. An alternative form is the metal-oxide type shown in Fig. 6, in which an emitter diffusion-region serves as one electrode, an oxide



Note: n+ indicates a heavily-doped n region

FIG. 6—METAL-OXIDE CAPACITOR

layer as the dielectric, and an aluminium film on the dielectric is used as the upper electrode. With this type of construction the capacitance is no longer voltage-dependent, better tolerances can be obtained, and *Q*-factors of up to 100 can be achieved. The metal-oxide type of construction is thus an improvement on the reversed-biassed junction, but it is more expensive to produce.

Inductors

At the present time, inductors are the most difficult circuit elements to obtain in any type of integrated circuit, and they cannot be produced by normal semiconductor techniques, although some experimental work is being done on methods of introducing frequency-determining elements. It is perhaps worth noting that the interconnexions in an integrated circuit are so short that their inductance is negligible compared to that of the leads in a normal discrete circuit.

Interconnexions

Some of the interconnexions between the circuit elements of an s.i.c. are internal to the silicon chip, and the others are provided by depositing aluminium conductors over the oxide layer on the surface of the chip. Cross-overs have to be provided either by using bonded wires, as for the terminal leads, or by using a diffused layer as a conductor, and should be avoided wherever possible.

Design Considerations

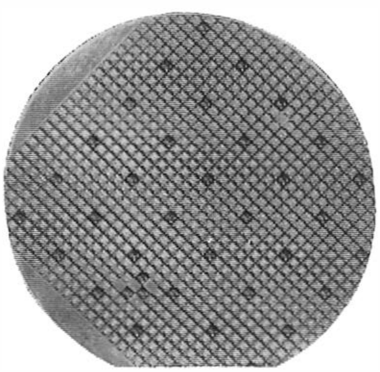
A typical s.i.c. is fabricated in a chip of silicon about 1 mm square, and several hundred circuits may be produced at the same time in a single slice. Although the initial tooling costs are high the subsequent cost of producing a single circuit is very low, the major part of the cost of the finished unit being associated with the testing and mounting of the chip. Since the packaging cost is almost independent of the complexity of the circuit it would seem that the greater the number of elements in the circuit the lower the cost per element. If the yield of good chips obtained from the slice were independent of the area of the chip this would be so, but as the area occupied by the circuit increases so the yield goes down, and one of the main aims when designing a circuit for integration is to keep the area to a minimum. Since transistors occupy less area than resistors and capacitors, their use is preferred whenever possible; this is the reverse of normal practice with discrete components and makes some types of circuit attractive in integrated form which would not be economic in discrete form.

Circuits which enable several elements to be produced in the same isolation area help to reduce both the area and the number of interconnexions required on the surface of the chip. These include such arrangements as common-collector transistors in which one collector region is common to several base diffusions, multi-emitter transistors in which one base region is common to several emitter diffusions, and arrays of diodes having a common electrode.

Production

The production of a s.i.c. involves a large number of highly-complex processing stages, which are basically similar to those used in the production of planar transistors. This has been described previously[10] and involves covering a slice of silicon (normally about 1 in. in diameter) with a layer of oxide, cutting windows in the oxide layer using photolithographic techniques to define the areas where particular diffusions are required, and diffusing the required impurities into the silicon through the windows. Since even a small particle of dust on the slice is sufficient to render a circuit useless a large part of the processing has to be carried out in specially designed clean rooms.[11] Generally, all the circuit elements are produced by the three diffusion stages corresponding to the collector, base and emitter of a transistor. Finally the evaporated-aluminium interconnexion pattern, and the contacts for the leads to the package terminals, are provided by similar photolithographic techniques.

Several hundred circuits are made in one slice, and the processing masks must be accurate and must have precise registration with one another. The circuit patterns are first drawn about 500 times full-scale using special co-ordinate plotting tables, and finally the processing masks for the slice are obtained by using a step-and-repeat camera to form a matrix in which the circuit pattern is repeated many times. A photograph of a slice of silicon containing over 700 circuits is shown in Fig. 7, while



The slice is approximately 3·25 cm in diameter

FIG. 7—A SLICE OF SILICON CONTAINING OVER 700 INTEGRATED CIRCUITS

Fig. 8 shows an enlarged view of a single chip in the slice. In this particular instance the integrated circuit contained in each chip is actually four independent logic circuits which are to be mounted in a single package.

Since the slice contains circuits which have all been produced by a common process the cost per circuit at

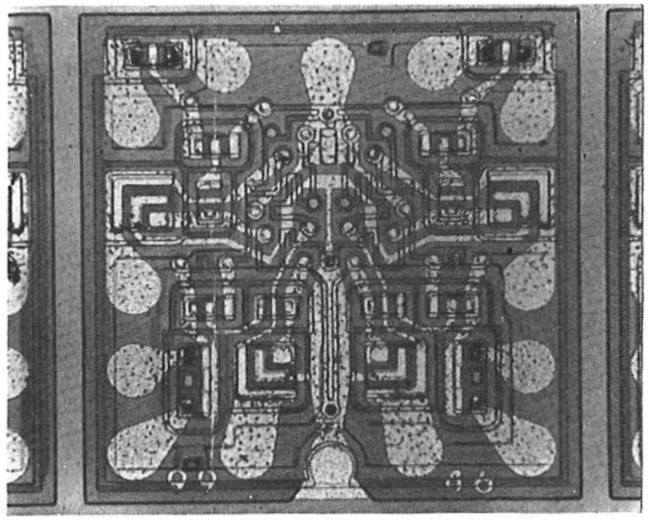


FIG. 8—ENLARGED VIEW OF ONE OF THE CHIPS SHOWN IN FIG. 7

this stage is small. Once the circuits are separated and processed as individual units the cost rises rapidly, so certain electrical tests are carried out before separation using multi-electrode probes which make contact with the aluminium contact areas on the slice, and any circuits which are faulty in any respect are marked and later discarded. After these preliminary tests the slices are broken up into individual chips by scribing along the lines between the circuits, and each individual chip is mounted in a package. Connexions from the chip to the package leads are made by the controlled bonding of gold or aluminium wires.

Types of Package

Semiconductor integrated circuits are currently available in three main types of package, and some examples of these are shown in Fig. 9. The first type to be used was a modified transistor-type TO-5 can, and this is normally obtainable with eight or 10 leads. The leads are designed for soldering into a circuit or to printed-circuit boards, and, although the method of attachment does not involve any new techniques, problems arise due to the arrangement of the leads and the large number which have to be accommodated.

A rectangular flat package was next introduced, and several varieties of this are shown in Fig. 9. It is about $\frac{1}{4}$ in. square, or $\frac{1}{4}$ in. × $\frac{1}{8}$ in., and has up to 14 flat leads spaced at 0·05 in. centres. The package is designed for welding to a circuit board, and this involves the use of specially-designed welding equipment and special types of circuit boards in order to obtain consistently reliable welds.

The third type of package has only recently been introduced and is generally known as the "dual in-line" package. Several varieties of this are now made, of which two are shown in Fig. 9. It is normally available with 14 leads, spaced at 0·1 in. centres and arranged in two parallel rows each of 7 leads, although longer versions can be made which will accommodate 22 or more leads.

Of the three types shown in Fig. 9 the flat package is the most expensive but is probably the most suitable when extreme miniaturization is required. The dual in-line type is suitable for use with production soldering techniques, and seems the most promising type for Post Office use in applications where many similar packages are to be

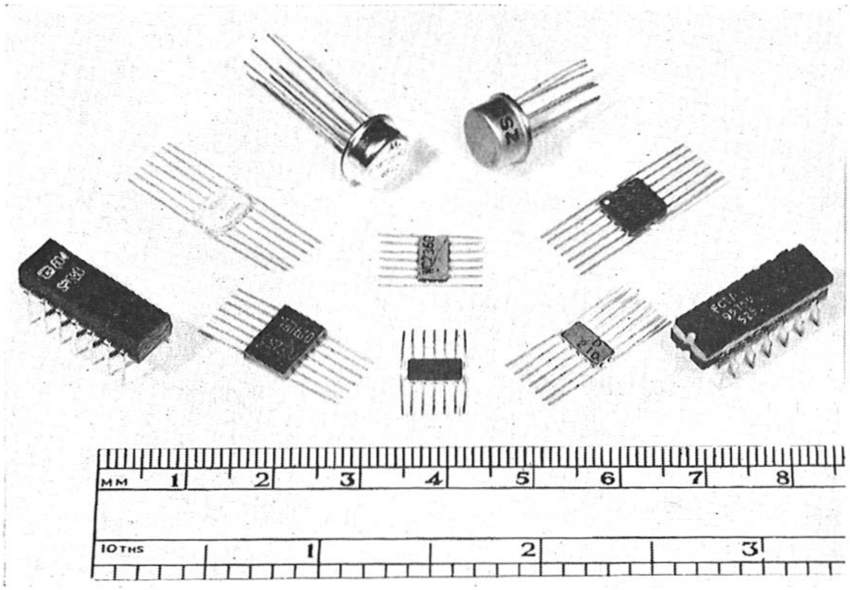


FIG. 9.--TYPICAL PACKAGES USED FOR SEMICONDUCTOR INTEGRATED CIRCUITS

mounted on a circuit board. The TO-5 can type is the only package on which any useful reliability data have so far been obtained, and it may have advantages when integrated circuits are to be mixed with discrete components; its main disadvantage is that the limited number of leads restricts the types of circuit which can be accommodated. At the present time all circuits are not available in all packages, so the one which has to be accommodated in a particular equipment may depend on the type of circuit which is to be used.

Perhaps the biggest problem which arises with the use of s.i.c.s is that of suitably mounting and interconnecting the packages, and as yet no generally acceptable method has been devised. It is not possible to consider this problem here, but many varied and elegant methods, ranging from close-packed modules to multi-layer circuit boards having up to 10 layers, have been devised for specific applications.

HYBRID INTEGRATED CIRCUITS

Circuits which are produced using a combination of different techniques may be classified as hybrid circuits. Several combinations are possible: thin-film circuits which include discrete active devices could be so classified; so could monolithic circuits which have thin-film passive elements deposited on the oxide coating and which are sometimes called "compatible circuits." Other possibilities are a monolithic amplifier mounted on the same insulating substrate as the thin-film elements which define its gain, and separate chips containing semiconductor integrated elements and thin-film elements which are mounted in the same package to form a multi-chip hybrid unit.

APPLICATIONS

It has been seen that only a limited range of poor-quality resistors and capacitors can normally be produced in an s.i.c. and that inductors cannot be obtained at all. Any circuits produced in this form must be designed to work satisfactorily with worst-case tolerances on all the circuit elements, and must be required in large numbers in order to be economic. Despite these limitations, and further restrictions imposed by the lack of isolation, by power dissipation. and other factors, a surprisingly large number of circuits can be produced in the form of s.i.c.s. At the present time most of the circuits available are for digital applications since these are very suitable for standardization, and only a few basic circuits are required in larger numbers for the complex logic systems in computer, etc. Other suitable circuits are those in which the performance is dependent on the relative values of the passive elements rather than on their actual values. Differential amplifiers are an example of this type, and, because the circuit elements are formed at the same time under the same conditions, extremely good matching can be obtained.

Thin-film circuits are more versatile than s.i.c.s: a wider range of better-quality passive components can be produced to closer tolerances, there is no difficult isolation problem, and power dissipations of up to several watts can be obtained. A few thin-film circuits are available as standard items from the manufacturers, but the number is very small compared to the ever-increasing number of s.i.c.s on the market, and it seems unlikely that they will be able to compete economically with s.i.c.s for the types of circuit mentioned above when large quantities are required. Thin-film and hybrid circuits are more suitable for relatively small quantities of custom-made circuits, and for circuits requiring close tolerances on the passive components.

With hybrid circuits of various types it is possible to combine the advantages of both techniques, and circuits of this type seem likely to find increasing use during the next few years.

Most of the circuits available as standard items from the manufacturers are digital logic circuits, and these will be considered in Part 2 of this article. Analogue circuits are also available, however, some of which are true s.i.c.s whilst others are hybrid circuits. Differential and wideband amplifiers are available with performances ranging from a gain of 70 dB for a bandwidth of100 kHz to 20 dB for a bandwidth of 45 MHz. Amongst other units which can be obtained are an amplifier having an input impedance of 10 megohms, an audio amplifier capable of supplying 1 watt into 16 ohms, and voltage regulators for voltages in the region of 6–12 volts. Although linear amplifiers are not so amenable to standardization as digital circuits, there are many applications where a standard wideband amplifier can be used in combination with discrete or thin-film components which modify its performance to suit the circuit requirements.

ADVANTAGES OF INTEGRATED CIRCUITS

The most obvious advantage of the integrated circuits which are currently available is their small size, and, since a single package no larger than that normally used for a single transistor might contain the equivalent of some 50 discrete components, there are obvious applications in the miniaturization of equipment. Space is generally not at such a premium in Post Office equipment, but the integrated circuit has two further possible advantages that make it worthy of consideration for most applications: reliability and cheapness.

At the present time the integrated circuit is still a relatively new device, and it is not possible to quote any actual figures for reliability which have much meaning when applied to a possible working life of 20 to 40 years, but an s.i.c., for example, might be expected to have a similar failure rate to that of a single planar transistor. In any equipment, one s.i.c. would replace several discrete components and their interconnexions, and the overall reliability of the equipment should be considerably improved.

It has already been stated that the cost of producing a standard s.i.c. can be very low, and such circuits produced in large numbers should be very cheap. The prices of standard s.i.c.s have been falling rapidly over the last few years, and, although the circuits have so far been used in applications where size and reliability are more important than price, the time is just about here when their use will be justified on economic grounds alone. It should also be mentioned that there is an appreciable saving in design time when integrated circuits are used, for systems can be built up from functional units having a specified performance instead of from the normal basic components.

METAL-OXIDE-SEMICONDUCTOR TRANSISTORS

The semiconductor integrated circuits described above use normal (bipolar) types of transistors. The metal-oxide-semiconductor transistor (m.o.s.t.) is a type of insulated-gate field-effect transistor, a unipolar device, and this can also be used for integrated circuits.[12] Only one diffusion process is required in the construction of the m.o.s.t. and the device has an extremely high input impedance (greater than 1×10^6 megohms). This can be a disadvantage in many applications, for even stray electrostatic charges introduced when handling the device may be sufficient to break down the gate input capacitance, and with integrated circuits some form of built-in protection may have to be provided on the input to prevent this happening. The main advantage of the m.o.s.t. is that circuits incorporating these devices occupy only about one-tenth of the area of silicon required by corresponding circuits using bipolar transistors. Very much more complex circuits can thus be constructed in a given area of silicon, and use of the m.o.s.t. seems likely to provide the cheapest method of producing complex circuits. The speed of integrated logic circuits using m.o.s.t. devices is at present limited to about 2 MHz (compared with about 30 MHz obtainable with bipolar s.i.c.s), and the most promising initial application is for storage purposes. At least two manufacturers are marketing standard circuits of this type, and there is already a 100-bit shift-register on the market which contains over 600 devices on a single chip.

COMPLEX CIRCUITS

When a basic logic circuit is made in the form of an s.i.c. several hundred circuits are produced in a silicon slice, and this is then broken up into small chips which are packaged separately. A large proportion of the total cost of a unit is due to the packaging and testing, and the user then has the problem of connecting the packages together to give the logic network required. The next obvious step in integration is to interconnect several logic circuits on a single chip to form a sub-system. This should result in increased reliability and a lower cost per basic logic function, and some circuits of this type, e.g. decade counters, are already available.

As the logic function on the chip is made more complex, lower yields are obtained and standardization of circuits becomes more difficult. Much work is being done on possible methods of overcoming these difficulties, and one of these is mentioned below to indicate the potentialities of semiconductor integrated circuits. If several redundant basic circuits are provided in the chip, and each circuit is tested by means of probes in order to eliminate the faulty ones, the good circuits could then be interconnected to provide the sub-system required. This procedure transfers many of the package interconnexion problems, e.g. cross-overs, to the circuit manufacturer and may mean many different interconnexion patterns for the same circuit, but is has been suggested that the process could be computer controlled. If such a scheme proves practicable, and it becomes possible to produce very complex networks on a single chip of silicon, it would be a relatively small step to use a similar method for the production of custom-made circuits.

AVAILABILITY

The technology for the production of thin-film passive elements is now well established, and several manufacturers are equipped to make thin-film circuits to customers' requirements.

So far, the majority of the semiconductor integrated circuits available have come from the U.S.A., but some British manufacturers should soon be in a position to supply them in quantity. Many of these circuits will be the same types as those now available from the U.S.A., but there are one or two manufacturers who will be producing units of their own design.

Integrated m.o.s.t. circuits can be obtained from the U.S.A. and several British manufacturers are evaluating this type of device, but standard circuits are unlikely to be available in quantity until some time after the bipolar type of circuit.

CONCLUSIONS

Standard types of semiconductor integrated circuits will soon be available from British manufacturers at prices which will make them very competitive with normal circuits constructed from discrete components. Their small size will result in appreciable saving of space, and they show promise of being very reliable. These possible advantages are so great that the use of semiconductor integrated circuits should be considered for all prototype equipment. In cases where suitable standard circuits are not available, and either the numbers required do not justify the design of a special circuit or the tolerances are too critical, the use of thin-film or hybrid circuits should be considered.

ACKNOWLEDGEMENTS

Fig. 1 is reproduced by courtesy of Mullard, Ltd., and Fig. 7 and 8 by courtesy of S.G.S. Fairchild, Ltd.

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(*To be continued*)

Book Reviews

"Circuits Using Direct Current Relays." A. H. Bruinsma. Iliffe Books, Ltd. v+86 pp. 66 ill. 13s. 6d.

This addition to the Philips Paperbacks series is translated from the Dutch. The author sets out to show that, although in recent years devices have been developed which can replace relays, advances in electronics have created new opportunities for their use in association with valves or solid-state devices, or both. After an introductory chapter on the general construction of relays, basic phenomena are covered in detail. This is presented in an interesting way and ranges widely, the author drawing freely on his experience to describe features harmful to circuit performance.

A chapter is then devoted to methods of controlling the switching-in and switching-out of relays by valves and transistors. The design approach, using typical circuit parameters, is outlined in simple terms, the determination of optimum working conditions by load-lines being admirably explained. Two chapters describe the control of relay characteristics by *CR* networks to give increased time-delays. Wisely, the author does not omit the possibility of oscillatory decay of coil current and flux, which, unless effectively damped, may actually decrease the release-time. The treatment of basic elements is rounded-off with chapters on the transitory operation of relays and their control by physical phenomena such as light.

Three chapters cover larger circuits designed to change state under the control of pulses applied via a single input-lead, providing bistable switching, pulse-counting and sequential relay operations. The final chapter describes miscellaneous circuits, including an interesting transistor-circuit arrangement in which progressive increase of current via a single input-lead forms a multi-state system analogous to a stepping-relay.

Although the author remarks that the circuits given would probably rarely be used at the professional level, there is much in this small book of interest and value to both the traditional relay and circuit engineer and his modern electronic counterpart. More books of this kind, linking theory with practice and pointing out limitations encountered during working experience, should be written for the applications engineer.

The book is well translated and clearly illustrated. Unfortunately these admirable qualities highlight points at which the terminology and symbols differ from those in common British usage. The introductory illustration of the construction of a relay shows an over-simplified example, with the yoke described as an "iron supporting bracket" and the residual strip as a "copper anti-sticking ridge." Similarly, change-over contact-units are referred to as "alternating" contacts; relays are held by "take-over" current—later, they are "cut-out" and "fall-away." The technical translator wishing to avoid such inaccuracies is well-advised to have by him glossaries of terms and definitions, and reference works, for the field concerned.

W.L.S.

"The Lighting of Building Sites and Works of Engineering Construction." I.E.S. report on a paper by J. Gordon-Scott. Illuminating Engineering Society. 16 pp. 8 ill. 12s. 6d.

The temporary lighting arrangements used on building sites and works of engineering construction are necessarily different from permanent installations and are subject to different requirements.

This Report, first published in 1962 and now revised, is written for practising engineers, architects or building contractors, and makes recommendations on the types of lighting which should be provided on these sites and on the maintenance of the equipment. It is virtually confined to electric lighting. "Flame sources" are dismissed in a line and a half.

After an introductory paragraph the legislation covering the subject is briefly discussed.

The main part of the Report includes sections on interior lighting, exterior lighting, special work, hazardous locations, distribution and maintenance. These are generally informative and useful, but the sub-sections touching on electrical safety could have been amplified with advantage.

There are five appendices as follows: the cost of accidents; tungsten, tungsten-iodine, and fluorescent lamps; floodlighting; recommendations (summary); bibliography.

The Report which is the work of a Study Panel of the Technical Committee of the Illuminating Engineering Society, forms a good basis of special study for anyone directly concerned with the lighting of building sites or works of engineering construction.

R.W.H.

Information Indexing by Computer

F. C. HEWARD†

U.D.C. 025.3:681.3

The great and rapidly-expanding mass of technical information now available makes the search for particular items increasingly difficult. The indexing of such information is itself both difficult and laborious, and automatic indexing systems are of great value. Computer-based indexing systems in use in the British Post Office are described, and some current indexing systems are discussed.

INTRODUCTION

A PARADOXICAL situation exists in this day and age of "the information explosion"—so much information exists that it is often difficult to find out just where any specifically required information can be found! The individual technologist's problems and difficulties in information tracing or recovery are magnified in scale when considering the information-retrieval problems of any major engineering or scientific organization. Probably hundreds of reports, memoranda, diagrams and technical drawings will have been generated as the result of the organization's internal effort; these, together with related material from other establishments and the published technical literature, would form the information storage and retrieval tasks of a centralized information service. A major problem, among many others (the total information problem is not discussed here; it is described at length elsewhere[1]), facing such an information service is that of arranging a classification and indexing system so that details of a report, book or drawing are available to a potential user as soon as possible after his need for the information arises—preferably in such a manner that the inquirer is directed to the source documents without reference to the information staff.

The Indexing Problem

The indexing of information for optimum retrieval is a highly-skilled art and a laborious task. The supply of suitable persons for such work is sparse, and the need for such people is not often acknowledged, except in very enlightened organizations, or in those in which the need becomes pressing. Information storage and retrieval is, therefore, more often than not, a haphazard affair. One can justifiably suspect that information is frequently searched for, re-collected, or re-calculated, when that same information, probably with another investigator's observations or analysis, already exists within the organization, carefully filed, but not readily available through lack of dissemination of the information or inadequate indexing.

General indexing schemes are available and meet with a fair degree of success in application, especially where subjects can be broken down into mutually exclusive classes, e.g. geographical areas by continent, by country, by county, by parish. The problems arise where things are described by a combination of several attributes, i.e. words describing essential characteristics of the subject matter, which exist side by side, and where there are no grounds for the selection of one attribute for citation before another.

Users acknowledge that most standard indexing systems, being generalized, require slight modification to suit the specialized requirements of an individual organization, and may well demand a detailed knowledge of, at least, the technical terms or main processes of the industry. A simple example, under the Universal Decimal Classification (U.D.C.), may illustrate this point—a medical library, with comparatively few electrical engineering textbooks, might well find it satisfactory to file them using the U.D.C. coding .62 (the code used for engineering sciences), whereas a library such as that in the Post Office Engineering Department would require considerably greater sub-division for the accurate placement of identical volumes.

The shortage of skilled indexers and the amount of work awaiting their attention seems to indicate that, if suitable automatic-indexing methods can be devised, this subject could be satisfactory ground for the application of computers. If the bulk of the labour content is removed, greater accuracy and security should result, and existing indexing staff could be re-deployed to better effect. The purpose of this article is to describe how computer-based indexing systems have been provided in the British Post Office Engineering Department and to discuss, generally, some aspects of indexing systems in current use.

Current Effort

All that has been stated above regarding indexing and indexers applies to the search for information too: the problem of automatic information indexing and retrieval is receiving considerable effort and the expenditure of a lot of money. One can read[2] of huge data-processing installations devouring whole volumes of literature for storage on multi-tape-deck machines, and the subsequent production of indexes by

(*a*) the conversion of each noun to a standard word by reference to a thesaurus stored in the machine,

(*b*) searching for frequently-recurring terms or groups of words which, if they occur at greater than a predetermined frequency, are used as indexing terms,

(*c*) searching for the proximity of certain words,

(*d*) searching by statistical sampling of the text,

(*e*) taking the combination of nouns and modifiers following prepositions, or

(*f*) checking the significance factor of words, i.e. the comparison of the frequency of use of a word in the document to its frequency of every-day use.

Also in use are information-retrieval systems whereby a request for information is converted, by reference to a thesaurus, to a form whereby the question stands most chance of being answered by the stored information. Obviously such systems as these, which require large computers, have their place in big organizations, but much less elaborate systems must be provided if automatic information-processing is to be implemented on

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smaller machines. One such method is to search the introductory and concluding paragraphs of a document for the extraction of indexing material.

Mention might, perhaps, be made here of the work of Dr. Lee McMahon of Bell Telephone Laboratories who has, for information analysis and retrieval purposes, proposed a system of standard English[3] for the authors of technical documents or for the writers of abstracts. This new version of the language has been called FASE (Fundamentally Analysable Simplified English) and aims to establish a definite sequence of subject, verb and object, with other parts of speech falling into line to form an unambiguous syntax defined by a complicated set of rules.

The FASE subset of English grammar would be used either in the course of original exposition or for extracting purposes. To quote from the Bell Abstract on the subject, "The principal requirement for writers of FASE is ingenuity in saying the same thing differently. They must be facile paraphrasers. . . . A writer of FASE must, however, write with conscious knowledge of the syntax, since many sentences of English, which his habits might produce automatically, are not proper sentences of FASE; and many sentences of standard English would even receive false analysis in FASE. . . . The restrictive limits on allowable syntactic constructions may produce a somewhat flat prose, if FASE is used for long passages; again, the ingenuity of the writer is needed to make the style palatable."

It is understood that an IBM 7094 computer program has been written for analysing FASIC documents; the retrieval of full text items should follow—the main problem would seem to be that of semantic ambiguity.

INDEXING SYSTEMS

The three major classes of indexing systems in general use are:

(*i*) hierarchical indexing,
(*ii*) subject indexing, and
(*iii*) co-ordinate indexing.

In the hierarchical system, classification is achieved by an increasingly-detailed family tree. This has, at its head, very general classification titles, each of which is then divided into further sub-classifications and so on until the desired degree of detail is reached. This indexing method is probably best known through the U.D.C. system, and is in use in many technical libraries. It has the advantage of showing the inter-relationships of the subjects indexed, but has the disadvantage that it is difficult in some instances to decide which of two or more sub-divisions should be chosen. Another weakness is that, until a new higher-level class is assigned to them, modern developments tend to be allocated long numbers. For example, the original U.D.C. classification number, 621.396.615.141.2, for the magnetron was longer than the word it represented—it has now been changed to 621.385.64.

In a subject index each piece of information is categorized under a number of descriptive subject headings, each of equal status. This is the most common form of index found in libraries and bookshops, but is generally not sufficiently detailed to permit accurate retrieval of information. This method also suffers from the problem of mixed subject matter, unless some from of cross-referencing is used. The main use of subject indexes in the technical sphere is to help researchers make an assessment of the activity in an area of interest by reference to the date of origin, nationality, research organization and quantity of papers published. Perhaps one of the best applications of this method is to be found in the British Technology Index.[1]

In the co-ordinate system, information is classified or retrieved by the logical relationship displayed by two or more terms or concepts. The terms or concepts may be abstracted from the main body of information by skilled indexing staff or, as will be seen more frequently in the near future, by automatic indexing programs. The essential difference between the co-ordinate system and the hierarchical and subject methods is that it does not rely on the existence of a uniform classification or pre-indexing structure into which items are to be fitted. As the possible logical relationships between two concepts may be (*i*) disjunctive (A or B), (*ii*) exclusive (A and not B), or (*iii*) conjunctive (A and B), the co-ordinate method of information retrieval is ideally suited to computer processing, though programs for interrogation of information by disjunction or exclusion can be very complex.

Keyword Indexes

All indexes are in effect keyword indexes,* but the specialized use of the term is usually associated with the manner in which the keywords are chosen. The following methods of selection are used.

(*a*) Perusal of the documents by skilled abstracters, i.e. skilled both in indexing and the subject matter, for selection of a series of terms, concepts or attributes which may be used for adequate indexing and retrieval of essential information contained in the document. This method is undoubtedly very efficient and is the basis of many complex systems;[2] it is, however, heavily reliant on that precious commodity, the skilled indexer.

(*b*) Nomination of keywords in a document title (or, alternatively, the introductory paragraph) by a skilled technician, i.e. a person skilled in the subject matter but not a professional information officer (see Fig. 1).

*A keyword is a term which conveys an attribute likely to be sought in the use of an index.

```
1500 AUTO TELEX SERVICE. MACHINE IMPULSING 20A* TG 1500£
1501 TELEPRINTER CONFERENCE WORKING. AUXILIARY EQPT* TG/TGW 1501 DN£
1502 TORN TAPE RELAY SYSTEM. LINE EQPT FOR DUPLEX NIGHT CONCENTRATOR CCTS, USING AUTOTRANSMITTER 2F* TG/TGW 1502£
1503 TELEPRINTER OMNIBUS SIGNALLING & SELECTIVE CALL RELAY SET WITH PATCHING JACKFIELD* TG/TGW 1503 DN£
1504 TRANSMITTER AUTO 2E OR 2F ASSOCIATED WITH TRANSMITTER SERIAL NUMBERING 1A* TG/TGW 1504£
1505 AUTO TELEX SERVICE. SPEED & RATIO TEST SWITCH FOR MACHINE PULSING 20A* TG 1505£
1506 AUTO TELEX SERVICE. ERROR CORRECTED RADIO SYSTEMS. SIEMENS HALSKE T LOCH 15A REPERFORATOR TRANSMITTER, TABLE
 CONNECTIONS* TG/TGW 1506£
1507 ?CANCELLED* TG/TGW 1507£
1508 TELEPRINTER, AUTOTRANSMITTER, & PRINTING REPERFORATOR. ALTERNATIVE SIMPLEX AND DUPLEX TERMINATIONS* TG/TGW 1508 DN£
1509 TAPE RELAY SYSTEM. PUSHBUTTON SWITCHING & INCOMING CONCENTRATOR. DUPLEX LINE RELAY SET* TG/TGW 1509£
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FIG. 1—TYPICAL NOMINATED-KEYWORD INPUT DATA, SHOWING FIELD MARKERS AND UNDERLINED KEYWORDS

(*c*) Automatic selection of keywords, in a computer, by referring all words in a document title (or any other selection of text) to a stored dictionary of non-indexable words, i.e. a "stop list."

When keywords have been selected, from all the documents being referenced, a full information index may be produced by punched-card machines or computer.

Because of the unreliable information content of titles (e.g. the title 'Fingers or Fists' to describe a report comparing binary and decimal notation!) many professional indexers[2,5] display a marked lack of enthusiasm for indexes where the keywords are chosen from titles, though some[6,7] are strong in its defence or proclaim its advantages. However, if a title has inadequate information yield it can be supplemented (or, to use an appropriate American term, "enriched") by the editorial insertion of keywords intended to reveal further the contents of the document.

KWIC Indexes

A currently popular and elementary form of logical-product co-ordinate indexing is that of the "keyword-in-context" (KWIC) indexing system. This system is usually based on the titles of books, documents or articles: titles for indexing are punched on cards or paper-tape and fed into the machine for production of a so-called permuted index. A single-line index entry is then produced for each keyword in the titles, the line being so arranged that the selected keyword is clearly displayed in the centre of the page, surrounded by its immediate context, and having a reference to the information source concerned. Take, for example, the title of Post Office diagram TG 1401: TAT-1 ALARM-REPORTING EQPT. PULSE GENERATOR CHANGE-OVER PANEL. If the terms TAT-1, ALARM, PULSE and CHANGE-OVER had been nominated as keywords, the resultant index entries would be as indicated in Fig. 2.

	Keyword	*Document Reference*
	TAT-1 ALARM-REPORTING EQPT. PULSE GENERATOR CHANGE-OVER PANEL	1401
TAT-1	ALARM-REPORTING EQPT. PULSE GENERATOR CHANGE-OVER PANEL	1401
TAT-1 ALARM-REPORTING EQPT.	PULSE GENERATOR CHANGE-OVER PANEL	1401
TAT-1 ALARM-REPORTING EQPT. PULSE GENERATOR	CHANGE-OVER PANEL	1401

FIG. 2—INDEX ENTRIES RELATING TO DIAGRAM TG 1401

Several points may require further explanation.

(*a*) This is not strictly a permuted index but, to use more acceptable terms, a cyclic or rotated index.

(*b*) It has the weakness that information search can be by only one attribute at a time, though it is easy to run down the list manually and link associated attributes to define the associated source document.

(*c*) Full titles may occupy more space than is available on one index-entry line. Any individual entry is then incomplete as far as the complete context of the keyword is concerned; the display of associated attributes is thus limited and could result in a more protracted search for the reference to the appropriate source document.

(*d*) A technique of contextual wrap-around has to be devised, as part of the rotating entries, if the full entry can be inserted within the space of one line. Longer entries have to be slashed (usually by the use of a symbol) in such a manner that the keyword is shown within one line of immediate context.

(*e*) After all the document titles have had their keywords identified, an index will be produced with the entries in order of placement of the keywords in the title. These will then require sorting into alphabetical sequence.

Fig. 3 shows an ordered section of such an index.

KWOC Indexes

KWOC indexes are subject-type indexes produced by the use of keywords as subject-indexing terms. The keyword appears, out of its context (hence the acronym KWOC), at the beginning of the first line of the index entry and is followed by the complete title and index reference of the document (see Fig. 4); author names are sometimes used as keywords with this method. This type of index may be regarded by some as less effective in its use than KWIC type indexes, but it is undoubtedly of greater value as a browsing document.

POST OFFICE ENGINEERING DEPARTMENT APPLICATIONS

It is desirable that all staff be provided with ready access to information sources in order to give a better service and improve productivity. This aim requires that some new form of indexing system, suitable for use on a Post Office computer, be quickly established to provide information on those areas of literature, diagrams and reports that have not already been adequately indexed. Two major exercises have been undertaken: (*i*) to put the technical library catalogue on to a computer as a magnetic-tape record—this will allow for easy updating of the catalogue and more frequent reissues; (*ii*) to experiment with the use of key-word indexes for the following reasons.

COMMON TELEPRINTER POSITION EQPT TO CONNECT	AUTOTRANSMITTERS DIRECTLY TO LINES WITH SWITCHING FACILITY TO A	3163
TELEPRINTER	AUTOTRANSMITTERS 1A & 1B.	0852
/G WITH BROADCAST FACILITY FOR 6 LINES, USING 2	AUTOTRANSMITTERS 3A,6 PRINTING REPERFORATORS, & A TELEPRINTER /	1658
OF REPERFORATORS & MONITORING TELEPRINTERS TO 4	AUTOTRANSMITTERS. *SWITCHING	3047
200 OUTLET FINAL SELECTOR WITH 2-10 LINE	AUXILIARY GROUP FACILITIES. *AUTO TELEX SERVICE.	5462
LINES. AND HUNTING BATTERY (FX) FOR GROUPS OF	AUXILIARY STATION LINES. *AUTO TELEX SERVICE. NP FOR SPARE	5293
	B	
TASS.	B TYPE COMMON SIGNAL DISTRIBUTION RACK.	5610
TASS.	B TYPE SIGNAL DISTRIBUTION RACK FOR FINAL SELECTORS.	5612
TASS.	B TYPE SIGNAL DISTRIBUTION RACK FOR RELAY SET RACKS.	5616
	B.O.A.C. AIRWAYS TERMINAL MODIFIED UNIT TELEX NO. 2.	2121
USING CREED MACHINES	B.O.A.C. E.S.S. POSITION EQPT. FOR RECEIVE-ONLY OUTSTATIONS	2083
EQPT.	B.O.A.C. E.S.S. RECEIVE-ONLY WAY-STATION WITH TELETYPE MODEL 28	2087

FIG. 3—SECTION OF KEYWORD-IN-CONTEXT (KWIC) INDEX

RADIO

A MONITOR FOR SEVEN-UNIT, SYNCHRONOUS, ERROR-CORRECTING SIGNALS FOR USE ON RADIO TELEGRAPH CIRCUITS.(21. 3.60). 20367

RADIO

ADDITIONAL AUXILIARY CHANNEL FILTERS FOR RECEIVER, RADIO, NO. 22 (FILTER, FREQUENCY, NO. 111C AND FILTER,FREQUENCY, NO. 111D).(17. 1.61). 20377

RADIO

AN INVESTIGATION OF MULTIPATH TIME DELAY DIFFERENCES ON CERTAIN BAND POINT-TO-POINT RADIO CIRCUITS DURING THE PERIOD OCTOBER 1953 TO JULY 1957.(14. 7.60). 20543

RADIO

THE DESIGN OF FOUR FIXED-FREQUENCY OSCILLATORS FOR TYPE-APPROVAL TESTING OF V.H.F. MOBILE RADIO EQUIPMENT.(2. 9.59). 20184

RADIO

THE PERFORMANCE OF AN EXPERIMENTAL FREQUENCY MODULATOR AND DEMODULATOR FOR USE IN VERY HIGH-CAPACITY RADIO RELAY SYSTEMS.(1. 8.61). 20483

RADIO

AN EXPERIMENTAL 210 MC/S BROADBAND AMPLIFIER FOR USE IN HIGH-CAPACITY F.M. RADIO SYSTEMS: (AMPLIFIER NO. 134A).(6. 9.61). 20485

FIG. 4—SECTION OF KEYWORD-OUT-OF-CONTEXT (KWOC) INDEX

(*a*) The titles on most internal information documents are usually single-sentence summaries of the facilities described or shown therein and are, thus, good indexing material. Those that are not could readily be amended, and future titles could be drawn up with the indexing system in mind.

(*b*) The Post Office Engineering Department suffers from a dearth of professional information staff, and it is necessary that indexes for internal use be prepared automatically from ordinary sources, such as titles, or conform to a standard indexing system.

Library Catalogue

The main Engineering Department Library consists of about 2,000 modern reference textbooks, their number increasing at a rate of approximately 150 volumes per year. The U.D.C. system has been used to classify the books, and many of them have multiple references. A monthly notice of stock additions is circulated to all major engineering and scientific staff, but a revised catalogue has not been issued since 1958. The monthly library circulars were used as source documents for punching paper tape as input to the computer. The specification requirements were as follows.

(*a*) The new catalogue should consist of two indexes: (*i*) a list of authors, in alphabetical sequence (and with cross-references in the case of multiple authors, e.g. second author, see first author entry) with U.D.C. sequence of books in those cases where the library had several books by the same author; (*ii*) a subject list in U.D.C. ascending sequence, with authors in alphabetical sequence wherever there were several books with common U.D.C. numbers (multi-entry U.D.C. numbers were to have separate cross-reference entries). Problems of sequencing arise: some reference books, e.g. atlases, have 1-digit or 2-digit coding and others, owing to the precision of classification or a linked reference, might have up to 30 characters, including such meaningful auxiliary symbols as +, / or brackets.

(*b*) For aesthetic reasons, all output was to be in mixed case, i.e. in capitals and in small letters. The program suite was arranged to read the input data, and produce the index in sequence on magnetic tape. The output was arranged to be a punched paper-tape for use as input to an electric typewriter, for the mixed-case preparation of master stencils.

During the course of testing the output program, contact was made with a service bureau offering the facility of photo-typesetting from magnetic tape; this has the attraction of allowing high-speed output from the indexing program (compared to the slow typewriter print-up) and a selection of mixed-case output forms a range of three type styles at any one time. Information in Elliott code, held on Elliott 503 magnetic tape, cannot be used as input to the typesetting computer without conversion to International Tele-typesetting code. Experiments with this form of output are proceeding. Economically, it does not at present compare favourably with conventional means of output, but the range of type-fount and the vastly improved appearance will appeal to those with the task of producing special information indexes.

Updating of the library catalogue will be by 6-monthly cumulative supplements and biennial re-issue.

Diagram Facilities Index

For the trial KWIC indexing scheme it was decided to deal initially with only the 5,000 diagrams used for telegraph and data-transmission equipment. The previous index had been one in numerical sequence; obsolescence of older apparatus, a net growth of about 100 diagrams a year, and the pressure of enquiries from field staff, unable to interpret quickly or efficiently the numerical list, caused this initial demand for some form of cyclic-entry diagram-facilities index. The title of each diagram was checked for adequacy and accuracy of description, and keywords were nominated by underlining the first character of the required indexing words. After the addition of a few field markers (as in Fig. 1), this information was used for data preparation—a straightforward paper-tape punching task. Fig. 5 shows a section of the numerical index. Updating of the index will probably be on an annual reissue basis.

With little or no modification this computer program can be used to index other series of engineering drawings, specifications, etc., or any other subject where card-indexing schemes are in use. The resultant index produced by this program contains many refinements in layout not previously seen in indexes of this type.

1274	CANCELLED	TG/TGW 1274
1275	MODIFICATION TO BASEBOARD 27C (MARK 1) OR 27E (MARK 1) FOR USE ON DOUBLE CURRENT SIGNALLING TELEPRINTER POSITION(NON CCIT.), USING TABLE TELEPRINTER 5A OR BENCH MOUNTED	TG 1275
1276	ADAPTOR TELEPRINTER 5, INTERNAL CONNECTIONS	TG/TGW 1276
1277	ADAPTOR 15, INTERNAL CONNECTIONS	TG/TGW 1277
1278	TELEPRINTER PW WORKING, SPECIAL ARRANGEMENT FOR USING BPO. MACHINES IN ASSOCIATION WITH AMERICAN TELETYPEWRITER SETTYPE 131.8.2	TG/TGW 1278
1279	TELEPRINTER CONFERENCE WORKING. KEY SWITCHING FOR AUTO TRANSMITTER & CONFERENCE UNITS	TG/TGW 1279
1280	TELEPRINTER CONFERENCE WORKING. OUTSTATION EQPT FOR USAF., UK WEATHER LOOP	TG 1280
1281	TABLE TELEPRINTER 5A, EQUIPPED FOR MANUAL TELEX	TG 1281 U,X
1282	TABLE TELEPRINTER 5A, EQUIPPED FOR MANUAL TELEX, AUTOTRANSMITTER POSITION	TG 1282
1283	TABLE TELEPRINTER 5A, EQUIPPED FOR MANUAL TELEX. TELEPRINTER WITH AUTOTRANSMITTER & REPERFORATOR	TG 1283

FIG. 5—SECTION OF NUMERICAL INDEX

Index of Research Reports

There are 10,000 filed and documented research reports, each of which is a concise description of an investigation in one of the diverse range of subjects embraced by the telecommunications art. The reports cover the whole range of Post Office interests, past, present and looking to the future, under such activities as behaviour of materials, causes of failure, experimentation with physical and chemical phenomena, and specialized production techniques for such items as quartz crystals, long-ife valves, high-quality transistors. The essential need is that any member of the staff undertaking a new research or development case should be informed quickly and effectively of all related previous work. Bell Telephone Laboratories, with a similar, but larger, problem, have devised a form of KWIC index called BEPIPER[8] (Bell permuted index program). This program, by reference to a dictionary of 568 non-indexable words, was used to produce a very effective index of their technical reports.

A program is being written for the Engineering Department computer which will provide KWIC or KWOC facilities, as required. The dictionary of non-indexable words will consist of about 750 items, with the added facility that, if the program is required for the generalized production of indexes, the dictionary can readily be changed to suit individual requirements.

CONCLUSIONS

This elementary start in the field of information indexing requires the user's personal effort to search for and retrieve information. Some attempts at computer-based indexing in the Post Office Engineering Department have been described, although the field of application has been purposely restricted in order to gain experience in the formation and use of such indexes.

It is expected that users will soon demand more elaborate facilities, such as the retrieval of information by a multi-attribute search and other techniques proper to the total information problem; these will probably require facilities beyond thecapabilities of the Engineering Department's Elliott 503 computer.

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Book Received

"Regulations for the Electrical Equipment of Buildings." 14th Edition. Published by The Institute of Electrical Engineers. v+242 pp. 17s. 6d. (post free).

For this, the 14th edition, the Regulations have been completely reviewed and recast. In particular, their requirements, and especially those of Part I covering requirements for safety, have been reviewed to take account of the Building Standards (Scotland) Regulations issued in 1963, in which the Institution's Regulations are referred to. At the same time a close relationship has been maintained with the other statutory regulations to which the Institution's Regulations are supplementary, especially the Electricity Supply Regulations, 1937. This new edition has been approved by the Minister of Power and the Secretary of State for Scotland for their purposes, including those of the Building Standards (Scotland) Regulations and the Electricity Supply Regulations.

In the new edition a large number of detailed technical changes are introduced, and, to meet requests by users and to facilitate the use of the Regulations, the presentation has been altered as follows.

(*a*) A new method of identifying the sections and numbering the Regulations has been introduced.

(*b*) The main list of contents is now supplemented by more detailed contents lists prefacing each section of Part II, which covers the means of securing compliance with Part I.

(*c*) The sectional lists of contents incorporate cross-references to the corresponding requirements of Part I.

(*d*) A straightforward alphabetical index, considerably more comprehensive than hitherto, has been provided.

Sections relating specifically to caravan and caravan-site installations, and to agricultural and horticultural installations, have been introduced for the first time, and the "Recommended Practice for Electrical Installations in Caravans," hitherto published separately by The Institution of Electrical Engineers, has been withdrawn.

Planning and Works Aspects of 24-Circuit Pulse-Code-Modulation Systems

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U.D.C. 621.376.56:658.5

"Supply and install" contracts for the first operational p.c.m. systems, each providing 24 audio circuits on two deloaded audio pairs, have been placed and are due for completion by the end of 1967. Other contracts to provide equipment for installation by direct labour are to follow. This article describes some of the problems encountered in deciding when to use such systems, and in dealing with their ordering and installation.

INTRODUCTION

EXPLOITATION of pulse-code-modulation (p.c.m.) principles put forward about 1938 has had to await the full-scale introduction of transistors to produce commercially-viable systems. Such principles can be applied to deal with various numbers of circuits of various bandwidths provided over different media. They have, however, in this and other countries, led first to the development of systems providing about 24 audio circuits on two audio pairs. In this country small-scale trials of proprietary designs have been held in conjunction with three manufacturers. Using information from these trials and from other sources the British Post Office has produced a specification for p.c.m. equipment, providing 24 audio circuits on two deloaded audio pairs, which has been used to order further trial equipment, and, subsequently, the first 100 or so operational systems. By the time this article is published equipment for more such systems will have been ordered, and preparatory cable work for the first systems should be well in hand.

Readers will, no doubt, be aware from other sources[1] of the way in which such p.c.m. systems work. Briefly, for any one speech channel, the amplitude of the speech signal is sampled at 8,000 Hz. Each sample is then represented by a pulse code in which constant-amplitude pulses or the absence of pulses in seven time-slots permit 128 sample amplitudes to be indicated. An eighth time-slot is used to convey signalling (and synchronizing) information, and the 8-pulse codes for 24 speech channels are then combined in sequence to make up (with various refinements) the line pulse-train, giving a pulse rate of 1·536 megabits/second. Non-linear coding is used in order to maintain an adequate signal-to-quantization-noise ratio for small signals. At "amplifying" points, it is only necessary to recognize the existence or absence of the individual pulses and to regenerate pulses in those time-slots which should contain them. Thus, there is no successive deterioration in signal-to-noise ratio, and p.c.m. systems can work satisfactorily over transmission media which, from an analogue point of view, would be considered bad.

The availability of p.c.m. systems gives a further choice to the network planner, and present indications are that p.c.m. will find considerable use where, at present, the longer audio or shorter h.f. systems would be provided. An advantage is that the new p.c.m. systems are provided on deloaded audio pairs, many of which are already in the ground and, therefore, save new cable and duct provision. It is the intention of this article to show how the choice of p.c.m., as against audio or frequency-division multiplex (f.d.m.), may be made, and to describe some of the practical problems which will be encountered. In doing so it must be stressed that, at the time of writing, p.c.m. practices are evolving: certainly, some of the more practical problems are arising and being dealt with on a day-to-day basis. It would not be surprising if practical experience, which will be available soon from the further trial scheme previously mentioned, resulted in changes, including relaxations of the present admittedly somewhat cautious planning rules.

PLANNING ASPECTS

Economics

Perhaps the first decision needing to be taken in selecting the means by which certain circuit requirements will be met is the economic one. This must, of course, take into account not only the initial requirement but the rate-of-growth forecast. The traditional method is to compare various proposals, e.g. audio, p.c.m. and f.d.m., on the basis of present value of annual charges.[2] A particular scheme can prove to be fairly complex if it is regarded as more likely to be a small expanding network in its own right rather than a simple point-to-point problem. However, it is desirable to keep the necessity for detailed scheme costing down, and an appreciation of the mileage range over which p.c.m. is likely to be economic helps avoid wasted effort. To this end, cost comparisons of p.c.m. and 2-wire audio circuit provision on 10 lb/mile cable have been made for various rates of growth, and these show that p.c.m. becomes economic compared with audio at distances above about 10–14 miles, depending on the rate of growth.

Lower rates of growth are more favourable to p.c.m. because the smaller audio cables, which would be used to meet low rates of growth, cost more per pair. Fig. 1 illustrates the comparison for a relatively high rate of growth of 128 circuits/year, using present-day copper prices and early p.c.m. equipment costs. The present elevated copper prices tend to favour p.c.m., using cable already in the ground, at slightly lower mileages, as would any drop in equipment prices, resulting, possibly, from new developments and from large-scale ordering.

The comparison between p.c.m. and f.d.m. provision is less easy to establish at this time. As may be seen from Fig. 1, the appropriate graph lines have similar slopes and a small error in either can cause a large error in the intersection point. The f.d.m. costs, though considerably changed in recent years through competitive purchasing and change of equipment practice, are nevertheless reasonably well established, but, as mentioned above, it is too early to have the same confidence in p.c.m. costs. For the longer distances, evidence is still awaited that systems will perform satisfactorily in respect of cumulative jitter (due to timing imperfections), whieh would cause noise on channels; also, suitable existing audio pairs become more difficult to find. Thus, any introduction of

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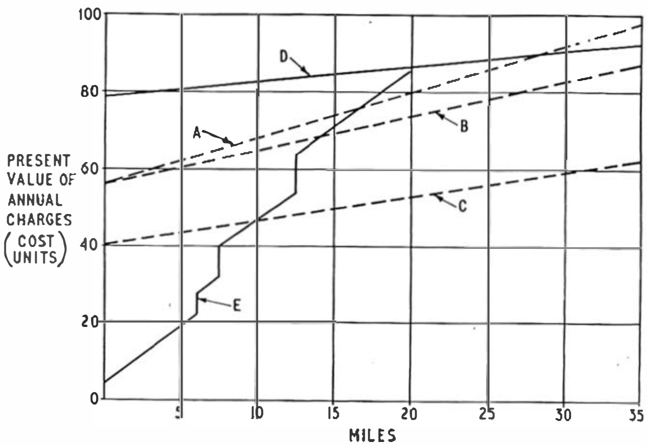
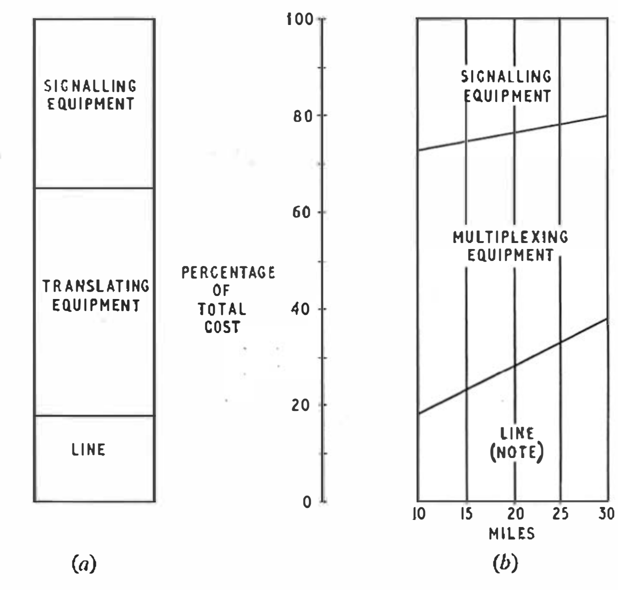


A—P.C.M. on two new cables
B—P.C.M. on existing cable pairs
C—P.C.M. (half capital cost)
D—Small-diameter (0·174 in.) 4 MHz coaxial cable
E—Two-wire audio circuits on 10 lb/mile cable.
Rate of growth: 128 circuits/year

FIG. 1—RELATIVE COSTS OF CIRCUIT PROVISION

this type of system into the trunk network may be expected to be limited to the shorter trunk circuits (say up to 50 miles), but, even so, to be on a carefully controlled basis as experience with working systems is gained.

For many years now there has been great interest in the proportionate costs of the line, terminal translating and signalling elements of f.d.m. systems, and Fig. 2(*a*) shows a recent analysis.[3] Though perhaps not strictly relevant to the subject of this article, and perhaps not even a fair comparison in some respects, a similar analysis (Fig. 2(*b*)) is given for early p.c.m. systems. It shows a tendency for a slightly lower proportion of the terminal costs to be attributable to wholly signalling equipment, but, with the p.c.m. system, some portion of the line and multiplexing costs results from the transmission of signalling information.



(*a*) Capital Costs (1965) of 100-Mile Trunk Connexion on Heavy Traffic Route using Modern Broadband Plant
Note: Includes cost of cable work (deloading, etc.) but not cost of cable or duct.
(*b*) Capital Costs (1966) of Typical P.C.M. Connexion

FIG. 2—PROPORTIONATE COSTS OF TERMINAL EQUIPMENT AND LINES FOR FREQUENCY-DIVISION MULTIPLEX AND PULSE-CODE MODULATION MULTIPLEX

The divisions of cost shown in Fig. 2 depend on the extent to which use is made of common plant, i.e. the extent to which full capacities are taken up; the figures quoted refer to full capacity in each instance.

Cable Availability

A p.c.m. system to the current Post Office specification provides 24 circuits on two pairs, one for each direction of transmission. Forty-eight regenerators (on 24 cards) are accommodated in a Case, Repeater Equipment, No. 1 (C.R.E. No. 1) (Fig. 3), giving it a capacity of 576 circuits,

FIG. 3—REPEATER EQUIPMENT CASE USED TO ACCOMMODATE P.C.M. REGENERATORS

assuming that a single C.R.E. No. 1 is used for both directions of transmission and that all pairs are equipped for p.c.m. However, the problem is one of dealing with audio cables whose performances at frequencies approaching 1 MHz have been little known hitherto. Tolerant of the quality of the medium as p.c.m. is, there are limits, and the question becomes one of determining the number of 24-circuit systems various cables can carry. The limitations on available cable data have led to a cautious approach in fixing planning rules for early systems. For example, though 10, 20 or 40 lb/mile paper-core quad trunk, paper-core quad local or paper-core quad cables, and 20 or 40 lb/mile paper-core multiple-twin cables will be used, early schemes will avoid 10 lb/mile cable, where possible, until more confidence is established.

The cable factors most in doubt are crosstalk at high (p.c.m.) frequencies and induction into p.c.m. systems of impulsive noise from non-p.c.m.-carrying pairs. Such effects, by introducing errors into the p.c.m. signal, would produce noise on individual circuits.

Near-end crosstalk, which would cause high-level outputs to "talk" into low-level inputs, is overcome by either 2-cable working or, for single-cable working, by segregation of transmit and receive channels into different balancing groups with maximum (at least one layer) separation between such groups. In addition, in order to limit the cumulative effects of distant-end crosstalk, the number of systems within any balancing group or adjacent groups is limited to 24 with, at least, a layer separation used between groups of 24 systems. Initially, 2-cable working is being preferred.

In 2-cable working all 48 regenerators within a C.R.E. No. 1 operate in the same direction. However, the connexions made between stub-cable pairs and regenerators are such that a change can be made to single-cable working by reversing alternate regenerator cards relative to their sockets.

Whilst requiring only 104 pairs, the stub-cable used to extend the main-cable pairs into the C.R.E. No. 1 is now of 150 pairs. This is partly in order to cater for the possibility of future equipment providing more than 48 regenerators per C.R.E. No. 1; but, in the meantime, for single-cable working it permits the segregation of transmit and receive channels to be extended right through the stub-cable. Originally, it was thought that the performance of the cable stub in respect of near-end crosstalk would mean that 2-cable working automatically required two sets of repeater equipment cases as, for practical reasons, only one stub-cable per C.R.E. No. 1 is possible. However, it is now being planned to provide on low-density routes one C.R.E. No. 1 to serve two main cables, and also with 2-cable working, to permit unsegregated transmit and receive channels in the stub-cable.

Any survey on cable availability should take into account the age and fault record of the cable, and its accessibility from the point of view of deloading and of routing the deloaded pairs via the repeater equipment cases. With older cables, spurs and repair lengths tend to be of a different gauge from that of the main cable. Mixed gauges, and, preferably, mixed types, of cables should be avoided. Each regenerator is equipped with an equalizer to suit the preceding length of cable, and mixing cables within a section length would make the choice of equalizer a difficult task. In some instances new spur cables or additional regenerators have been used to avoid mixed sections.

Impulsive noise induced from non-p.c.m.-carrying pairs may also tend to cause interference with p.c.m. systems. Obviously, this noise is at a maximum in the vicinity of exchanges, and, until more information is available, its effects are to be minimized by appropriate siting of regenerators, with the object of maintaining a good p.c.m. signal-to-impulsive-noise ratio. Where possible, pairs selected for p.c.m. use should not be within the same balancing group as pairs connected to short spurs serving exchanges by-passed by the p.c.m. system. Such spurs longer than 1,000 yd or connecting to main-cable pairs separated by at least one balancing group from the p.c.m. pairs may be ignored as noise sources. Otherwise, and for the time being, regenerators near exchanges are being positioned so that the distance between an exchange and the nearest regenerator, in the receive direction of transmission, is between 750 and 1,250 yd, i.e. nominally a half-section. Where the regenerators appropriate to the transmit and receive directions are not co-sited (a possibility with 2-cable working), a distance in the transmit direction of transmission up to a full section is being allowed.

Signalling

With p.c.m. equipment there is direct association of the signalling terminations (the p.c.m. equivalent of relay-sets) with the multiplexing equipment. Approximately half of the volume of the multiplexing equipment is used to house its 24 signalling terminations. These are of various types, according to the class of circuit provided.

To date, four signalling terminations have been specified and designed, providing

(*a*) outgoing signalling termination without metering,
(*b*) outgoing signalling termination with metering,
(*c*) incoming signalling termination without forward hold, and
(*d*) incoming signalling termination with forward hold.

In addition, two signalling extension cards (with and without gain) have been specified which extend earth-phantom signalling conditions, permitting the use of a conventional signalling system A.C. No. 8 relay-set.[4] Signalling terminations providing other facilities will be specified as soon as possible.

In general terms, this means that, whilst p.c.m. systems may already be planned to route most types of traffic circuits between Strowger-type exchanges, until additional designs of p.c.m. signalling terminations or electro-mechanical relay-sets, or both, are available there are exceptions. These include circuits between unit automatic exchanges (U.A.X.s) with subscriber trunk dialling (S.T.D.) and their group switching centre (G.S.C.), circuits from director exchanges to outgoing centralized register-translator units, and circuits from director exchanges to main tandem exchanges if they give access to certain manual-board services.

EXTERNAL WORK

The p.c.m. systems described make use, in general, of cables already in the ground. There is, however, aconsiderable amount of work to be done in deloading such cable pairs and in making them available in C.R.E.s No. 1 which, at present, are the external housings. Thus, it is desirable that pairs for the full, or ultimate, capacity of each C.R.E. No. 1 are diverted when it is installed.

P.C.M. regenerators will be located at loading points, i.e. at 2,000 yd spacing, where possible. Repeater equipment cases will be located in the loading manhole only under favourable circumstances, e.g. from the point of view of freedom from traffic hazard or from flooding, and, hence, the length of the stub-cable provided has been set at 30 ft to cater for various possibilities such as road crossings. Where footway boxes are used, they will, as are footway boxes used for repeater equipment cases for coaxial systems, be of modified (shallow) dimensions.

Even on the "supply and install" contracts already placed for p.c.m. equipment, it is a Post Office responsibility to perform the external cable work. To this end, a supply is being arranged of 30 ft lengths of Cable, P.V.C., No. 7, 150-pair 10 lb/mile, suitably equipped with glands and with the quads already terminated on connector sockets by which connexion will be made to the equipment. Fig. 4 shows a photograph of an early sample of such a stub-cable, partially unpacked, but otherwise showing how it may be expected to arrive on site. Connexion to the main cable may entail use of auxiliary stub-cables or by-pass cables, or both, depending on the particular existing loading arrangement.

In addition to the repeater equipment case and the stub-cable, other items, such as the pressure contactor, desiccator, etc., and associated mounting plate, will also be available as Post Office items from the Post Office Supplies Department.

The 24 regenerator cards fit into a framework within the repeater equipment case. This framework will

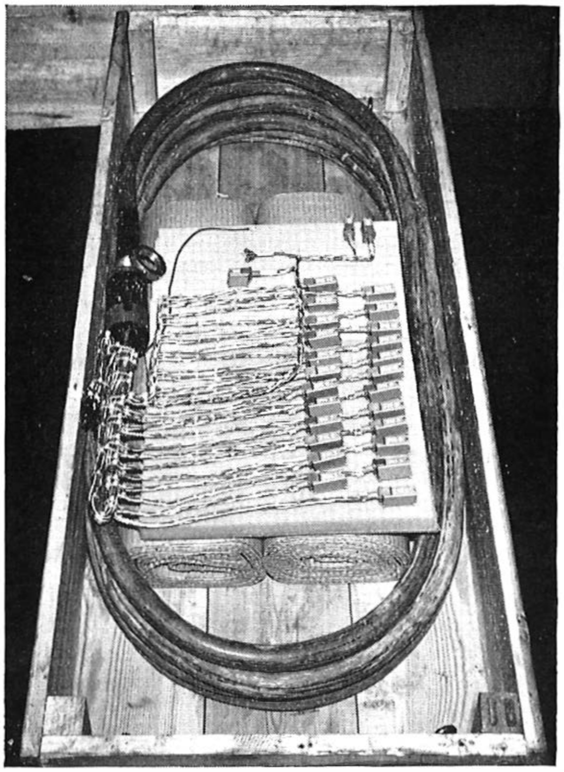


FIG. 4—STUB-CABLE AS DELIVERED TO SITE

normally be fitted when the case is installed, and the use of loading-coil cards (with loading coils supplied by the Post Office) in place of regenerator cards permits the pairs to be reloaded and connected through until such time as they are taken into use for p.c.m. The loading-coil card is then simply replaced by the regenerator card.

There will be instances when the first loading point is less than 750 yd from the exchange, and regenerators are, therefore, fitted beyond the loading point. This presents a problem as to how best to deal with those pairs not immediately in use for p.c.m. assuming that complete release of all the pairs cannot be arranged. In such circumstances the proper course is to deload the pairs at the original loading point, reload at the regenerator point, and make the necessary adjustments (in respect of building-out) to the affected sections.

At present three C.R.E.s No. 1 can be accommodated in the largest jointing box (type J.R.F. 10). On heavily-loaded routes a need will arise to accommodate many such equipment cases. The C.R.E. No. 1 is intended for bolting to the floor and has a heavy lid. It is not, therefore, ideal for the larger routes, and a new type of case suitable for wall mounting is being developed. It is planned that six of the new type should be capable of being mounted in a J.R.F. 10 type jointing box or 12 in a manhole used exclusively for p.c.m. regenerators. Identification of repeater equipment then becomes of great importance, and, where these are accommodated in more than one joint box at a single site, the contents of each joint box needs to be readily identifiable.

INTERNAL WORK

Fig. 5(*a*) shows a typical layout of a rack of multiplexing equipment, and Fig. 5(*b*) a rack of line-terminating equipment. The arrangement of the line-terminating equipment on each apparatus shelf is shown in Fig. 5(*c*). At terminal exchanges both racks are required, unless the ultimate p.c.m. requirement is so small that it can be met by having a combined rack. Line-terminating racks are also required at the ends of line sections, such sections then being ready for inter-connexion either to other sections or to multiplexing equipment. The form of construction is 62-type, and the volume occupied by the various component parts can, and will, vary from contractor to contractor within certain overall restrictions which it will be necessary to impose to permit handling of future jobs on a direct-labour basis. At present, as the layouts show, to equip 48 pairs (i.e. all pairs in the repeater equipment cases carrying p.c.m., assuming single-cable working) requires one rack of line-terminating equipment and eight racks of multiplexing equipment.

The layouts shown in Fig. 5 are for 10 ft 6 in. racks, which will normally be used in telephone-exchange apparatus rooms. In repeater-station apparatus rooms a 9 ft rack, having fewer dummy panels but the same equipment content, will be used. It is expected that the capacity of the line-terminating rack will be increased, and the 10-volt and 78–0–78-volt power units will be superseded.

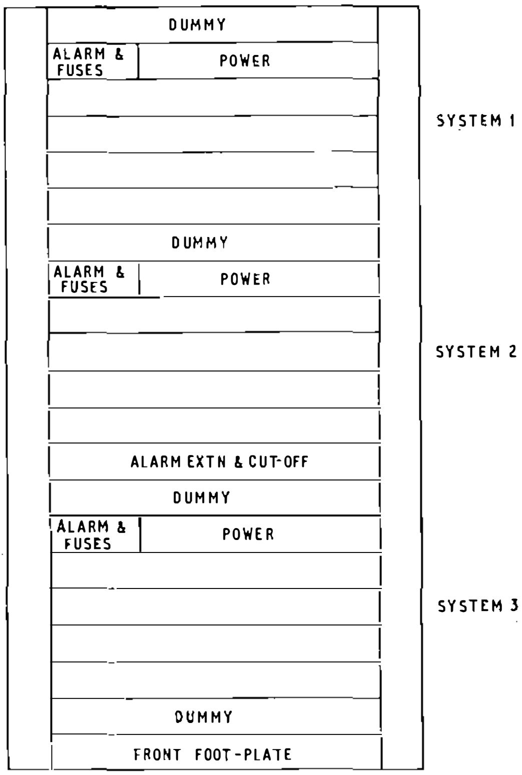
Each multiplexing equipment is complete as regards its power arrangements, which will operate from either 24-volt or 50-volt supply, as available. Certain signalling terminations will, however, require 50-volt exchange supplies, e.g. for metering and feeding line current to subscribers' instruments.

The main objects of the line-terminating apparatus are to cater for power feeding and to provide a "receive line amplifier." The power feed, derived from 50 or 24 volts, is at constant current (50 mA maximum, d.c.) over the phantom circuit derived from two pairs; with single-cable working these would be the two pairs of a system. The power-feeding voltage on the cable is restricted to ± 75 volts to earth.

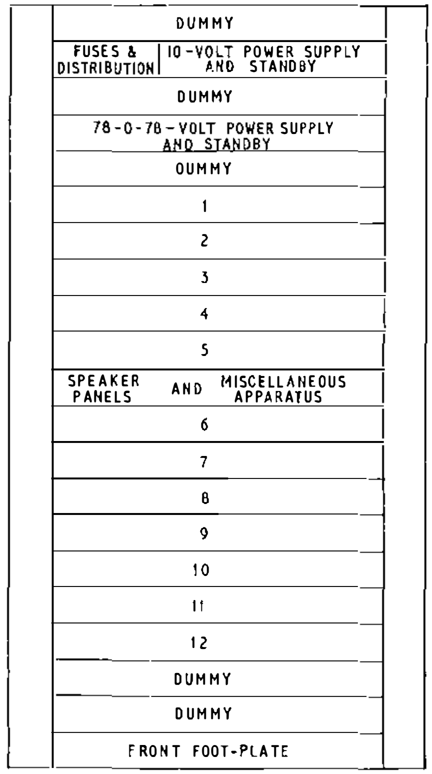
Power feeding is required to cater for a number of regenerators (up to at least seven each side from a power-feeding point), but where the number of regenerators to be supplied does not exceed two a simplified power-feeding unit may be used.

The line-terminating apparatus is cabled to the main distribution frame (M.D.F.) or to the cable-terminating rack (C.T.R.) using Cable, Carrier, Twin, and is terminated directly on the office side of the fuse mounting or test tablet carrying the external pairs, without jumpers or intermediate terminal blocks. Connexions between the line-terminating apparatus and the multiplexing equipment are of double-screened coaxial cable, and the length of these connexions should not exceed 50 yd. In stations with concentrations of p.c.m. systems, an h.f. flexibility frame may be interposed to simplify rearrangements and to cater for growth of the p.c.m. network. Spare-line patching is catered for on the line-terminating equipment.

Audio connexions to the multiplexing equipment may be 3-wire (positive, negative and P) where signalling terminations are used, or 4-wire where the signalling-extension card is used with earth signalling conditions extended over the phantom circuit. A simple 4-wire extension may also be used, for example, for private-circuit purposes. These connexions are made to the intermediate distribution frame (I.D.F.), using Cable P.V.C., $6\frac{1}{2}$ lb/mile, and four wires will normally be run



(a) Multiplexing Equipment



(b) Line-Terminating Equipment

POWER FEED	TRANSMIT	TRANSMIT	POWER FEED	RECEIVE	RECEIVE
POWER FEED	TRANSMIT	RECEIVE	POWER FEED	TRANSMIT	RECEIVE

The arrangement shown on the upper shelf is used for 2-cable working; that on the lower shelf is used for single-cable working

(c) Arrangement of Apparatus Shelves on Terminating Equipment

FIG. 5—LAYOUT OF TERMINAL EQUIPMENT (10 ft 6 in. Racks)

for each circuit. Connexions are then made from the I.D.F. to the test-jack frame (T.J.F.).

P.C.M. equipment will be accommodated close to the telephone-exchange equipment it serves, usually in an exchange apparatus room, as no repeater apparatus room will exist in the building. Exceptionally, in a joint telephone exchange and repeater station, where conditions are otherwise favourable, there is sometimes scope for installing the p.c.m. equipment in the repeater apparatus room. The p.c.m. equipment practice is a transmission-equipment practice, and dimensions are such that the racks cannot readily be interspersed within suites of telephone-exchange equipment, whereas, in a repeater apparatus room, the dimensions comply with normal rack and suite spacing. In such joint buildings, therefore, the siting of the equipment merits a critical look at the cabling involved, bearing in mind (*a*) where the external cables terminate, (*b*) the distances involved to distribution frames and T.J.F., and (*c*) the ease of blending with existing equipment. It has been suggested that cabling could be direct from the multiplexing equipment to the T.J.F., eliminating either repeater distribution frame (R.D.F.) or I.D.F. intermediate connexion, as appropriate. This, however, may prove to be unacceptable if arrangement of circuits in order on the T.J.F. continues to be a requirement.

There is a limit of 20 ohms to the overall resistance of the P-wire connexion. This corresponds to about 270 yd of cable, and, if the building layout is such that this distance is exceeded, it will be necessary to provide P-wire link circuits; these are simple signal-repeating circuits. A variety of them is available, many offering additional facilities.

The total power dissipation of a complete 24-channel multiplexing apparatus, including signalling terminations, will be up to 150 watts, depending on which contractor's equipment is involved and on signalling terminations. This figure does not include the line-feeding current to the telephone instrument, which is derived via outgoing signalling terminations. With at least three multiplexing equipments on a rack the dissipation can, therefore, approach 0·5 kW. This is appreciably above the normal for 62-type equipment, and, obviously, with any grouping of such racks the temperature rise is a factor to watch. The line-terminating rack when fully equipped will represent a load of some 400 watts, and about half of this may be dissipated within the rack.

TESTING, ALARM AND SPEAKER EQUIPMENT

In addition to p.c.m.-carrying pairs, deloaded pairs are also required for gas-pressure alarm, regenerator-fault location, and speaker purposes. Initial plans are for two speaker circuits: a local speaker for communication between adjacent regenerator points, and a system speaker for communication between exchanges and between exchanges and intermediate points. In this latter case the speaker circuit effectively reloads the pair. For systems yet to be ordered, arrangements are expected to be made to provide speaker facilities using direct exchange lines.

Indications are given at the terminals of (*a*) loss of synchronization, (*b*) excessive sustained digital-error rate, (*c*) failure of digital line transmission, (*d*) failure of common transmission apparatus, and (*e*) power stabilizer and converter failure. Any one of the above results in a system-fail alarm. Extension of this and any other alarms may be made to an alarm-extension apparatus, which can be mounted centrally on the rack. Extension of the station alarms will be to suit local requirements.

Three items of test equipment (all portable) are specified. One of these is a digital-error detector for in-service use in association with counters or recorders or both. In this sense a digital error is a violation of the bi-polar pattern, i.e. a failure of successive pulses to be alternately positive going and negative going. The bi-polar nature of the line pulse-train is one of the "refinements" to which reference was made in the introduction. Successive pulses are made alternately positive and negative going in order to simplify transmission, both by removing the d.c. component and by effectively reducing the frequency.

The remaining two items are used in conjunction with one another, and with the digital supervisory pairs mentioned above, for out-of-service tests. The first, a digital-pattern generator, is capable of injecting into a repeatered line digital test signals, each containing a pre-selected audio component; for this purpose the bi-polar pattern is deliberately modified. Auxiliary outputs of all the regenerators in a repeater equipment case (regardless of direction of transmission) are connected via an audio low-pass filter to the supervisory pair, so that the second item, a selective measuring set, when connected at the appropriate exchange to the supervisory pair, can detect the audio frequency. By allocating different-frequency filters to the several repeater equipment cases, and by varying the audio-frequency content of the digital signal, the digital pulse-train can be proved at successive regenerator outputs along the route until the faulty one fails to produce its audio frequency on the supervisory pair. Eighteen audio frequencies are used for this purpose in the range 1,100–3,100 Hz. The same testers may be used to give advance warning of deterioration of a regenerator. Facilities are provided on the pattern generator to increase the magnitude of the audio-frequency content, by increasing the extent of bi-polar violation. By determining the maximum audio-frequency component tolerable before digital failure occurs, and comparing with results of earlier tests, deterioration can be detected.

On the initial scheme a liberal provision has been made for spare equipped line sections and spare multiplexing equipment, and also for test equipment and spares for equipping a maintenance repair centre. Rapid substitution of a spare line for a faulty one between multiplexing equipments can be made by patching. On the other hand, rapid substitution of a complete multiplexing equipment by another is not possible because of its 24 circuit ends, and in such circumstances individual card changing is to be used to clear faults.

THE FUTURE

As far as p.c.m. is concerned the basic principles may be established but the practice is evolving. Mention was made in the introduction of certain contracts already placed. These are "supply and install" contracts. The future ordering mentioned, however, will be for supply only, with installation by direct labour. The consequent problems of compatibility between one contractor's equipment (e.g. multiplexing equipment, regenerators, signalling terminations, etc.) and another's are being tackled, as well as the questions of coding and stocking such items, and nomenclature for utilization, maintenance and record purposes.

It is likely that in the future regenerators will be smaller, permitting, for example, more per existing type of repeater equipment case or a similar number in a much smaller container, which, of course, highlights the question of a new container. Already a smaller container could well be used as p.c.m. appears economic on routes of low growth rate, where 576 circuits may be far too many. In London, C.R.E.s No.1 have already proved an embarrassment to locate in cable tunnels, and consideration is being given to housing the regenerator framework in a modified loading-coil case. Experience will show whether containers should remain easily openable or if they can be more permanently sealed.

Current exploitation of p.c.m. is limited to 24-circuit systems on deloaded audio cables. However, the principles may be applied to the transmission of more than 24 channels, or to other types of signal of totally different bandwidth, and to interleaving the coded digits of various types of signal on a common highway. Bandwidth requirements for such assemblies of signals will be great, and certainly too great for economic exploitation of audio cables. Examination of possible new applications for p.c.m., and hence of the capabilities of carrier balanced-pair cables and coaxial cables in respect of digital-rate capacity, are in hand, and it will not be very long before the appraisement of other types of p.c.m. systems will be necessary.

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Computer Simulation of a Character-Recognition Machine

Part 1—Processing a Character for Recognition

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U.D.C. 681.327.12:371.693.4

This article describes the simulation, on a computer, of a machine that will recognize handwritten and printed alpha-numeric characters. Methods of coding, smoothing, standardizing and thinning are discussed in Part 1. The recognition procedure, based on the coding system, is presented in Part 2.

INTRODUCTION

THIS article discusses a possible technique that is being developed for the recognition of handwritten and printed alpha-numeric characters, with a view to its application to the automatic sorting of mail.

The technique employed here involves the representation of a character as a simple code consisting of a series of numbers (representing eight possible feature directions) and junction numbers. Prior to the character being obtained in the coded form, it is processed so that any gaps in the feature due to bad-quality print are joined and all redundant information, e.g. serifs and curlicues, are ignored. The character also undergoes a "thinning" process. The various stages involved in the technique are outlined in Fig. 1.

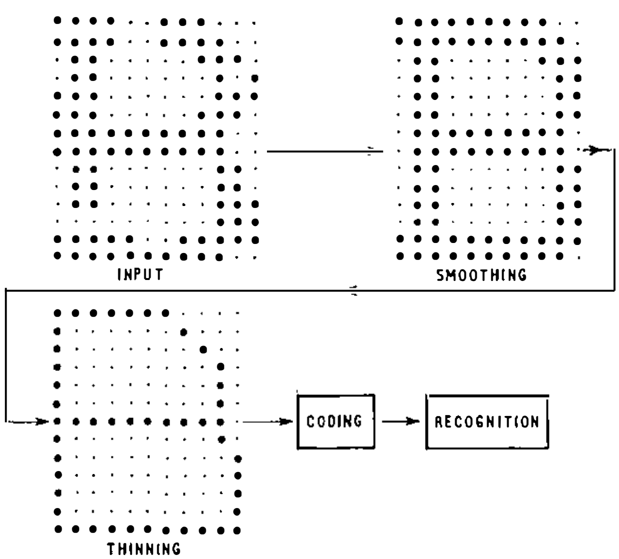


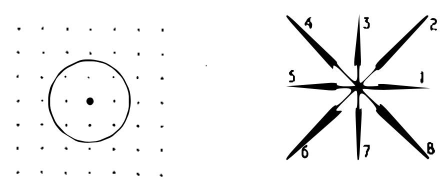
FIG. 1—STAGES INVOLVED IN CHARACTER RECOGNITION

The article is divided into two parts. Part 1 discusses the ideas and algorithms involved in all the processing stages of a character up to the final stage of recognition, and includes simple examples. The actual recognition technique is presented in Part 2, together with further examples of various tests that have been carried out by simulation on a modified Elliott 803 computer.

The present work deals with "binarized" input characters, i.e. quantized in levels of black and white. Taylor,[1] and Clayden, Clowes and Parks[2] have developed analogue techniques, but their main success is confined to recognition of characters whose shapes are fairly well defined. The problem here, however, is to deal with countless samples of shapes of unknown definition. For similar reasons, the work of Rosenblatt,[3] and Greenberg and Konheim,[4] in exploiting linear separability has not been followed. The method described here, involving the use of multi-dimensional vector space geometry, partitions a given space into the number of character classifications required. The vectorial representation of the input character derived from the input signals establishes its location in the space and, hence, its class. However, the present work has precedent in the work of Sherman[5] and, more recently, in that of Greanias, *et al.*[6] The thinning technique described is different from that described by Dinneen,[7] which employs threshold logic.

CODING SYSTEM

In a rectangular matrix of points, any given element, say $A_{i,j}$, has eight nearest neighbours (see Fig. 2(*a*)). Assuming that movement from any one point may take place only to one of the eight surrounding points, and

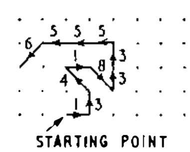


(*a*) Showing the Eight Nearest Points to Element $A_{i,j}$ (*b*) Illustrating the Eight Direction Numbers

FIG. 2—CODING OF DIRECTIONS OF MOVEMENT FROM A POINT IN A MATRIX

so on, all point-to-point movement can be registered as a series of "direction numbers" as shown in Fig. 2(*b*). Fig. 3 shows a pattern joining up various points on the matrix, the pattern being coded in accordance with the direction numbers chosen, starting at the point shown.

It is evident that the location of the given pattern on the matrix is immaterial, and, provided the same starting point is used, the pattern can be reproduced anywhere on the point matrix provided the latter is large enough.



Code: 13418335556

FIG. 3—ENCODING A SIMPLE PATTERN

Rotation of any such encoded pattern by n multiples of $\pi/4$ in an anti-clockwise direction can be effected by adding n to each of the direction numbers in the string on a modulo eight basis, and replacing any number exceeding eight, or the highest possible multiple thereof,

†Post Office Research Station.

by its excess over it. Further manipulations using this coding system are possible. It facilitates the determination of the existence of the closure of a curve or pattern, the curve length, and the area it encloses. Path reversal and reduction, and expansion or contraction, of patterns is also possible; these manipulations have been described elsewhere.[8, 9, 10]

So far only manipulations of continuous contours have been mentioned, but their inadequacy for alphanumeric representation is obvious. Consider the pattern shown in Fig. 4. It consists of the pattern of Fig. 3 with

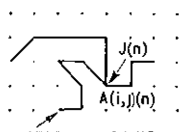


FIG. 4—THE PATTERN OF FIG. 3 WITH AN ADDITIONAL BRANCH AT $A_{i,j}$. ELEMENT $A_{i,j}$ IS NODE POINT No. n

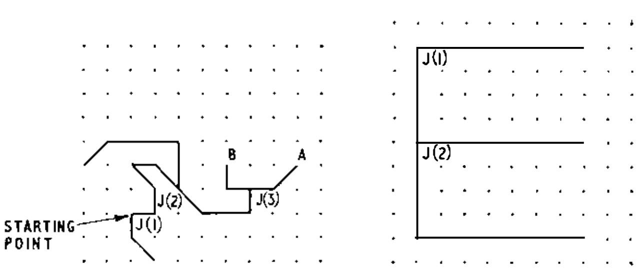
an extra branch at junction point $A_{i,j}$ Whereas the sequence of movement along the pattern in Fig. 3 is obvious, that along Fig. 4 can take one of two forms at junction point $A_{i,j}$. To cope with such situations a serial junction-point (or node) number, n, of co-ordinates $(i, j)(n)$, is assigned to the meeting point of more than two branches (an exception to this is rule (*iv*) below), and the following rules of procedure are used to code the pattern.

(*i*) Assign the node number, value n, and store co-ordinates $(i, j)(n)$, as above mentioned. Enter the junction number as J(n) in the chain of direction numbers; this is for use in the recognition procedure, the J( ) serving to distinguish a node number from a direction number.

(*ii*) If possible (*a*) proceed along the same direction of travel as before, or, if this is not possible, (*b*) proceed in the direction of lowest direction number.

(*iii*) On arrival at the end of a branch, return to the uncompleted node point of lowest value n, re-enter junction node J(n) in the chain and continue as in (*ii*) (*b*).

(*iv*) Treat a starting point having more than one branch leaving it as a junction point, i.e. register the junction node J(1) at the beginning of the chain and proceed as in (*ii*) (*b*).



(*a*) Multi-Nodal Pattern Coding (*b*) Typical Pattern with Two Junction Points

FIG. 5—PATTERNS INVOLVING NON-CONTINUOUS CONTOURS

Thus, in Fig. 4, the pattern would be coded as:

13418J(1)131J(1)335556,

and that in Fig. 5(*a*) as:

J(1)13418J(2)8113J(3)12J(1)78J(2)335556J(3)53.

Fig. 5(*b*) would be coded as follows:

J(1)1111111J(1)7777J(2)77771111111J(2)1111111.

Two difficulties arise: that concerning the handling of closed loops (assume, for example, points A and B in Fig. 5(*a*) were joined) and that concerning the choice of the starting point. Both these problems will be discussed later.

COMPUTER PROGRAM REQUIREMENTS

It is important for any character-recognizing machine that it be insensitive to imperfections in shape, to gaps and discontinuities, to variations in line thickness, to orientation, or to the presence of any irrelevant information.

Fig. 6 shows 15 different characters. It is obvious that even though the characters on each row are defective or

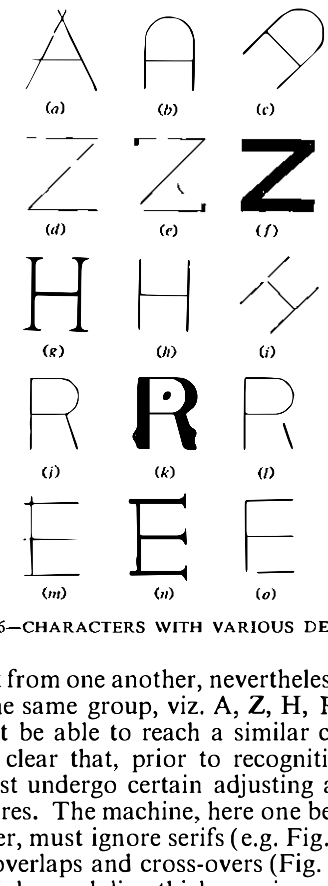


FIG. 6—CHARACTERS WITH VARIOUS DEFECTS

look different from one another, nevertheless, they belong to one and the same group, viz. A, Z, H, R and E. The machine must be able to reach a similar conclusion. It is, therefore, clear that, prior to recognition, the input character must undergo certain adjusting and standardizing procedures. The machine, here one being simulated on a computer, must ignore serifs (e.g. Fig. 6(*g*) and (*n*)), unnecessary overlaps and cross-overs (Fig. 6(*a*) and (*m*)), cope with kinks and line-thickness irregularities (Fig. 6 (*k*)), and other spurious "blobs" (Fig. 6(*e*) and (*k*)), as none of them contribute "recognition information." Gaps, if any, due to poor print must be joined (Fig. 6 (*d*), (*l*) and (*o*)), otherwise, for example, the character in Fig. 6(*o*) may be recognized as an F. On the other hand, joining the serifs on the top and the bottom of the H in Fig. 6(*g*) will yield a different character altogether.

The character must also be thinned so that it can be represented as a pattern of single-element-thickness features, for, not only is the contribution of line thickness nil, it also increases the complexity in coding.

For greater clarity, free use will be made of terms descriptive of human operations in describing the ensuing processes, but, prior to this, brief mention will be made of the method of input of the character into the computer.

The character to be recognized is photographed and the film scanned by a flying-spot scanner. The information on the film is superimposed on to a 30 × 20 matrix of output cells. Each cell in the matrix can have the value either 0 or 1, depending upon whether any part of a feature of the input character lies on that element cell or not. At those points where the black feature is well contrasted to its white background, the element is assigned the value 1, but certain "weighing up" procedures must be undergone where the contrast is not so good before assigning a value to a particular cell. Fig. 7 shows an oscilloscope display of two characters on the matrix. For a better visual effect the cells having the value 1 have been expanded to occupy a complete rectangle.

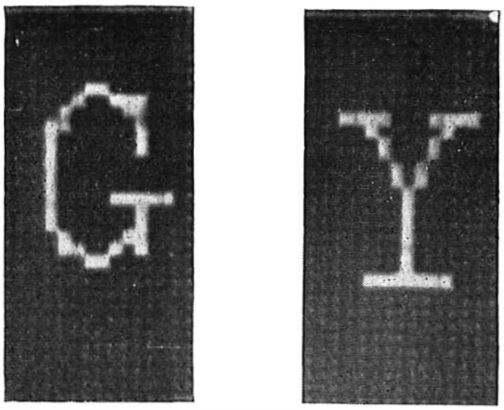


FIG. 7—INPUT CHARACTER SUPERIMPOSED ON MATRIX OF CELLS

PROCESSING THE CHARACTER

Smoothing Procedure

Consider the input character matrix in Fig. 1. The character presented, a letter B, has numerous imperfections and redundancies in its feature representation, and it is the object of the smoothing procedure to eliminate them. The steps of the procedure are outlined in the computer flow diagram in Fig. 8.

The 30 × 20 matrix A, of which the element common to the ith row and jth column is called $A_{i,j}$, is stored in the computer together with its superimposed input character. Next, the overall height and width of the character in terms of row and column occupancy are determined, the character then being imagined to be constrained within a rectangle of this height and width; this defines the search area. The size of this constraining rectangle will be used subsequently, by means of a parameter, D, dependent upon it, in deciding whether an apparent feature of the character is real or not.

The computer will now examine, in turn, each element in the search area, starting from the uppermost row in the constraining rectangle and moving to the right searching for an element ($A_{i,j}$) having a value equal to 1. Having found such an element, a search for the existence of branches in all the eight directions, and of minimum length D, is commenced. The next element in the row, $A_{i,j+1}$, is examined should there be no such branch.

The value of D selected ensures that the machine, rather than "locking" itself on to a spurious small feature of print and offering that as a character to be recognized, locks itself on to the character proper. Once the machine has attached itself to the character, the number of branches at the starting point is memorized together with the starting-point co-ordinates.

The machine moves, element by element, along one of the branches, transfering the information on the element just investigated to a new matrix, matrix a, and erasing the element in matrix A. This prevents continuous traverse along a closed path, but causes no loss in information as matrix a is also consulted throughout the computation. Prior to any move in the direction of travel being executed, the value, 1 or 0, of the next element is determined. If it is of the former value, a move is executed and the number of branches, if any, leaving the new element is registered. Gaps to branches alongside are joined and registered as taking part in forming the node point. Three parameters are involved in registering a node point: the node number n, the number of branches at that node, $x(n)$ (note that $x(n) > 2$), and the node co-ordinates $(i, j)(n)$.

The element may have the value 0 because of irregularities in the thickness of the print, because of gaps, either along the direction of travel or in the formation of a junction of features further on, or, finally, in the absence of any of these causes, because the end of a branch may have been reached. The computer examines these possibilities.

In the process of filling-in gaps, all elements participating have their values changed from 0 to 1, and the travel procedure is continued along these elements. In this manner a "bootstrap" operation is executed whereby the computer lays its own tracks. In all cases the allowable extent of hunting for a gap is a function of parameter D.

Irregularities in line thickness are overcome by consulting neighbouring a-matrix and A-matrix elements which form the line thickness, but, should the end of a branch have been reached, a traverse along a new branch leaving the previous element is attempted. In the absence of such a branch the travel procedure re-commences from the junction point of lowest node value n, with the number

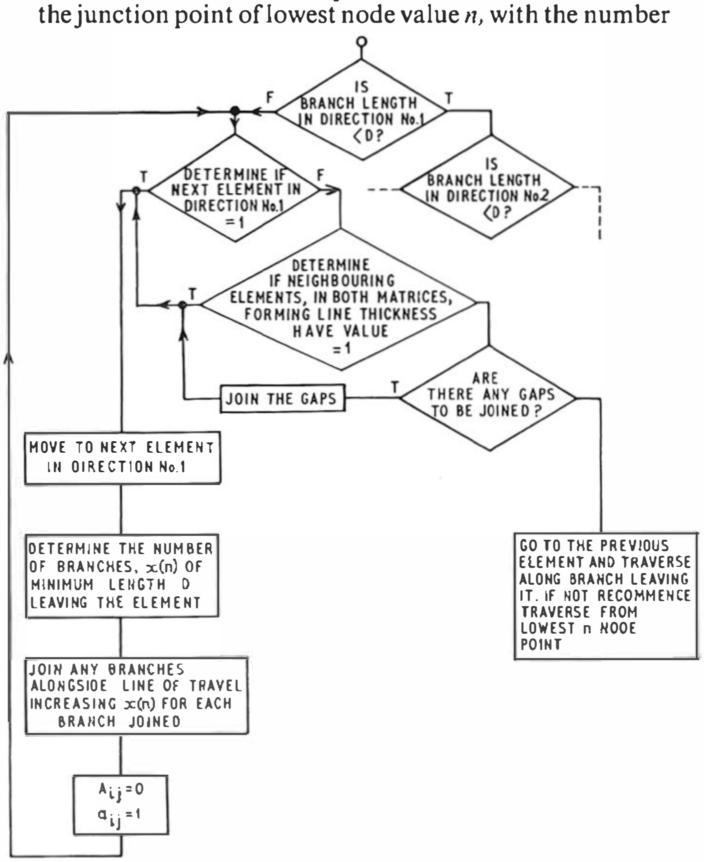


FIG. 8—FLOW DIAGRAM OF SMOOTHING PROCESS

of branches at that node, $x(n)$, reduced by 1. This process continues until the value of $x(n)$ for the junction point with the maximum n is zero, at which point the procedure is terminated. Fig. 9 shows some of the results thus obtained. It will be observed that the curves in the C (Fig. 9(*e*)) and B (Fig. 9(*f*)) are degraded, an effect that will be discussed later.

Thinning Procedure

In Fig. 1 the smoothed input character B can be pro-

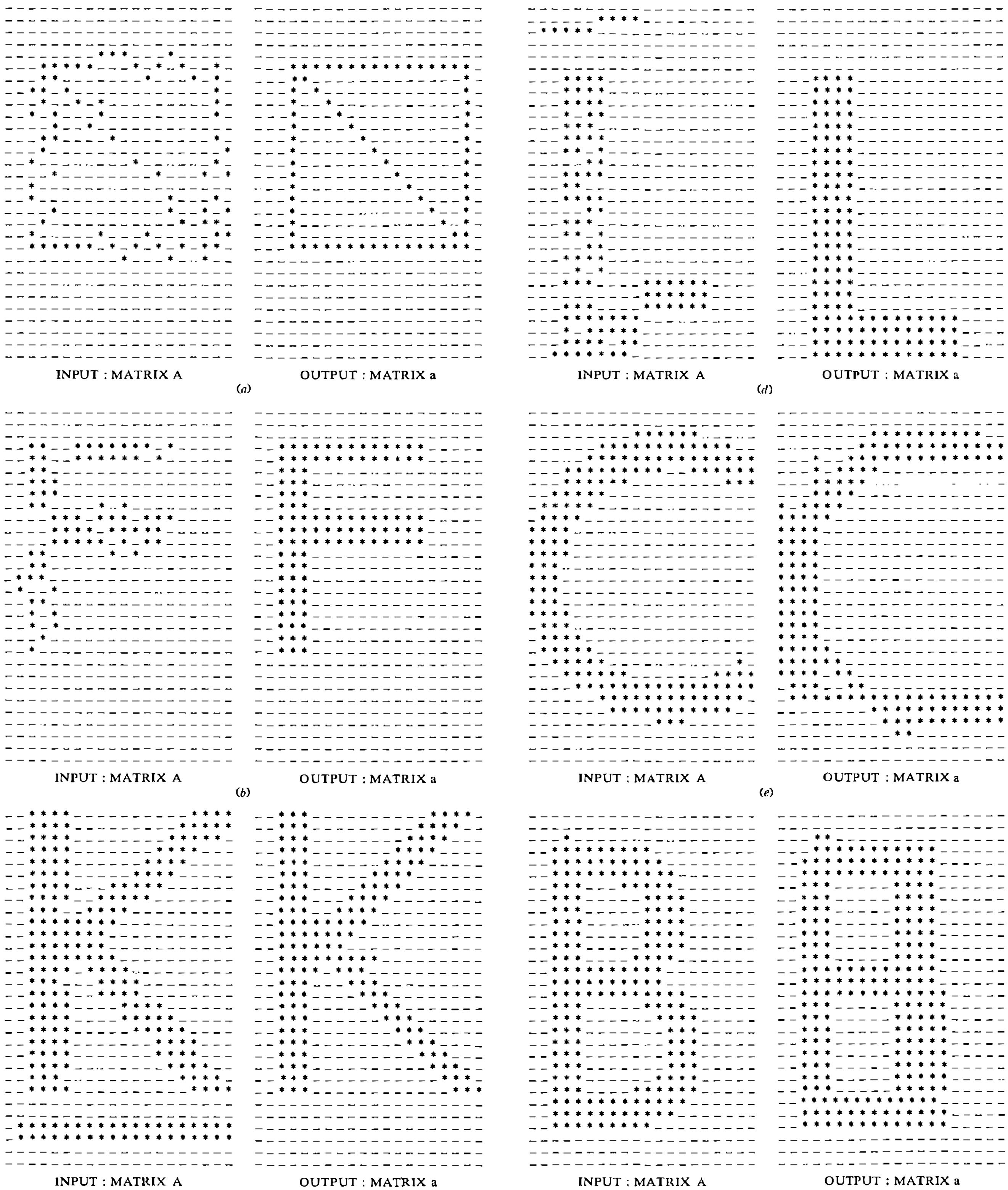


FIG. 9—RESULTS OF SMOOTHING PROCESS

cessed further. It will be observed that the thickness of features and the presence of serifs in no way contribute to a better character presentation. The features are therefore thinned, and serifs as well as other redundancies are eliminated. Fig. 10 shows the computer flow diagram of this process.

The residue in matrix A is no longer needed and is, therefore, eliminated. The contents of matrix a are then transferred to matrix A. The $x(n)$, and $(i, j)(n)$ stores are also cleared. Prior to thinning, the line thickness, L, is determined. The character is examined element by element and the thickness of a feature in terms of elements is found. Line thickness is measured horizontally for all branches except horizontal ones, for which the line thickness is measured vertically. No measurement is made at node points and the mean of the values obtained is assigned to the variable L. The computer then starts to examine each element, moving within the search area from top left and to the right, but not beyond the mid point of the width of the rectangular constraint. This arrangement ensures that the coded starting point is within a predetermined area, thereby facilitating the recognition procedure.

The "locking" procedure of the thinning process differs from that described above for the smoothing process in that a better starting point can be selected. In obtaining the starting point by the new method, the computer hunts around the element and determines whether there is nearby a node point possessing a higher value of $x(n)$, i.e. a greater number of branches. Should this be so, the latter element is considered as the starting point. In this way, projections and serifs do not contribute to the starting point and, hence, are ignored.

The character is examined element by element, and elements of branches forming line thickness are erased, except at junction points where such erasure could lead to loss of information. Again, erasure of each element along the line of traverse and its transfer to the a matrix take place. The method of determining the junction points is as before. The node characteristics n, $x(n)$, and $(i, j)(n)$ are stored but, this time, together with variables indicating branch directions at the particular node. The program also ensures that movement parallel to a direction already traversed can not take place. This can happen if the local line thickness is greater than L, thus enabling, possibly, the un-erased line thickness to be registered unnecessarily as a branch from a different node. The program also includes a further refinement for the enhancement of the curvature of a feature. Fig. 11 shows some of the results obtained.

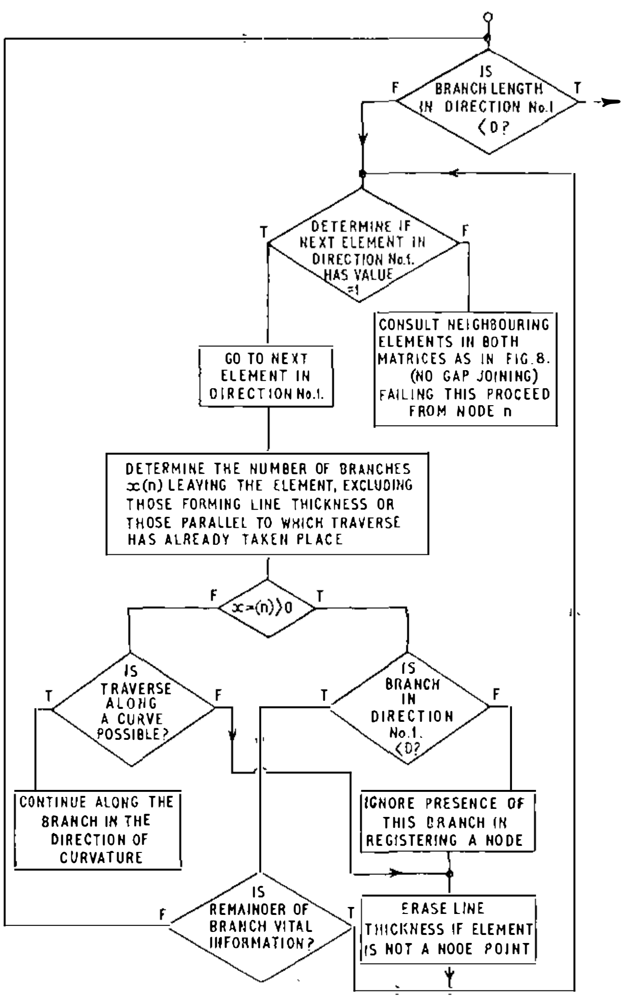


FIG. 10—FLOW DIAGRAM OF THINNING PROCESS

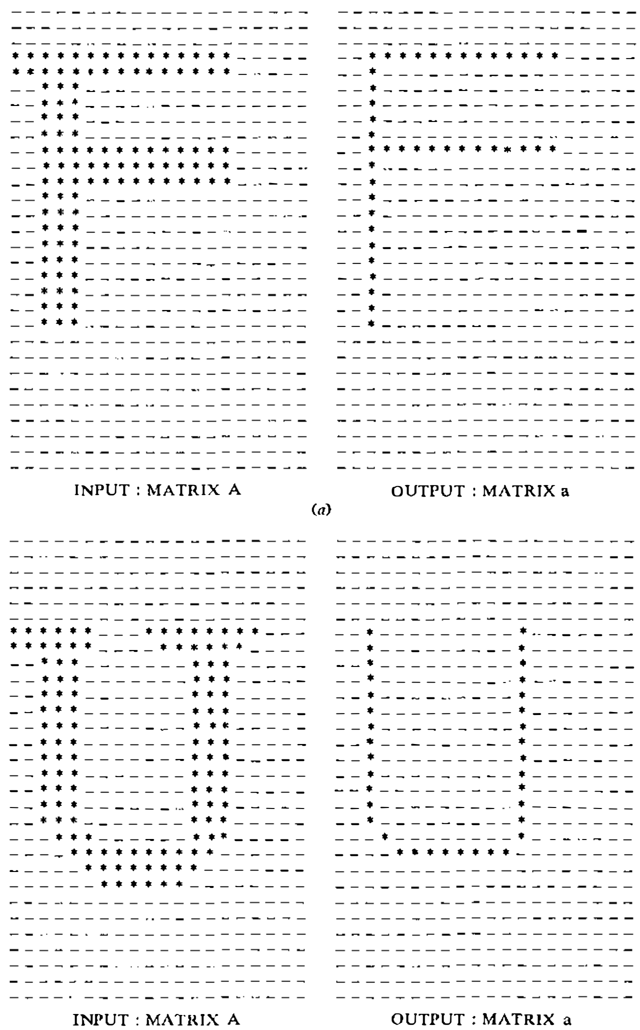


FIG. 11—RESULTS OF THINNING PROCESS

CONCLUSIONS

Consider Fig. 9(*a*): it may possibly be argued that since the shape of the input pattern is different from that of the output pattern they should, therefore, constitute characters of different classes, thus rendering incorrect the eventual identification of the input as a rectangle with a diagonal across it. However, the overall shape of the input and the tendency of its features (and it is this that is considered vital in recognizing characters) indicate that the input figure is identifiable with the output obtained.

In Fig. 9(*e*) the features of the output C have been enlarged, and its curvature, as also for the output B of Fig. 9(*f*), has been slightly degraded. A small gap in the feature also occurred (bottom left). While this does not aggravate the difficulty of recognition generally, it is an unnecessary distortion and ought to be overcome. It is thought that the curvature-enhancement procedure employed in the thinning process will overcome this.

A serious disadvantage, at present, is the lack of test directions other than those discussed above. This could lead to a serious loss in input information, and a program has been developed to cope with such situations but no results are yet available.

(*To be continued*)

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Quality Control of Brazed Seals in Deep-Sea Repeaters

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U.D.C. 621.315.28:621.375-758.32:621.791.38:658.562

The method used for maintaining the quality of the brazed seals of high-tensile-steel deep-sea repeater housings is described. Test results obtained have inspired a high degree of confidence in the sealing processes, and this confidence has been reinforced by the completely satisfactory behaviour of over 900 repeaters which have now been laid.

INTRODUCTION

A deep-sea repeater housing containing the internal unit and sectioned through one end is shown in Fig. 1(*a*). The main mechanical features of the housing are illustrated, namely, the high-strength steel casing, the cable termination and glanding, and the bulkhead sealed into the casing by a circumferential braze which forms the high-pressure seal, a cross-sectional diagram of which is shown in Fig. 1(*b*). Although housings have been laid in depths of sea water of 2,500 fathoms, corresponding to an external hydrostatic pressure of the order of 3 tons/in^2, in the new Madang–Guam submarine telephone-cable system the cable traverses the Mariana Trench, where pressures may rise to about 6·3 tons/in^2. As the housing is designed for a life in excess of 20 years, the reliability of the brazed seal is very important under these service conditions, where failure of a repeater in a system means a loss of earnings on the system and inconvenience to the users during the period of repair. Hence, as the brazed seal is such an important feature of the housing it is extremely desirable that the production brazing process should be subjected to the most stringent quality-control methods.

Radiography cannot detect areas of non-adhesion in a braze, but tests carried out at the Aeronautical Inspection Department, Harefield, demonstrated that ultrasonics could be used effectively for this purpose. However, interpretation of ultrasonic results is somewhat operator dependent, and, because it is thus rather difficult to evolve a standard of inspection, this testing method has not yet been used during production.

Very good definition by radiography has been obtained using 120 kV on a $\frac{3}{8}$ in. braze section. The full $1\frac{1}{4}$ in. unmachined section of the braze seal has been radiographed successfully at 200 kV, but the resolution is not as good as with the reduced section; capillary penetration can just be distinguished but inclusions can only be seen in the well of the braze.

High-frequency induction brazing of the repeater housing is effected at 690°C, and is accurately controlled by thermocouples embedded in the casing wall. The steel used for the repeater housings (En 25) suffers a phase change which in some steel casts occurs at a temperature as low as 700°C. This phase change is accompanied by

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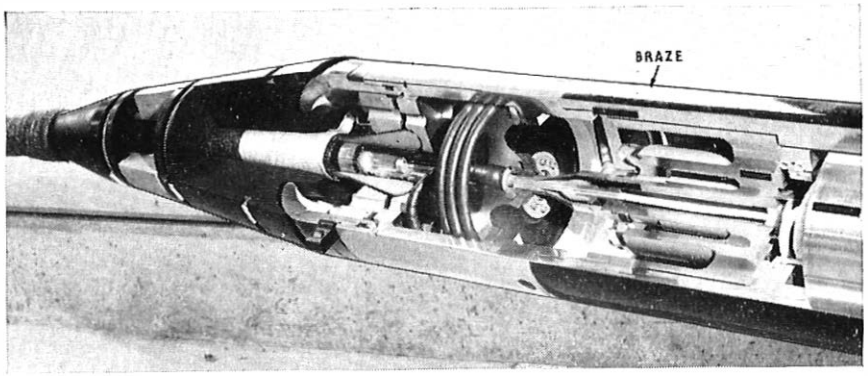
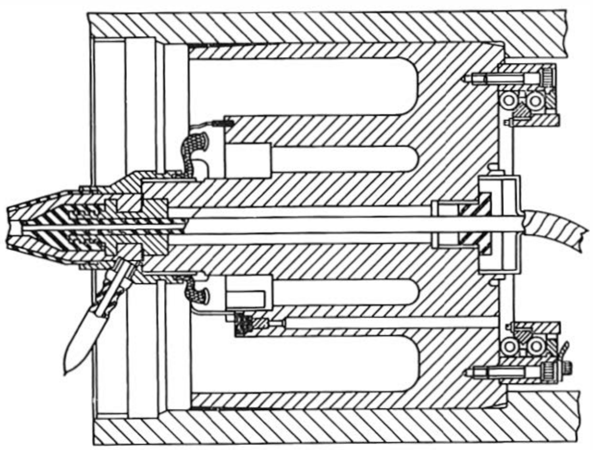


(*a*) Photograph of Cut-Away Repeater Housing Showing Bulkhead Braze



(*b*) Cross-Sectional Diagram of Bulkhead Braze
FIG. 1—BRAZED SEAL IN DEEP-SEA REPEATER

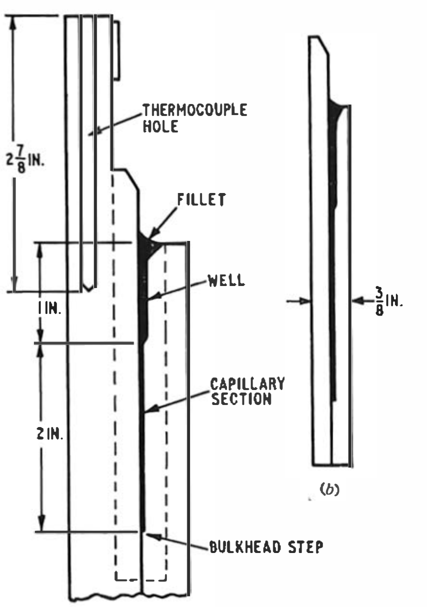
local volumetric changes that cause shearing in the solidified braze during cooling. Hence, although radiographic examination reveals the depth of penetration of the braze and the distribution of flux inclusions, these factors alone do not denote sound brazing. Since it was not possible to ensure the maintenance of quality by non-destructive means, a system was introduced in which a dummy housing is sealed-off after each production run of 20 housings, the dummy being subjected to the usual pressure test and then to destructive examination.

THE BULKHEAD-TO-CASING SEAL

Radiography of adequate sensitivity could not be produced from the full section of the braze of the bulkhead-to-casing seal shown in Fig. 2(*a*). The dummy joint was, therefore, parted from the housing and reduced in section, as shown in Fig. 2(*b*), and six radiographs were taken to give complete coverage of the joint. A typical radiograph is shown in Fig. 3.

The brazing operation inevitably produces residual stresses and distortion of the joint, and these effects are revealed, respectively, by a change in diameter of the test ring when it is cut for sampling, and by a tapering of the sides of the braze well. Brazing temperatures up to 700°C tend to produce a closing of the ring and a well-shape which narrows at the fillet end. The reverse is found with temperatures above 700°C, and, as a guide to the consistency of the process, appropriate measurements were made with each dummy housing.

About 25 segments, $\frac{5}{8}$ in. wide, are then cut from the



(*a*)
Dotted line shows section illustrated in (*b*)
(*a*) Section of Joint
(*b*) Reduced Section used for Radiography
FIG. 2—SECTION OF BRAZE

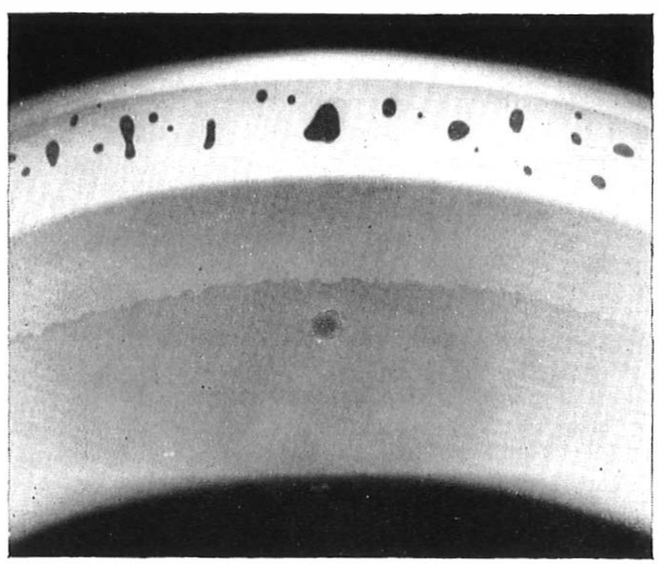
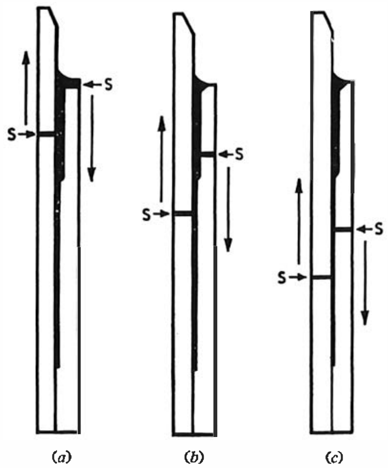


FIG. 3—RADIOGRAPH OF BRAZED JOINT

test ring, and six of these are split apart. A narrow band of flux below the braze line shows that the fluxing operation had been carried out satisfactorily. Shear tests are carried out on the remaining segments, the location of the test being defined by two saw cuts. Fig. 4(*a*), (*b*) and (*c*) show shear test-pieces for testing the top, middle, and bottom portions of the joint.



(*a*) Specimen with Saw Cut at Top
(*b*) Specimen with Saw Cuts in Middle
(*c*) Specimen with Saw Cuts at Bottom
S—Saw Cut
FIG. 4—SHEAR-TEST SPECIMENS

THE GAS-FILLER POST SEAL

The gas-filler post is machined on the intermediate skirt of the bulkhead, and its design, in sectional view, is shown in Fig. 5; it permits nitrogen flushing of the internal free space of the casing. After the gas-filler posts have been sealed, the relative humidity of the internal atmosphere can be monitored by a moisture-sensing element during the pressure confidence test on the housing. Thus, should either of the main brazes leak an estimate of the rate of leakage can be formed.

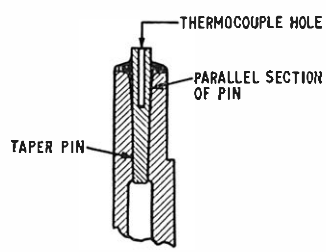


FIG. 5—SECTION THROUGH GAS-FILLER POST

The location of the post in the bulkhead does not permit radiographic examination to be carried out. The posts were, therefore, sawn from the dummy bulkheads and were cut in half longitudinally. The halves were then radiographed to reveal the depth of penetration of braze material and the presence of any cavities or flux inclusions; a typical radiograph is shown in Fig. 6. The sawn surfaces of the posts were then prepared for metallographic examination so that the depth of penetration of braze material could be confirmed and an assessment of bonding quality could be made. No suitable technique could be found for shear testing the joints, but the half pins were prised from the half posts so that the resulting fractures could be visually examined.

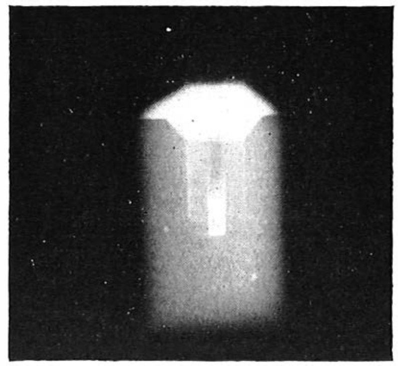


FIG. 6—RADIOGRAPH OF A SECTIONED GAS-FILLER POST

RESULTS OF THE TESTS

Twenty dummy brazes made during production of the U.S.A.–Bermuda and COMPAC cable systems were examined; all of these were considered to be satisfactory, although results for the main seal showed considerable variation in quality from braze to braze. Of particular interest was the quantity and shape of flux inclusions to be seen in the wells of the joints. The radiographs showed areas of high concentration of inclusions, areas almost devoid of inclusions, and areas containing horizontal and vertical inclusions. A vertical inclusion which bridged the braze area would obviously constitute a potential leak path, but, fortunately, vertical inclusions of this magnitude were not encountered. The depth of penetration of the silver brazing alloy into the capillary gap also varied, the average for all dummy brazes being $\frac{11}{16}$ in. Local areas of reduced penetration were seen, and were shown to be associated with capillary gaps which had become too narrow because of distortion of the casing during brazing. The bulkhead-step dimension was increased to prevent this effect.

Reasonably consistent shear-test results were obtained, the average figure being 10·6 tons/in^2. None of the results suggested that bonding was unsatisfactory or that shearing of the silver brazing alloy had occurred during cooling.

All of the gas-filler seals were satisfactory, but there was some variation from seal to seal in depth of penetration of silver brazing alloy. Bonding between the mild-steel taper pin and the silver brazing alloy was, in the capillary gap, superior to that between the high-tensile steel post and the silver brazing alloy.

CONCLUSIONS

Stringent quality-control of repeater seals is now a well-established and satisfactory method, and the consistently good test results have inspired a high degree of confidence in the brazed seals, confidence that has been reinforced by the completely satisfactory behaviour of over 900 repeaters which have now been laid.

A New Artificial Ear

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U.D.C. 612.85:621.317.34:621.395.62

The true electro-acoustic performance of a telephone receiver can only be measured when it is working into its correct acoustic load, provided either by a real ear or by a laboratory device which closely simulates the acoustic impedance of the average human ear. Existing artificial ears fall some way short of this ideal. The article describes a new survey of a large sample of real ears, leading to a new design of artificial ear of much improved performance.

INTRODUCTION

THE designation "artificial ear" is perhaps in itself a little misleading: the device is not a replacement for a missing or defective organ. It is purely a laboratory device for measuring the acoustic output of an earphone, and it is termed an artificial ear because it offers to the earphone the same sort of acoustic load as a human ear.

The modern telephone receiver[1] has a light alloy diaphragm coupled to an iron armature. The diaphragm is restrained by clamping its outer rim, and the armature is restrained by torsion bars. Such a system, having mass and stiffness, is inherently resonant, and without further control would have a frequency response exhibiting one or more sharp peaks. The designer is able to modify the response by making use of air cavities, in front of and behind the diaphragm and coupled through controlled air leaks, to provide resistive damping, but the acoustic system of the receiver is not complete until it is held against an ear. The ear contains a small volume of air in an enclosure having a complex lining of bone and tissue, and this presents to the receiver diaphragm an acoustic load which further modifies the receiver response.

This characteristic of the ear can be expressed as an "acoustic impedance." To those not accustomed to acoustical terms it may be explained that the mathematical treatment of vibration problems in acoustics and mechanics is very similar to that of electrical-circuit analysis, and that direct analogies exist between voltage and sound pressure, and electrical current and acoustical volume current (i.e. flow rate). Thus, acoustical impedance is defined as the ratio of alternating pressure to alternating rate of volume displacement. For example, if a small piston of area s is vibrating with velocity v, and a pressure p per unit area is developed at its surface due to its contact with the air, then the acoustical impedance seen by the piston is p/sv. This is, in general, a complex quantity. The unit is the acoustical ohm (generally measured in c.g.s. units), and is defined as the impedance which, for a pressure of 1 dyne/cm^2, results in a volume velocity of 1 cm^3/second.

The relevance of the impedance concept is apparent from the analogy with the electrical counterpart, where the voltage produced by a generator of known impedance across a load depends upon the impedance of the load. Earphone and ear bear precisely the same relationship. It will be clear that an earphone will only develop its intended acoustic output when working into the appropriate acoustic impedance. Thus, when a telephone handset is held well away from the head and the receiver is radiating sound into substantially free air, the load impedance seen by the diaphragm is quite incorrect and the frequency response appears changed.

†Post Office Research Station.

Perhaps the most common earphone calibration required is that of the sound pressure developed within the ear by a given electrical input. Since quite large differences exist between the ears of different people (and for other obvious reasons) it is not practicable to use real ears for all earphone calibrations. What is needed is an artificial ear which reproduces the essential characteristics of the average real ear.

The need for such an artificial ear was recognized in the earlier days of telephony, and in 1929 Mr. W. West of the Post Office Research Station at Dollis Hill made the first such device based on measurements of the acoustic impedance of real ears.[2] The measurements were, by today's standards, made with the simplest of apparatus, and were limited to five discrete frequencies between 370 and 2,600 c/s. Altogether Mr. West measured 12 different ears, and from the results he deduced that a reasonable approximation to an average ear would be provided by a hard-walled cavity of 3 cm^3 volume together with an acoustical resistance of 120 ohms. This resistance he obtained by means of a long brass tube which became progressively more and more filled with darning wool along its length.

It is now known that this British Post Office artificial ear is not really a very good approximation to a real ear at the lower frequencies. Nevertheless, at the time it represented a great step forward and earned for Mr. West international recognition in the field of acoustics.

Other countries followed suit and produced their own artificial ears, most of them broadly similar in conception. In Britain the Post Office design was accepted by industry, and in 1953 it was adopted, with minor modifications, by the British Standards Institution as the British national standard.[3] It is noteworthy that all measurements of telephone-receiver performance in this country are still being based on Mr. West's original work of 1929.

LIMITATIONS OF THE EXISTING ARTIFICIAL EAR

It is important to recognize the limitations of existing artificial ears. Ideally, a perfect artificial ear could be used to compare the performance of telephone receivers of differing types and designs. Thus, suppose there were available four quite different designs of receiver. On the artificial ear it would be possible to measure the sensitivity/frequency response of each one. If then a person was found whose ear impedance lay in the middle of the human range, and the actual response of each of the four receivers on his ear was measured (using a probe-tube microphone* to measure the sound pressure actually developed within his ear), the same four response curves should be obtained as on the artificial ear.

In practice, with existing artificial ears, this is not so,

*Probe-tube microphone—a microphone in which the sound is carried to the transducer along a small-bore probe tube, thus enabling sound-pressure measurements to be made without substantially disturbing the sound field.

and it is found that the apparent differences between the receivers on the artificial ear are not the same as the actual differences between them on the chosen real ear. Nevertheless, the British Standard Artificial Ear is reasonably satisfactory for factory acceptance testing of telephone receivers; in such tests the production item has to be compared with a standard item of the same pattern.

A different and perhaps more realistic approach was that of the American National Bureau of Standards (N.B.S.) which, recognizing the imperfections of so-called artificial ears, standardized on a simple "coupler" which made no pretence to be anything more than a comparison device for comparing earphones of the same type. It is basically a hard-walled cylindrical cavity of 6 cm^3 volume having the far end closed by a pressure-measuring microphone, and what it measures is not the same thing as the response on a real ear. It is unfortunate that this is not more widely appreciated, for it is not unknown to see manufacturers quoting as the response curve of a receiver the response measured on the N.B.S. coupler.

In the field of audiometry the position is generally much less satisfactory than in telephonometry. An audiometer is a device widely used by the medical profession to investigate a patient's acuity of hearing, and it does this by measuring his hearing threshold at various points on the frequency scale. The calibration of the earphone must, therefore, be known quite accurately over a wide frequency range, and this can be done by a laborious method using real ears of subjects who are known to have normal hearing. Only a very limited number of earphones can be calibrated in this manner, and the artificial ear is used to check the performance of other earphones of the same pattern against the calibrated sample. There is thus a real need in the audiometry field for an artificial ear of more realistic performance over a much wider frequency range than is at present available.

PROGRESS TOWARDS A NEW ARTIFICIAL EAR

In 1960 the International Electrotechnical Commission set up a committee (TC29/WG11) to consider whether it was yet practicable to produce a new artificial ear which would be so much more realistic that all participating countries would be prepared to adopt it in preference to their own present national standards. The British Post Office was represented on this Committee, and agreed with other members to attempt a new determination of real-ear impedance. Clearly, if the findings were to be acceptable internationally, they must be based on results from a number of different laboratories.

The Post Office undertook to play its part, and in 1962 work was commenced at its Research Station on a new determination of the acoustic impedance of real ears, covering a wider frequency range and much larger sample of ears, using volunteers drawn from the staff of the Research Station. Over the next 2 years a small team devised and perfected rapid and accurate means of measuring ear impedance, and carried out hundreds of observations.

Scope of Study

In order to make the results of value in as broad a field as possible, a study of ear impedance needs to take account of both the impedance proper to the ear itself, and that due to the particular earcap being used. The effect of the earcap is interposed between the transducer and the ear, as shown diagrammatically in Fig. 1, but if a plane surface is used against the

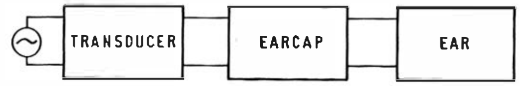
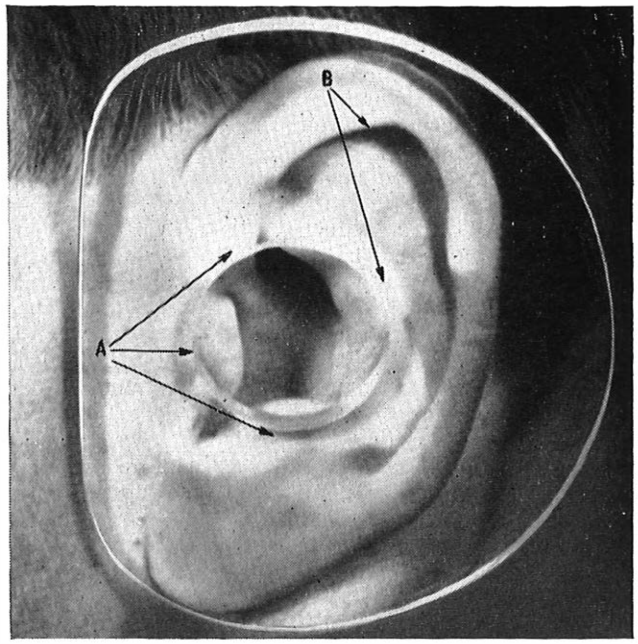


FIG. 1—EFFECT OF EARCAP

ear, the series impedance due to the earcap vanishes and the properties of the ear alone can be measured. This approach has been used for all the measurements which have been undertaken to establish basic data on the ear alone. The basic, planar, earcap used for the tests was made from a D-shaped piece of transparent Perspex sheet to facilitate observation of any possible leakage paths. Fig. 2 shows this plane earcap



A—Leaks B—Seal (whitening of flesh)
FIG. 2—D-SHAPED PERSPEX MEASURING PLANE, SHOWING DEGREE OF SEALING

held to an ear, and the sealed and leaking regions can be seen. The effect of a leak is to introduce an unwanted, often low, shunt impedance across that of the ear it is desired to measure, and in order not to confuse the issue it was decided to seal the ear to the earcap using a polymeric impressioning plastic. This technique had the minor disadvantage that the plastic tended to fill a small part of the outer ear, thus slightly changing its impedance.

Measuring Techniques

For the measurement of ear impedance, two distinct techniques were used. The first and most accurate approach has been described in detail elsewhere[4] and it suffices here to say that a "measuring device," comprising a sounder and probe-tube microphone, was presented in turn with the following conditions: (*i*) open-circuit, (*ii*) known impedance, and (*iii*) unknown impedance. The ear being measured was, of course, the "unknown," and the impedance was obtained as a direct reading in Z / θ form by an ingenious set of ancillary equipment. This method, which will be referred to as the substitution method, proved to be rather slow, and only yielded individual measurements at single frequencies.

An alternative method was subsequently developed which was much more rapid in operation, and enabled continuous-curve traces to be drawn of impedance and angle against frequency. This second method employed a 1 in. diameter capacitor-microphone cartridge as a high-impedance sounder producing a substantially constant acoustical-volume current. Application of the analogy described above, together with Ohm's Law, shows that the magnitude and phase of the sound pressure developed in the ear are directly related to its $|Z|$ and $/ \theta$, respectively, and may be traced by a pen-recorder, as shown in Fig. 3.

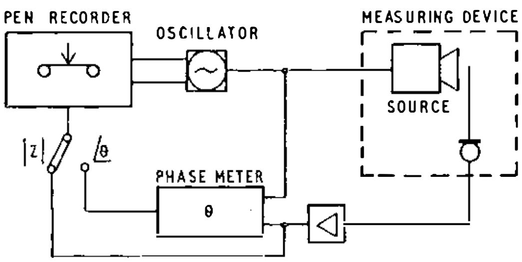


FIG. 3—CONTINUOUS-TRACE METHOD

This method will be referred to as the continuous-trace method.

The "measuring device" was common to both methods of measurement, and is illustrated in Fig. 4, where the Perspex measuring-plane is shown attached. It was quite light and was fixed by a gimbal mounting to a spring headband exerting a clamping force of approximately 0·8 kg to the subject's ear.

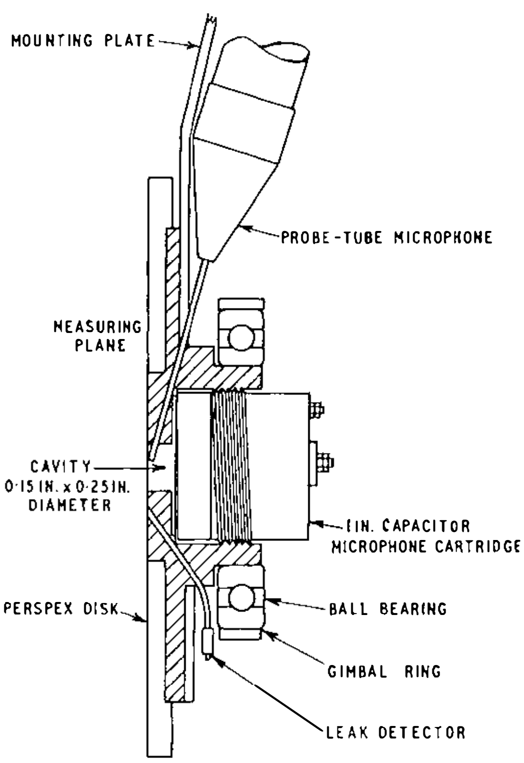


FIG. 4—MEASURING DEVICE

One final feature of the equipment was a laboratory development of the inverted-bell manometer to detect any possible leakage effects. In its final state this device could detect changes of less than 0·01 mm water gauge with a dead-beat movement in less than ½ second and showed up leaks of 100 kilohms (c.g.s.).

Results of Measurements

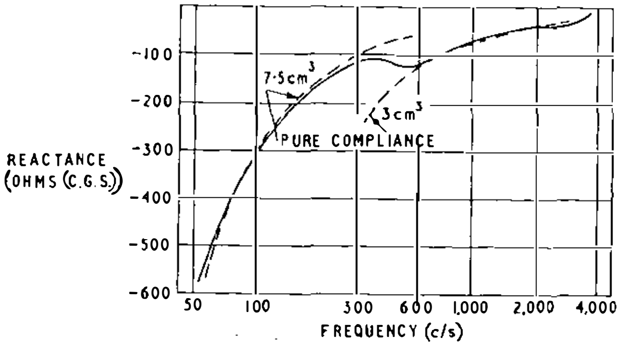
Three separate sets of measurements had to be taken before the true shape of the impedance-frequency locus could be defined with reasonable accuracy. In the first set, using the substitution method, measurements were made at what were thought to be reasonable-spaced frequency intervals between 120 c/s and 4,000 c/s inclusive, but it became clear afterwards that the behaviour of the reactive component was not being adequately resolved in the region 300–600 c/s. The experimental design[6] was such that the test could not readily be extended and so, although the one question was partly solved, another had been posed.

The anomaly in the 300–600 c/s region was clearly of importance, and to get a clearer picture of it, the equipment was rebuilt to extend its range down to 20 c/s. The continuous-trace method was evolved and measurements were then made on over 50 subjects, divided approximately equally between the two methods. Great difficulty was experienced in making the low-frequency measurements because of disturbances from the subject's pulse. With the substitution method, the operator searching for the balance point had to ignore the audible pulse beats, and could do so without introducing excessive error. The continuous-trace method, on the other hand, relied for its operation upon the modulus and phase of the sound pressure within the ear, and any disturbances were therefore recorded, incorrectly, as an impedance change. The heartbeat caused a transient change in the volume of the ear, each beat reducing the enclosed volume below its quiescent value. Any attempt to filter out the transient merely averaged the pulses in with the steady value and gave incorrect results. A solution to this "noise" problem was found in greatly increasing the writing speed of the pen recorder, thus showing up the perturbations so that the underlying steady value could be extracted.

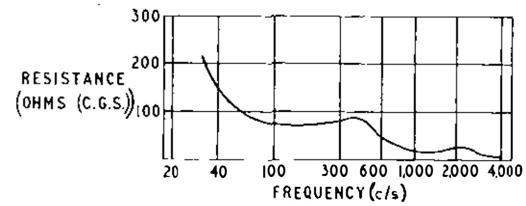
Results from the three separate sets of measurements form a consistent set. The anomalous variation of apparent volume is made clear in Fig. 5 where, for frequencies below 300 c/s, the reactive component of impedance is seen to behave as a simple volume of approximately 7·5 cm^3, whereas in the frequency range from 600–2,000 c/s the equivalent volume is only 3 cm^3. When plotting a set of results such as these, it is quite possible that the curve indicated by joining the calculated mean values bears little or no resemblance to any one constituent of the family of curves. This is not so here, however, for from the continuous-trace results it is known that it is, in fact, a typical characteristic. The nature of this anomalous variation of input volume is now quite well documented[6,7] but its cause is still rather obscure.

NEW ARTIFICIAL EAR

Having established the average acoustic impedance of real ears, the next step was to design a piece of hardware



(a) Reactive Component



(b) Resistive Component

FIG. 5—RESULTS OF MEASUREMENTS OF EAR IMPEDANCE

which closely simulated this impedance. It was also essential that the design be such that the device could readily be manufactured, and that it should not rely upon the use of any materials which are difficult to specify, such as rubber or leather. Ideally it should consist of a piece of brassware in which accurate machining to specified tolerances would automatically result in the correct performance without any need for critical final adjustments in the laboratory.

The first step was an attempt to simulate the impedance characteristics of real ears by means of an analogue electrical network. The changes of input impedance which occur in real ears were plotted on a Z-plane diagram and shown to correspond with the resonances which can occur in a transmission-line equivalent circuit when using graded lumped constants. Fig. 6

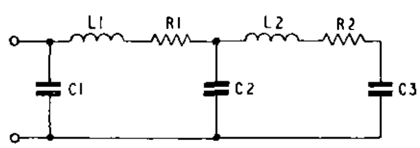


FIG. 6—ELECTRICAL ANALOGUE OF REAL EAR

shows such a circuit, where it can be qualitatively seen that, by causing successive sections to pass through resonance and become predominantly inductive, the input capacitance can be reduced in a controlled manner. Returning yet again to the electrical-acoustical analogy, it can be shown that a capacitor may be reproduced by a volume, whilst inductive resistors are analogous to pipes or slits depending upon the L/R ratio. Thus, the electrical analogue of a real ear shown in Fig. 6 may be reproduced as the acoustical circuit of Fig. 7. Fig. 8 shows a cross-section of the actual device, which is machined from solid brass. The input is at the mouth of the conical volume (volume 1, Fig. 7), from which an annular-slit resistance leads into an annular chamber (volume 2, Fig. 7). The wall of this chamber is pierced with four

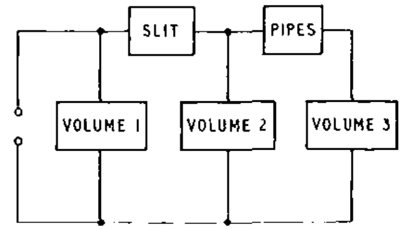


FIG. 7—ACOUSTICAL EQUIVALENT CIRCUIT

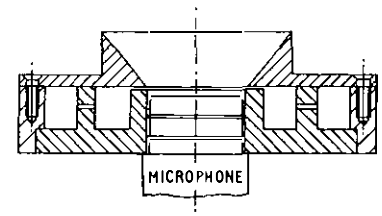


FIG. 8 -CROSS-SECTION OF ARTIFICIAL EAR

holes which lead to the outer chamber (volume 3, Fig. 7). Accurate machining is required to produce both a slit, which is only 0·004 in. wide within a tolerance of 0·0002 in., and four holes of 0·0157 in. diameter (No. 78 drill), but all the remaining work calls for only broad tolerances. The earphone to be calibrated is held against the upper rim, and the sound pressure detected by the microphone shown. The acoustical input-impedance curves are not reproduced, for they follow closely to the real-ear curves (Fig. 5(*a*) and (*b*)).

EARCAP EFFECT

It was mentioned earlier that the effect of the earcap had to be assessed separately and, if necessary, taken care of by an adaptor ring attached to the artificial-ear input. Recent work at the National Physical Laboratories at Teddington has measured both the impedance from a plane and that from a variety of audiometric earcaps, and hence the effect of at least those earcaps is now known.

At the Post Office Research Station, where work is continuing on the impedance offered to telephone receivers, it has been found that, although drastic changes to the sealed-ear impedance are caused by the sorts of leak which occur in telephone use, these large changes can nevertheless be reproduced by a very simple adaptor fitted to the basic artificial ear of Fig. 8. The adaptor is ring-shaped to simulate the extra volume included under a loosely-held earphone, and has a few radial holes carefully drilled to simulate the leak. It fits at one end on to the artificial ear, whilst offering location for a receiver-inset type 4T at the outer end. The load impedance seen by the inset is the same as that obtained in average telephone usage.

CONCLUSIONS

The artificial ear just described is felt to be a significant advance on previous designs, in that the input-impedance characteristic now closely simulates that of a real ear, and it is also both reproducible and stable within close limits. The new design has been submitted to the International Electrotechnical Commission as a tentative proposal for the new international standard. While it is perhaps too much to hope that it may meet with immediate acceptance in its present form, it does at least demonstrate that a satisfactory artificial ear can be produced, and this contribution should have helped to bring nearer the prospect of eventual agreement on a new standard.

International agreement on a new artificial ear will, of course, mean that acceptance testing of telephone receivers by the Test and Inspection Branch of the Post Office Engineering Department may eventually have to be done using the new ear instead of the present B.S.I. artificial ear, and that the relevant Post Office specifications will then have to be rewritten.

ACKNOWLEDGEMENTS

The authors wish both to acknowledge the assistance given by their colleagues Messrs. E. G. T. Johnson, P. E. White and R. F. Yates, and to offer their thanks to those subjects who did so willingly "lend their ears."

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Book Reviews

"American Ultraminiature Component Parts Data, 1965–66." Edited by G. W. A. Dummer and J. Mackenzie Robertson. Pergamon Press, Ltd. xi+485 pp. 140s.

This volume is one of a series based mainly on the general pattern of reprinting selected extracts from manufacturers' technical literature, and suitably classifying and editing same, so that the reader has the salient features of a shelf-full of manufacturers' catalogues of the field in question. It gives data on a comprehensive selection of the smallest electronic component parts available from manufacturers in the U.S.A. (Other volumes deal similarly with British, European, and Japanese components.)

The products of about 114 manufacturers are dealt with, and the scope can be seen from the following compression of the contents and index list. The numerals in brackets after each component indicate the number of types listed; of each of these types from one to five manufacturers' products are dealt with.

Accelerometers, actuators, blowers, boards—printed circuit, bobbins, cables (coaxial), capacitors—fixed (16), capacitors—variable (3), chokes, chokes (r.f.), choppers, coil forms, connectors (11), couplings, filters, fuse holders, jacks, lamps, lamp filters and lenses, meters (2), micro-components, miniaturized component range, motors (4), photocells, photoelectronic devices, relays (4) (including some reed relays), resistance thermometers, resistors—fixed (10), resistors—variable (9), sockets, springs, switches (7), switch cores (magnetic), tank circuits, temperature sensors, terminals, thermal convertors, thermistors (3), toroids, transducers—pressure, transformers (3), tuning forks.

It will be noted that the above list does not include valves, transistors, diodes or rectifiers.

This volume uses thinner paper than the "American Miniature and Microminiature Electronics Data Manual" previously reviewed in July 1964, and contains 125 more pages, though occupying about the same space (approx. 11 in. × 9 in. × 1 in.).

The printing and reproducitons are nearly all of good quality, and there are few misprints; oddly enough, one of these is in large print in the first line on the back of the title page.

The author's claim that the contents will be of special interest to all concerned with the design and engineering of modern high-density electronic equipment may well be justified, but readers must not expect to get a full treatment of every product of every firm in the relevant field.

A.A.N.

"Modern Electronic Components." G. W. A. Dummer, M.B.E., M.I.E.E., Sen. Mem. I.E.E.E. Pitman and Sons, Ltd. viii+516 pp. 256 ill. 63s.

For the benefit of those who are familiar with the very useful first edition of this book, published in 1959, one may say that the second edition has been improved by an increase in the number of pages from 472 to 516, which mainly arises from incorporating fresh information that has become available since 1959, by adding a chapter on changes in component characteristics with time and by substituting a chapter about future developments in the first edition by one on temperature, humidity and vibration categories of components.

For those who have not seen the previous edition, a list of what is included in the present book under the head of "Modern Electronic Components" will indicate its scope—viz. a list of components specifications; colour codes; conventional symbols; fixed and variable resistors; fixed and variable capacitors; wires and sleevings; relays (including a little on reed relays); switches; magnetic materials; inductors; transformers; transductors; pulsators; batteries, accumulators; miscellaneous components, temperature, humidity and vibration categories; components for high temperature; short-life ratings; performance in the tropics; performance in arctic areas; miniature components; components for printed wiring and automatic assembly; casting resins; effects of nuclear radiation; components for high altitudes; effects of vibration and shock; reliability; failure mechanisms; changes with time; testing methods and techniques; packaging, preservation, and identification.

The book can be recommended as a general-purpose source of information for designers of electronic equipment which involves individual components, especially where there is a bias towards Services requirements. It could also be useful to enthusiastic amateurs constructing electronic equipment. It should be noted that it does not cover valves, gas-filled devices, or semiconductor devices such as transistors or diodes.

To specialists in any of the individual fields listed above it would be of less interest.

A.A.N.

Synchronous Multiplex Telegraphy on Intercontinental Submarine Telephone Cables

A. C. CROISDALE, M.B.E., B.Sc.(Eng.), C.Eng., M.I.E.E., and C. S. HUNT†

U.D.C. 621.394.42:621.315.28

Synchronous operation offers a method of increasing the traffic-carrying capacity of frequency-shift voice-frequency telegraph circuits. Over long distances a 2-circuit time-division-multiplex system becomes economic, and the inherent characteristics of stable operation and signal regeneration are further advantages, particularly if the bearer-circuit noise is appreciable. Where the circuit noise is not excessive it is possible to employ a method of signal detection known as characteristic-distortion compensation, permitting three 50-baud teleprinter circuits to be operated over one 120 c/s-spaced frequency-shift voice-frequency circuit.

INTRODUCTION

AN electromechanical type of synchronous multiplex telegraph equipment has already been described in this Journal,[1] and equipments of this type have been in service between New York and London, and Montreal and London. This article describes a modern time-division telegraph system giving an improved performance with more facilities, requiring less space and virtually no maintenance, and costing less than the previous system. The modern system gives 2-circuit or 3-circuit multiplexing, but a special method of signal detection known as characteristic-distortion compensation (c.d.c.) is necessary if three teleprinter circuits are provided on each 120 c/s-spaced frequency-shift voice-frequency telegraph (f.s.v.f.t.) circuit.[2,3]

SYNCHRONOUS MULTIPLEX TELEGRAPHY

Basic Sender-Receiver Principles

Briefly, time-division-multiplex telegraph working is a method by which each of a number of teleprinter channels is given, in succession, exclusive use of a common transmission path. For the path to be operated in this manner it can only transmit equal-length signal elements from each of the sharing teleprinter channels, and these equal-length elements must be continuously and accurately produced from a timing control—usually a crystal-controlled oscillator. For reasons described later, the synchronous-multiplex telegraph system which is the subject of this article forms a combined synchronous signal by interleaving one element of teleprinter channel A, then one element of teleprinter channel B, and so on. This process is termed element interleaving, and the resulting combination of the channel elements forms the aggregate signal which is then transmitted over the common transmission path, in this case a f.s.v.f.t. channel.

At the receiving end it is necessary, first, to examine the incoming signal elements and, next, to identify each group of elements that represents one character. The signal elements should, ideally, be examined by strobing at the theoretical centre of each one. Adjusting the timing of the strobe device is known as synchronizing, and is usually effected by making small adjustments to the frequency divider providing the strobing signal. The adjustment of the receiver to give correct identification of the groups of six elements, which in this system form each character, is known as phasing. The adjustment (when required) is made in steps of one or more signal elements; after each step the character is re-examined.

Modulation Rate

The rate of transmission of characters by a multiplex system is determined by the following requirements.

(*a*) The correct transmission of start-stop characters which arrive at the input to the multiplex equipment at a rate slightly over the nominal 400 characters/minute, i.e. when the sending machine is running fast at the upper limit of its speed tolerance (the C.C.I.T.T.* limits are $\pm \frac{3}{4}$ per cent of the nominal speed).

(*b*) Characters of $145\frac{5}{6}$ ms duration, i.e. 411 characters/minute, from an automatic error-correction (ARQ) system[4] should be accepted by a tandem-connected synchronous-multiplex system. A tolerance of $\pm$ 1 part in 10^6 on the timing accuracy ensures that even under adverse tolerances the ARQ system will very rarely over-run the synchronous-multiplex system and cause the loss of a character.

Both these requirements are met by adopting a character duration of $145\frac{5}{6}$ ms, and by accepting characters at this speed it is possible to avoid the expedient of pulsing-in each character, as used on ARQ systems and often required on earlier types of synchronous-multiplex system.

In the complete system the rate at which characters are transmitted is determined by the frequency of the transmit-equipment oscillator and the frequency divider used to produce unit elements. The use of six elements/character (the reason for six elements is described later) on each channel within the period of $145\frac{5}{6}$ ms gives an element length of $145\frac{5}{6}/(6 \times 2)$ ms and a modulation rate of $(1{,}000 \times 6 \times 2)/145\frac{5}{6}$ bauds, i.e. $82\frac{2}{7}$ bauds.

Similarly, the modulation rate for three channels will be $(1{,}000 \times 6 \times 3)/145\frac{5}{6}$ bauds, i.e. $123\frac{3}{7}$ bauds.

FACILITIES REQUIRED FOR INTERCONTINENTAL TELEPRINTER CIRCUITS

To cater for the needs of intercontinental teleprinter circuits, synchronous multiplex systems must provide facilities for the following:

(*a*) Telex traffic with dial or keyboard selection, and supervisory signalling.

(*b*) Private circuits of 400, 200 or 100 characters/minute, with absolute secrecy for each user.

(*c*) Public message circuits.

(*d*) Gentex (international "public-message" switching).

(*e*) Cypher systems.

(*f*) Transmission, without restriction, of all combinations of the International Alphabet No. 2.

†Mr. Croisdale is in the External Plant and Protection Branch, but was formerly in the Telegraph and Data Systems Branch, E.-in-C.'s Office; Mr. Hunt is in the latter Branch.

*C.C.I.T.T.—International Telegraph and Telephone Consultative Committee.

In addition, the design should ensure that

(*a*) no spurious characters are produced under supervisory conditions,

(*b*) faults due to either the multiplex equipment or the line circuit must give fail-safe conditions on the telegraph circuits, as far as this is possible without the expense of using error correction, and

(*c*) operation is completely automatic after the initial system setting-up.

TELEX SIGNALLING

There are three types of telex signalling to be catered for:

(*i*) Type A, using keyboard-selection signals,

(*ii*) Type B, using keyboard-selection or dial-selection signals, and

(*iii*) Type C, using keyboard-selection signals.

These signalling conditions are laid down in C.C.I.T.T. Recommendation U1 and U11,[6] and international telex circuits are normally provided on the basis that if two Administrations operate their networks with different types of signalling, the calling country must signal the conditions required by the called country and receive the called country's type of signals on the backward path. Other arrangements are sometimes made by mutual agreement.

Where automatic switching over bothway circuits is involved, simultaneous seizure is possible, and this makes it highly desirable to provide a signalling system that has minimum transmission delay, since this reduces the period during which simultaneous seizure is possible. Element interleaving is, therefore, adopted for channelling, as this has the effect of reducing the transmission time of a change of condition on any channel, and is also advantageous in passing dial pulses over the system.

Since the time-division-multiplex system is designed for random arrival of signals from the sending machines it is necessary to provide a 1-character store in which the incoming character is staticized until the time comes for the character to be sent out in the multiplex signal. This delays the transmission of the signal, and in order to avoid this delay at the commencement of a call, a bypass unit is connected in circuit to reduce the time for the calling signal to reach the distant end. This bypass is normally switched out shortly after the channel is seized (between 97–121 ms), but for type-B dial selection it remains in circuit until the end of dialling. It is switched back into circuit by the clearing signal.

The synchronous multiplex system must provide for:

(*a*) transmission and reception of teleprinter characters during traffic operation,

(*b*) transmission and reception of dialling and signalling pulses of various durations and of either start or stop polarity, together with teleprinter characters during call setting-up and clearing, and

(*c*) minimum transmission delay through the equipment.

No additional requirements arise from non-telex use of the channels, except the choice of output polarity for line-fail conditions, and, hence, the design of the multiplex system was adapted to suit the telex requirements.

CHOICE OF SYNCHRONOUS CODE

A 6-unit code is necessary so that, as well as the 32 combinations of the 5-unit international telegraph C.C.I.T.T. Alphabet No. 2, it is possible to transmit the two supervisory conditions, i.e. continuous condition A and continuous condition Z.* The code allocations for all characters are the same as for the C.C.I.T.T. Alphabet No. 2 but with an additional preceding element which, except for combination No. 32, corresponds to condition A, as indicated in Table 1.

Table 1
Comparison of C.C.I.T.T. Alphabet No. 2 and Synchronous Code

Character	Signalling Condition of Elements	
	C.C.I.T.T. Alphabet No. 2 (5 units)	Synchronous Code (6 units)
Continuous start (alpha)	—	A A A A A A
Continuous stop (beta)	—	Z Z Z Z Z Z
A	Z Z A A A	A Z Z A A A
B	Z A A Z Z	A Z A A Z Z
(and so on)		
Combination 32 (the only character preceded by Z)	A A A A A	Z A A A A A

SECRECY IN TRANSMISSION

The adoption of synchronous operation introduces a risk that, due to failure of some component, characters of channel A may be received on channel B. This is overcome by providing that, by transposition of the information elements, each channel and sub-channel (see section below on "Sub-division") has a separate coding. As a result only garbled or mutilated characters are printed if for any reason the receiver does not correctly read the incoming signal. It is possible to effect this transposition merely by pre-determined wiring patterns, since, by staticizing—an inherent feature of the design—all the six elements are available simultaneously.

SUB-DIVISION

If required, a proportion of the full-character-rate circuits may be sub-divided into a number of lower-character-rate circuits, termed part-rate circuits. Thus, a full-rate circuit capable of transmitting 400 characters/minute can be divided to form two 200 characters/minute half-rate circuits or four 100 characters/minute quarter-rate circuits, the characters being allocated sequentially, one character per sub-channel in turn.

To designate circuits and sub-circuits the following method is adopted. Taking the control multiplex (see section below on "Principles of Design and Operation") as No. 1 of the group of six, the systems are numbered 1–6, each with channels A, B and C. If circuits are sub-divided, figures after the channel designation letter indicate the quarter-rate circuits 1–4, or half-rate circuits 1/3 or 2/4, i.e. each a pair of quarter-rate circuits. For example, the quarter-rate channel carrying the phasing signal is designated 1B4.

PRINCIPLES OF DESIGN AND OPERATION

In view of the large number of f.s.v.f.t. circuits

*Signalling condition A corresponds to start polarity and signalling condition Z corresponds to stop polarity.

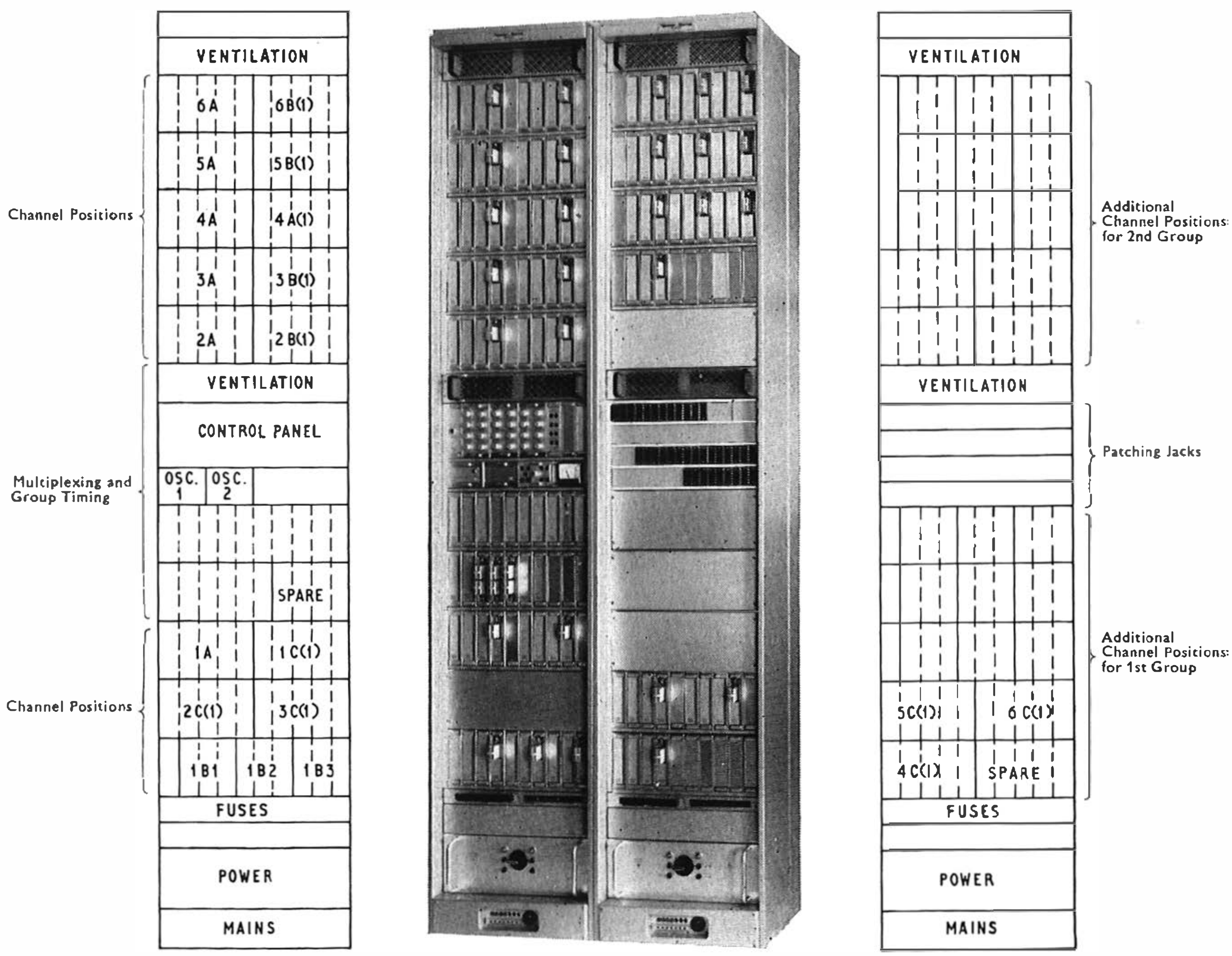
available, i.e. 22 circuits in each f.s.v.f.t. system, equipment arrangements for the multiplex system have been designed about a group of six f.s.v.f.t. circuits. A multiplex group is composed of six separate multiplex systems each connected to one of the six f.s.v.f.t. circuits. The first multiplex system, termed the control multiplex, contains a group timer driven by the system oscillator and controlled, through the synchronizing circuit, by the incoming signals on the f.s.v.f.t. channel connected to multiplex system No. 1. The group timer provides timing signals to the remaining five multiplex systems 2–6, which are termed dependent systems, thus providing an economy in equipment and costs.

Differences in propagation delay within the group of six f.s.v.f.t. channels are compensated for, providing optimum timing on all the dependent channels. The f.s.v.f.t. channel that has the mean value of delay of the group is used as the control channel, and each of the other channels has a range of adjustment of timing instants of ± 3 ms in approximately 0·5 ms steps.

The first channel of each multiplex (channel A) can only be operated as a full-character-rate channel, whereas the second channel (B) on each multiplex can be operated either at the full rate or at the part rates. An exception to this is channel B of multiplex system No. 1, which operates as four quarter-rate (or one half-rate and two quarter-rate) channels. Quarter-rate channel 1B4 carries the phasing signal for the whole of the group of six multiplexes. When triplex working is adopted, an additional channel (C) is made available on each of the multiplexes: the C channels can be operated at full-character or part-character rate.

Each fully-equipped group of six f.s.v.f.t. circuits yields either 11 (diplex operation) or 17 (triplex operation) full-character-rate plus three quarter-rate 50-baud start-stop circuits. Thus, if desired, the multiplex system enables a f.s.v.f.t. bearer circuit to be progressively loaded with additional telegraph circuits. The normal number of groups per bearer circuit (nominally 3 kc/s bandwidth) would be three, yielding, with the four remaining f.s.v.f.t. circuits of a 22-circuit system, 37 or 55 full-character-rate plus nine quarter-rate circuits.

One 9 ft high rack, termed the main rack, (see Fig. 1) accommodates most of the equipment for one group, the multiplexing and timing equipment, 17 channel units including the three subdivided circuits, and 14 telex units. A second rack, the auxiliary rack, accommodates units for six full-rate circuits with telex units and 18



) Main Rack (*b*) Main Rack and Auxiliary Rack (*c*) Auxiliary Rack

FIG. 1—LAYOUT AND APPEARANCE OF MAIN AND AUXILIARY RACKS

non-telex circuit units, together with a patching panel for inserting circuit sub-division facilities. The auxiliary rack is, in practice, shared by two groups.

Fig. 2 shows a block schematic diagram of the essential units in the transmit and receive paths. In addition, there

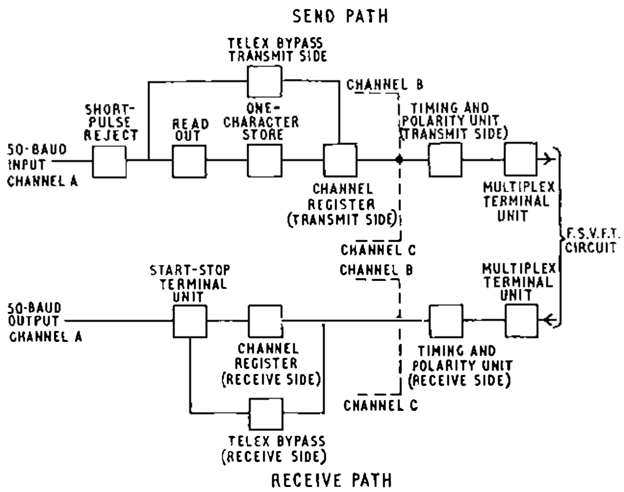


FIG. 2—SIMPLIFIED BLOCK SCHEMATIC DIAGRAM OF TRANSMIT AND RECEIVE PATHS OF MULTIPLEX TERMINAL EQUIPMENT

is an extensive system of pulse-generation units to provide the various pulses required to provide timing instants and examination pulses. These all bear a fixed relationship to each other and are derived from two oscillators, the main one, whose frequency is 15,798 c/s, being oven controlled. The second oscillator, which has a frequency of 800 c/s, is used to produce the 20 ms pulses required for the start-stop output signals. A number of divider stages are used to derive the various pulse periodicities required.

Transmit Path

For each full-character-rate channel the transmit path consists of a read-out unit, a one-character store, and a channel register. A timing and polarity unit combines the signals from each channel register on an interleaved-element basis; they then pass via a multiplex terminal unit to the f.s.v.f.t. channel as an aggregate signal.

The read-out unit accepts incoming 50-baud teleprinter signals arriving at random and, after passing through a short-pulse rejection circuit, reception of the start signal starts a 1:16 divider start-stop cycle which lasts for the period of one character. The divider produces 20 ms inspection pulses to test the polarity of the incoming sequential signal elements, and the character is staticized on a shift register. At the end of the divider cycle, and with the reception of the stop signal, the character is transferred to the character store; the function of this store is to hold the character until it can be transferred to the channel register. This is done during the time the sixth element of the previous character is being transmitted from the channel register into the aggregate, and here a delay of up to one character period, i.e. $145\frac{5}{6}$ ms, can take place.

In the channel register a series of pulses moves the stored elements along a shift register, the output of which is read off into the timing and polarity unit appropriate to the particular multiplex system.

The outputs of the channel registers are continuously examined at intervals of $12\frac{1}{7}\frac{1}{2}$ ms for two-channel operation, or $8\frac{1}{1}\frac{1}{8}$ ms for three-channel operation, and passed forward on an interleaved-element basis to a multiplex terminal unit, which converts from the typical logic outputs of -12 volts and zero volts to -6 volts and $+6$ volts, respectively, for operating the f.s.v.f.t. channel; alternatively, when required, the $\pm$ 6-volt signals can be used to drive an electromagnetic relay to give $\pm$ 80-volt signals.

Receiving Path

Conversely, on the receiving path the incoming aggregate signals from the f.s.v.f.t. channel are converted from $\pm$ 80 volts or $\pm$ 6 volts to logic-voltage levels in the multiplex terminal unit and then passed to the timing and polarity unit. Here, the aggregate signal is sampled by examination pulses connected to a toggle, the elements for channel A being transferred into a second toggle, and those for channel B to a third toggle. The first toggle retains the signal for channel C, when it is operating, and a pulse transfers the outputs of the three toggles into the respective channel registers, further pulses staticizing the incoming characters in the register store. The stored character is transferred to a further set of toggles where it is read out, in serial form at 50 bauds, by gating the outputs of the toggles with pulses from the start-stop output drive circuit in the start-stop terminal unit. The start and stop elements are re-inserted at this stage, and one of the toggles performs the function of changing state between the transmission of the stop and start signals for all characters with the exception of the alpha and beta conditions.

The 50-baud output signal is initially at $\pm$ 6 volts and is converted to $\pm$ 80 volts by means of a relay.

Phasing

Since phasing is required to be automatic while either traffic or idling-condition signals are being transmitted it is necessary to transmit a signal which can be identified at the receiving end as that appropriate to a particular channel or sub-channel. A special-combination signal, known as the phasing signal, is, therefore, transmitted at regular intervals, providing at the receiver automatic identification of the control channel and of all the dependent multiplex circuits.

The phasing signal (ZZAAZZ) is sent continuously on quarter-rate channel 1B4 of the group-control channel, and is received on a phase-detector unit. If the phasing signal is not recognized on three consecutive occasions, the phase detector examines the contents of the receive shift-register of each of the channel registers of the group-control channels. Providing the aggregate signal is being received without mutilation the phasing signal must appear in one of the channel registers within a period of four characters, i.e. $4 \times 145\frac{5}{6}$ ms.

When the phasing signal is detected in one of the channel registers, three dividers are reset, thereby adjusting the timing of the receive-pulse generators to the correct phase position in relation to the incoming signal. The operation is carried out in a period not longer than a few seconds even in the most adverse conditions.

After phase adjustment is made, a check for the reception of three correctly received phasing signals is carried out before the group commences to transmit traffic again.

The out-of-phase condition produces continuous A-polarity at the multiplex equipment output. If the f.s.v.f.t. tones are lost, however, the f.s.v.f.t. system pilot-fail alarm will inhibit the re-phasing operation and cause continuous A-polarity to be extended from the multiplex equipment outputs. In either event this will cause the clear-down of a telex call if the condition persists for more than 300 ms.

If a channel is used for an application that requires continuous Z-polarity under failure conditions, a switch enables a polarity reversal to be made. A manually operated phase-stepping operation can be selected by a switch if required.

Synchronizing

Synchronizing is dependent on receiving transitions from the sending end, and if all channels are idle on the multiplex group no transitions will be received other than the occasional phasing signal. It is arranged, therefore, that the signals of channel B of the control multiplex are inverted in polarity within the multiplex system in order that transitions are provided under idle conditions to enable the synchronizer in the group-timing circuit to operate. The input and output to the channel remains erect.

Telex Bypass Unit

The output from the short-pulse rejection circuit, which is connected to the input of the read-out unit, is also connected to the input of the telex bypass unit. This unit inspects the input condition at 1 ms intervals, and this condition is transferred at 24 ms intervals to the output of the channel register, thus passing on a change of condition to the timing and polarity unit without the delay which would be incurred if it passed via the read-out unit, character store and channel register.

The bypass unit counts either five elements of Z polarity, used to switch the bypass out, or two alpha characters, used to switch the bypass in on reception of the clearing signal. For type-B signalling, the switch-out is additionally dependent on the reception of one beta character on the receive side.

The input to the receive side of the bypass is connected to the output of the timing and polarity unit, and the output of the bypass is connected to a point in the start-stop terminal which drives the 50-baud output circuit. The receive side of the bypass is switched in on receipt of two alpha characters and switched out on reception of one beta character.

Dial pulses are transmitted via the bypass, and, at the receiver, are received as pulses of multiples of 24 ms. To re-transmit the dial pulses within the limits specified by the C.C.I.T.T. they are regenerated; the minimum periods of A (break) and Z (make) elements are 44 ms and 36 ms, respectively.

APPLICATION OF MULTIPLEX TO SUBMARINE CABLES

Transmission Considerations

Some f.s.v.f.t. equipment manufactured to C.C.I.T.T. Recommendation R35 with 120 c/s-spaced channels[3] performs at 85 bauds with a characteristic distortion of less than 18 per cent when all other channels are signalling at a similar rate. Generally, the channels have appreciably less distortion than this.

On ocean-cable circuits—even the longest ones—the noise level (uniform spectrum random noise (U.S.R.N.), i.e. white noise), as measured on a psophometer with the appropriate telephone weighting network, should not appreciably exceed -40 db relative to the test level in the bearer circuit. It can be shown that, with 2-circuit synchronous operation at 83 bauds, a noise level appreciably higher (some 10 db, in fact) can be tolerated before an element error-rate of 1 in 10^6 is introduced. In operating a synchronous system at this modulation rate there is, therefore, a considerable margin of operation, both in distortion, since the receiving margin of a well-designed synchronous system is greater than 45 per cent, and also relative to the noise level of the bearer circuit.

Characteristic-Distortion Compensation

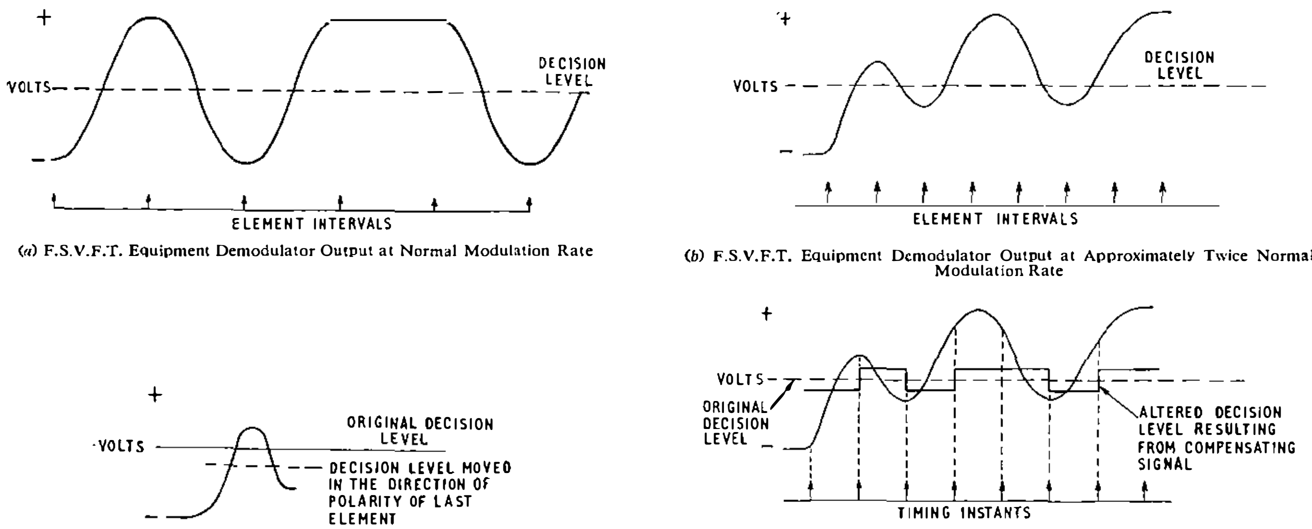
On a channel of finite bandwidth, as the modulation rate increases so the build-up time of the signal change becomes more significant, resulting in a decreasing amplitude of single elements until a point is reached where the signal is no longer detected. The "suppressed-singles" method of overcoming this effect has been successfully used on d.c. submarine telegraph cables for many years, and characteristic-distortion compensation (c.d.c.), an adaptation of this principle, has been developed to enable $123\frac{3}{7}$-baud signals to be passed over 120 c/s-spaced f.s.v.f.t. channels. The c.d.c. equipment is required only at the receiving end.

To understand the principle of c.d.c. refer to Fig. 3(*a*) and 3(*b*). The amplitudes of the shorter elements are considerably reduced as the modulation rate is increased, and the problem at the receiver is to determine at uniform time intervals whether a signal is nearer the negative or positive peak values. This is decided by recording whether the signal lies above or below the decision level, midway between the steady-state levels of positive and negative polarity. The phase of the signal-examination instants is arranged to coincide with the peak values of the shortest elements. It will be seen that the margin of detection is considerably reduced for some elements, depending on their position in the signal sequence. Since the reliability of the signal depends on the weakest element, security of reception at the higher modulation rates can be improved by increasing the margin of detection of single elements at the expense of the margin for those of larger amplitude.

This can be done, as shown in Fig. 3(*c*) and 3(*d*), by altering the decision level. It will be seen that if the decision level is changed towards the polarity of the last-detected signal there is a better chance of detecting a single-element change to the opposite polarity. It will be noted, however, that if succeeding elements are of the same polarity the margin of detection has been reduced by the amount of the change of decision level. In practical tests it has been found that the optimum value of feedback voltage is approximately 0·35 of the maximum steady-state signal excursion at the output of the post-discriminator filter of the f.s.v.f.t. channel, and that the optimum phase position of the examining pulse is approximately 52·5 per cent of the ideal element.

The interconnexion between the c.d.c. apparatus and the multiplex equipment is shown in Fig. 4, while typical performance figures of a c.d.c. channel are given in Fig. 5 for various values of signal-to-noise ratio in the telegraph channel.

Tests on long ocean-cable circuits, e.g. a London–



(*a*) F.S.V.F.T. Equipment Demodulator Output at Normal Modulation Rate

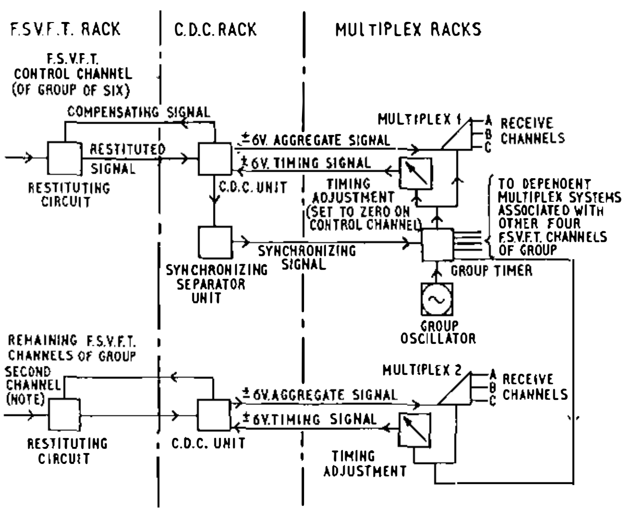
(*b*) F.S.V.F.T. Equipment Demodulator Output at Approximately Twice Normal Modulation Rate

(*c*) Increased Margin of Detection of Single Element due to Changed Decision Level

(*d*) Effect of Decision Level Changes Effected by C.D.C.

FIG. 3—PRINCIPLE OF CHARACTERISTIC-DISTORTION COMPENSATION (C.D.C.)

Sydney–London looped f.s.v.f.t. system of approximately 32,000 route miles, have shown that the error rates on a 50-baud teleprinter circuit utilizing the full 120 c/s band and the equivalent 50-baud teleprinter circuit derived



Note: The remaining four channels of the group are connected in a similar manner to the second channel

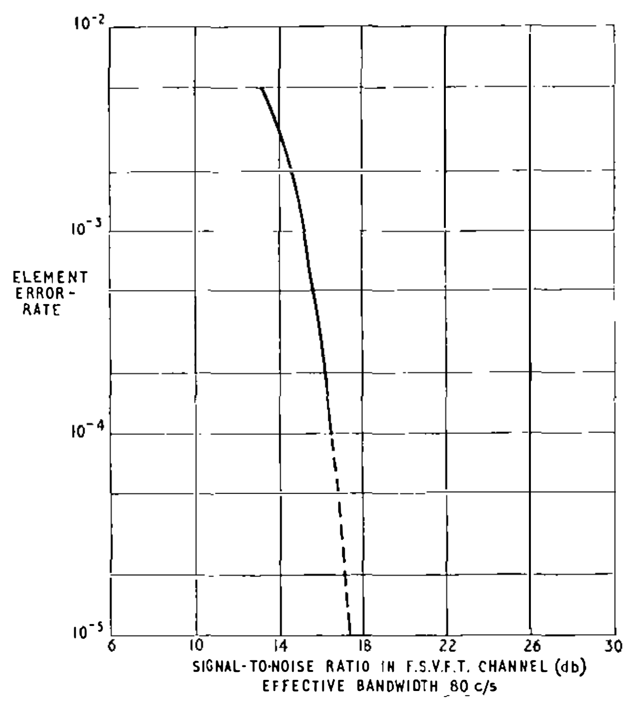
FIG. 4—ARRANGEMENT OF RECEIVE TERMINAL EQUIPMENT FOR 3-CHANNEL MULTIPLEX OPERATION OVER 120 c/s-SPACED F.S.V.F.T. CHANNEL

from either a 2-channel or 3-channel time-division multiplex system will be comparable, the errors being chiefly attributable to circuit interruptions on the route.

As a comparison of c.d.c. working with start-stop and synchronous methods of working Table 2 gives an indication of the noise levels (U.S.R.N.) in a 3 kc/s bearer circuit, which are estimated to produce an equivalent performance for the three methods of operation.

TESTS OF INTERCONTINENTAL CIRCUITS

The multiplex equipment described in this article and used by the British Post Office for intercontinental working was developed by Messrs. Haslers, of Berne, Switzerland,



- - - - Expected performance at signal-to-noise ratio of ordinate

FIG. 5—TYPICAL RESULT OF LABORATORY TEST OF ELEMENT ERROR-RATE AT A MODULATION RATE OF 125 BAUDS ON 120 c/s-SPACED F.S.V.F.T. CHANNEL

TABLE 2

Bearer-Circuit Noise Levels Giving an Equivalent Performance for Three Methods of Operation

Noise Level (U.S.R.N.) in Bearer Circuit (dbm0)*	Method of Operation for Equivalent Performance
−40	50-baud start-stop
−29	82-baud synchronous
−34·5	123-baud synchronous with c.d.c.

*dbm0—the ratio, in decibels, relative to the test level at any given point in the transmission path.

and the c.d.c. equipment by Standard Telephones and Cables, Ltd.

A series of proving tests has been carried out with various Administrations overseas to test for compatibility of working between the different versions of multiplex equipment engineered in other parts of the world. Compatibility was proved with equipments used by the Radio Corporation of America (R.C.A.), New York, and by Kokusai Denshin Denwa Co., Ltd., (K.D.D.), Tokyo, using the 2-channel (diplex) mode and with both full-rate and part-rate channels. The 3-channel (triplex) mode was also satisfactorily tested to Tokyo, using c.d.c. at both ends.

Error-rate tests based on the continuous transmission of test messages for periods of 12 to 24 hours have also been carried out to Tokyo, using both diplex and triplex operation in both directions, and to Sydney, using multiplex equipment of the same manufacture as that in London, with diplex operation in both directions and triplex operation in the direction Sydney–London. In each test a satisfactory character error-rate performance of not worse than 3 in 10^5 was obtained.

Satisfactory tests of telex signalling and selection have also been carried out to R.C.A. (New York) and K.D.D. (Tokyo).

CONCLUSIONS

Where high-value telegraph circuits are provided over intercontinental cable systems the use of a synchronous multiplex system may be economic, and, with a "grouped" design, the cost is far less than that of earlier systems.

Additional circuits are obtained without increasing the signal-power loading of the submarine-cable system, and, where circuit noise is high, the performance of the synchronous teleprinter channels of a 2-circuit system is better than for start-stop operation, and signal regeneration is provided inherently. In addition, subdivided, or part-rate circuits can be provided, if required, while the use of transistors and fully-automatic operation offers a system with little more maintenance liability than that of a f.s.v.f.t. system.

The use of bypassing on the channels of the synchronous system allows dialling and other pulse-type signals, as well as teleprinter characters, to be transmitted; this permits all types of telex signalling to be used.

Where the circuit noise is not excessive, three teleprinter circuits (or equivalent-rate sub-divided circuits) may be operated over each 120 c/s-spaced f.s.v.f.t. circuit.

ACKNOWLEDGEMENT

The authors wish to thank Messrs. Hasler of Berne, Switzerland, for permission to use the photograph in Fig. 1.

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[1]Evans, H. E., and Croisdale, A. C. Time-Division Multiplex Telegraphy on the Transatlantic Telephone Cable. *P.O.E.E.J.*, Vol. 54, p. 113, July 1961.

[2]Chittleburgh, W. F. S., Green, D., and Heywood, A. W. A Frequency-Modulated Voice-Frequency Telegraph System. *P.O.E.E.J.*, Vol. 50, p. 69, July 1957.

[3]Sallis, R. T. G. A Multi-Channel Voice-Frequency Telegraph System Using Transistors. *P.O.E.E.J.*, Vol, 57, p. 95, July 1964.

[4]Croisdale, A. C. Improvements in Automatic Error-Correction Equipment used on H.F. Radio Telegraph Services. *P.O.E.E.J.*, Vol. 55, p. 253, Jan. 1963.

[5]International Telegraph and Telephone Consultative Committee Blue Book, Vol. VII, Recommendations U1 and U11.

Book Reviews

"Electronic Computers." E. H. W. Hersee, M.A. (Oxon), D.C.Ae. Blackie and Son, Ltd. xi+261 pp. 49 ill. Board 25s., paperback 15s.

To be of any value, books on computers need to be up to date since the state of the art is changing so rapidly. The author has, therefore, been wise in re-issuing this successful book which first appeared in 1959.

This compact work forms a good general introduction to both digital and analogue computers: a chapter has also been included describing the less familiar incremental computer, or digital differential analyser. The main differences between the fields of use and the three types of computer are clearly brought out.

The chapters dealing with the art of programming digital computers are excellent: in particular, the introduction to higher-level programming languages is especially good, and their advantages and disadvantages are clearly brought out. The language FORTRAN is used as an example and its salient points are introduced in some six pages of text.

In the section dealing with analogue computers the author neatly shows the different approaches to problem solving of a mathematician and an engineer, and points out how the method of solution preferred by each can be manifested in an analogue computer.

It is perhaps unfortunate that the author allows himself the luxury of one somewhat out-of-place chapter on "Thought Processes:" this would be much more appropriate to an article in a philosophical journal than as a chapter in an elementary book on computers. This apart, however, the book forms an excellent introduction to computing in general, the mathematical content is minimal, and the diagrams, all of which are relevant, are very easy to follow.

C.A.M.

"The Use of Mathematics in the Electrical Industry." M. R. Scott, A. Brooks, A. W. Lee and H. B. Ramsey. Sir Isaac Pitman and Sons, Ltd. xv+101 pp. 4 ill. 30s.

This book is the report of an investigation by a research group within the Mathematics Department of the Royal College of Advanced Technology, Salford, into "The Use of Mathematics in the Electrical Industry."

Reports of this type, which are necessarily heavily laden with tables and analyses of the results of questionnaires, can often make very dull reading. It is a remarkableachievement on the part of the authors that this document is never dull. The presentation of the material is excellent and the discussion of the results is scholarly, competent and constructive.

The book can provide very valuable reading for anyone concerned with teaching mathematics to electrical engineers. It is entertaining reading to one who is simply interested in the field.

T.B.M.N.

Recent Changes to Telephone Exchange Equipment Engineering and Installation Methods

E. A. ASKEW†

U.D.C. 621.395.722:658.5

The continued increase in the exchange-installation program has accentuated the need for speedier methods of equipment installation and of carrying out engineering-design work. The changes to exchange-equipment installation described are designed to contribute to savings in manpower, both in the factory and the exchange.

INTRODUCTION

THE wide variety of exchange equipment and of the operations involved in the installation of a telephone exchange gives considerable scope for the introduction of new methods and design features to improve the productivity of all concerned. As a result of concentration of effort in this field the introduction of new methods into exchange installation has become a continuous process, and some of the methods recently introduced are reviewed.

When considering new or improved methods of installation it is essential, if the maximum improvement in productivity is to be achieved, to include the related design and engineering and production processes in the equipment-manufacturing organizations.

SECURING CABLES TO RUNWAYS

Because the time spent on installing cables in an exchange is of the order of 30 per cent of the total exchange installation time it is not surprising that cabling methods are under constant review.

For a very long period the British Post Office specified that cables installed in a telephone exchange should be secured to the runways which support them by a method of stitching with waxed twine, so that, in the event of a tie breaking, one cable only would be affected. In recent years such ties on horizontal runways were made at alternate stringers.

About 5 years ago various methods of securing cables to runways were given extended field trials,[1] and from the results it was decided that a form of cable stitching which did not secure each individual cable, but which, nevertheless, gave adequate support, should be introduced as standard. This method, which continues to use the conventional waxed twine, has become known as "reduced stitching." It is for application to horizontal runways only. The method of stitching individual cables to every runway stringer has been retained for vertical runways because the cables require more support on vertical than on horizontal runs.

With the reduced-stitching method the cables in the bottom layer of a bank of cables are secured to alternate runway stringers in pairs. On subsequent layers only the outer pairs are stitched, but they are joined with a tie across the intervening cables. Layers of cables wider than 15 in. are stitched at the centre pair of each layer in a similar manner to the outer layers (see Fig. 1). Where there are three or less cables per layer they are secured by means of a box stitch or pick-up stitch. Where cables are arranged in irregular cross-sections a combination of the stitching methods can be used.

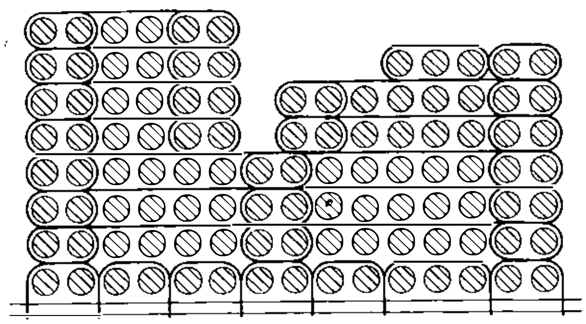

FIG. 1—REDUCED-STITCHING METHOD APPLIED TO IRREGULAR BLOCKS OF CABLES

Compared with the original method savings of the order of 15 per cent of both time and cost are achieved by the application of this method.

SEALING CABLE HOLES

It is the practice in telephone exchanges, where cables go through holes in walls or floors, to seal the hole with fireproof materials to prevent a current of air passing from one room to another in the event of fire. Normally, the degree of fire-proofing applied to a hole is commensurate with the fire-grading of the associated wall or floor. The conventional method of sealing holes by packing them with asbestos bags filled with asbestos fibre, and then covering the ends of holes with fireproof sheeting, was designed for walls and floors of some thickness. Because cable holes through thin ceilings of plywood or plasterboard have a fire-grading of ½ hour, the method described was clearly not suitable and a new one was required.

Thin ceilings are used in over-ceiling-cabled exchanges, where there may be 100, or even more, cable holes which need to be sealed. Of the methods investigated the cheapest and most successful proved to be the use of a rectangular piece of fireproof sheeting, cut across the centre, with each half shaped to fit the cables and to butt against the other half. The fireproof sheeting, which is a fairly soft grade of asbestos-cement sheet, extends beyond the edges of the hole by at least 2 in. The sheeting is fixed to the underside of the ceiling and neither asbestos packing nor cover is provided on the upperside. Soft-grade butyl mastic strip is sandwiched between the cables and the edge of the fireproof sheeting to close any small gaps and prevent air passing through the hole (see Fig. 2).

Before mastic was introduced as a feature of fireproofing the holes it had been the practice to cut a profile on the edge of the sheeting to make a close fit up to the

†Exchange Equipment and Accommodation Branch, E.-in-C.'s Office.

[1]ROBERTS, W. G., and MILLS, C. S. Improvement in Installation Methods for Telephone Exchanges. *P.O.E.E.J.*, Vol. 55, p. 92, July 1962.

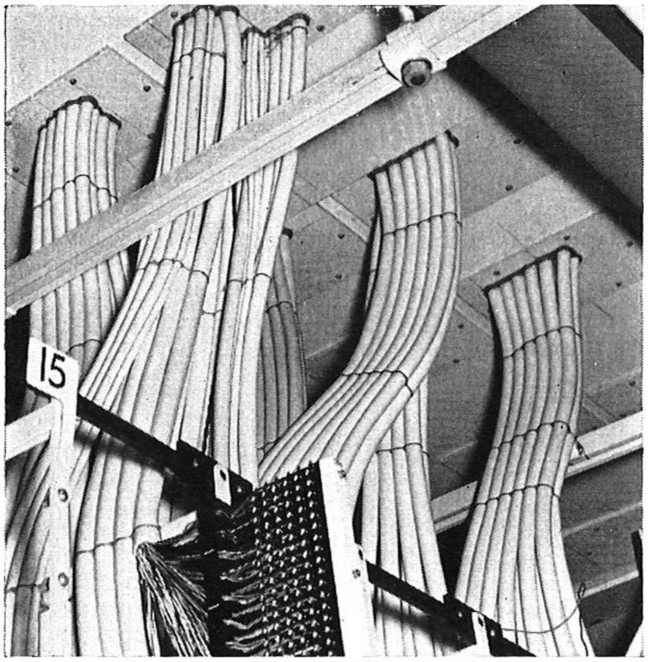

FIG. 2—CABLE HOLES SEALED BY MEANS OF MASTIC SANDWICHED BETWEEN CABLES AND FIREPROOF SHEETING

cables. This was a long laborious process involving the use of hacksaw and file, and the results were not always satisfactory. The use of mastic in the gap between the sheeting and cables has made this special shaping unnecessary, and, as a result, the time taken to fit the sheeting around the cables has been considerably reduced. Mastic is now also used for sealing the covers of holes through floors and walls.

The nature of the asbestos fibre used for packing is such that exposure to even low concentrations of the dust could be harmful to persons handling it, and dust masks should be worn whenever loose asbestos is used. Efforts are being made to find a suitable alternative which is free from injurious dust; meanwhile, the provision of a layer of loose asbestos fibre over the asbestos bags, which was required in holes through floors, has been discontinued.

IMPROVED EQUIPMENT LAYOUTS

The layout of equipment in an exchange, and the positions of racks, frames and cable holes in relation to one another, have a marked influence on the amount of cable required and the time taken to install it. There are, however, other factors which influence the layout of equipment, and these must be given priority, even though some increase in installation cost may result. These factors include ease of maintenance, ultimate equipment provision, and the dispersal of equipment with high heat output to reduce ventilation problems. Nevertheless, after all other factors have been taken into account the layout of equipment should be such that the minimum amount of cable is required. In general terms this condition requires that the equipment racks with the heaviest cable concentrations should be located as near as possible either to the verticals of the distribution frame on which their cables are terminated, or to the other equipment they serve.

In preparing a floor plan, i.e. the layout of equipment racks in the exchange, the design engineer should know the number of cables associated with each type of rack and so be able to assess the quantity of cable required for a particular layout. To determine the most economical layout it may then be necessary to compare two or more layouts of the same equipment. To assist in this comparison a table of rack cable-factors has been issued as part of the specification giving guidance in the design of the equipment layouts in telephone exchanges. The rack cable-factors are comparative values which take into account the cost of supplying and installing the cable required on a rack. Each factor is related to 1 yd of the cables required on a rack, so that the product of the factor and the length of cable route (in yd) will provide a value commensurate with the cabling costs of that particular rack. Where racks have more than one group of connecting cables there is a separate factor for each

Rack Cable-Factors of Some Types of Rack in Common Use

Type of Rack	Connexion To	Rack Cable-Factor
50-Point Linefinder	I.D.F. local side	2,340
	I.D.F. multiple side	330
Uniselector	I.D.F. local side	1,280
	I.D.F. local side	170
Final Selector, 400-Line Multiple	I.D.F. multiple side	936
	Penultimate group-selector rack	297
Final Selector, 600-Line Multiple	I.D.F. multiple side	1,400
	Penultimate group-selector rack	297
Final Selector, 800-Line Multiple	I.D.F. multiple side	1,870
	Penultimate group-selector rack	297
Group Selector (All except penultimate group selectors)	I.D.F. multiple side	284
	I.D.F. local side	710
Penultimate Group Selector	I.D.F. multiple side	284
	Final-selector rack	485
Meter	I.D.F. multiple side	1,540
Director	T.D.F. or I.D.F.	134
A-Digit Selector	T.D.F. or I.D.F.	1,140
Local-Call-Timer Relay-Set	I.D.F. multiple side	309
	I.D.F. local side	412
1st-Code Selector	T.D.F.	678
Coin-and-Fee-Checking Relay-Set	I.D.F. multiple side	67
	I.D.F. local side	71
Call-Trap Relay-Set	M.D.F. exchange side	2,580
	I.D.F. local side	2,910
Busy Relay	I.D.F. local side	6,314

I.D.F.—Intermediate distribution frame
M.D.F.—Main distribution frame
T.D.F.—Trunk distribution frame

group, e.g. for a 400-line multiple final-selector rack to the intermediate distribution frame (I.D.F.) the factor is 936, and for the same type of rack from the penultimate group-selectors the factor is 297.

The cabling costs of different layouts of the same equipment in part or all of an exchange can thus be compared by examining the totals of the comparative rack-cabling costs. The most economical layout, as far as cabling is concerned, will be represented by the smallest total. Comparison of individual rack cable-factors also gives a guide to the order of preference which should be given to racks in relation to their proximity to the I.D.F. A few hours spent in evaluating layouts in this manner can result in considerable economies in the labour and materials required to complete the exchange. The table shows the rack cable-factors of some of the more common types of racks.

MAINS-VOLTAGE SUPPLY DISTRIBUTION

In telephone exchanges provided and installed by equipment contractors the responsibility for the provision of mains-voltage services on the equipment is divided between the Post Office, normally at Telephone Area level, and the contractor. In the past a satisfactory arrangement existed whereby the Post Office provided 5 amp sub-circuits as far as ceiling boxes over the equipment area, and the contractor supplied and installed the remainder of the distribution for lighting and to socket-outlets and mains-voltage-powered equipment within the equipment area. The satisfactory working of the arrangement was dependent upon the equipment contractor providing, at least 6 months before the installation of exchange equipment commenced, full and accurate information concerning the positions of the ceiling boxes which the Post Office had to provide. Changes in equipment and mains-voltage supply requirements in the last 10 years have, however, created many complications in the wiring of sub-circuits, and the advance provision of access points in correct positions on the ceiling has become almost impossible. Many non-standard arrangements have been necessary to overcome these problems, and, as a result, difficulties have been experienced by the staffs of both the contractors and the Post Office. The arrangement for mains-voltage supply distribution has now been reviewed, and the telephone equipment contractors have agreed to new Post Office proposals which make the Post Office and the contractor less dependent upon one another in the completion of the distribution. At the same time the opportunity has been taken to use more modern items of equipment for the switches and socket-outlets.

In future, on Strowger-type equipment, the telephone equipment contractor will provide a complete mains-voltage supply distribution up to, and including, the distribution fuseboards. Included in the scheme will be a 2 in. by 2 in. cable trunking fitted to the top angle of the end racks of suites along one or both sides of the equipment area, and 8-way 5-amp distribution fuseboards will be mounted on the underside of the trunking over the wiring gangways, as required (see Fig. 3). All the 5-amp sub-circuits will be cabled to, and terminated in, the fuseboards by the equipment contractor. The equipment contractor will, as before, provide lighting fittings, power points and socket-outlets, as required, on equipment racks and distribution frames.

The Post Office will provide cable trunking to a pre-determined point of the inter-suite trunking and connect a supply with 30-amp fuse rating to the fuseboards. The Post Office will also provide a 30-amp supply to a point in the ring, when the socket-outlets are connected to a ring main, and any other supplies to equipment racks which require more than 5 amp.

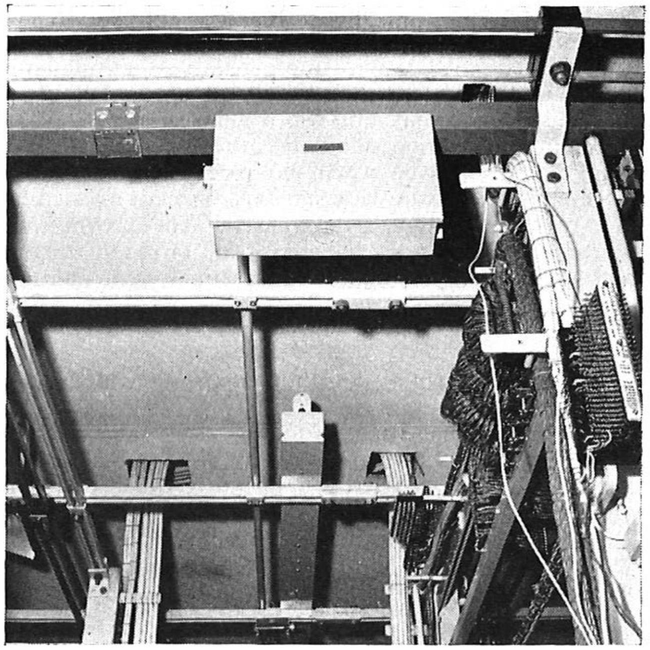

FIG. 3—DISTRIBUTION FUSEBOARD MOUNTED ON THE INTER-SUITE TRUNKING

The only information which the Post Office will require from the equipment contractor in advance of the exchange-equipment installation will be the quantity and point of entry of the 30-amp mains-voltage supplies required. The remainder of the instructions, covering lighting, socket-outlet and power-point provision, will be in the form of standard specifications. Equipment-rack lighting and power points for which standby supplies are specified will be connected to fuseboards which are separate from the regular supplies.

The socket-outlets fitted to equipment racks in new exchange installations will be for 13 amp on a ring-main distribution. Up to 30 13-amp socket-outlets will be permitted to be connected to one ring distribution in view of the limited amount of mains-voltage plug-in equipment which will be in use at any particular time. Connexions of the cable in the ring will be arranged so that the first and last socket-outlets will be those nearest to the point of access provided in the trunking for the Post Office supply cables. Retrospective action to make 13-amp socket-outlets standard in all exchanges cannot be justified, but action is being considered to provide a single standard of socket-outlet on the equipment racks in any one exchange. The type of socket-outlet fitted on equipment extensions will then be dependent upon the type of outlet already fitted in that exchange.

The well-known tumbler switch has for some time been superseded in commercial practice by the rocker switch, which is cheaper, more reliable and more compact. The rocker switch has now been specified for telephone exchanges, and advantage has been taken of its reduced size to include two switches in one switch-box wherever suitable. Cord-operated switches were considered for general application because of the savings in wiring and conduit made possible by their use, but it was decided that rocker switches were more reliable for long-term applications and that they should be used wherever a suitable mounting position was available.

Equipment-lighting standards in telephone exchanges were revised in 1958 when fluorescent-lighting fittings were introduced, and these standards are not affected by the new distribution arrangements. The program of retrospective action for the conversion of the lighting in old exchanges to the new standard is now almost complete.

GRID CABLE-PLATFORM

The conventional methods of supporting cables which run between two points in an exchange not designed for over-ceiling cabling has been to erect cable runways over the equipment racks and to fasten cables to them in an orderly fashion. Every equipment contractor has a selection of standard runway sections and fittings, but a cable runway scheme must be designed for each particular exchange contract. The scheme is dependent on a number of factors such as equipment layout, sizes of cable runs, apparatus-room shape and positions of building stanchions and beams. Much of the preliminary work on the quantities of equipment and the equipment layout must be completed before design, or engineering as it is known, of the cable runways can commence. Also, in association with the engineering of the cable runways the schedule of cable routes must be prepared. The build-up of cables on the runway must be planned to ensure that runway space is used efficiently, that space is left for extensions, and that, if at all possible, cable routes do not cross over one another. If a cross-over cannot be avoided then it must be sited away from beams projecting below the ceiling. When the design work is completed, drawings, unique to that particular exchange, must be prepared, for use during the exchange installation. Copies of the drawings are filed for reference for use when the exchange is to be extended.

To avoid much of the engineering work required for cabling in conventional exchanges the Post Office in 1960 introduced over-ceiling cabling[2] as the standard method for use in single-storey exchange buildings of suitable design. The method has been wholly satisfactory, savings in cable have proved to be in the order of 10 per cent, and the period needed for cable installation can be reduced by 6 weeks or more. Buildings specially designed for over-ceiling cabling did, at first, show a cost reduction over similar buildings for conventional cabling. Subsequent changes in building practices, however, have tended to make the provision of a cable loft an added feature, and hence an added expense, whereas before it was intrinsic in the building design. But, in spite of these changes, the advantages gained by the use of over-ceiling cabling more than offset the added cost of a cable loft. The savings in the equipment contractors' engineering and drawing-office time have made a considerable contribution to the achievements of reduced engineering periods for exchange contracts.

The Post Office has been anxious to exploit the advantages of over-ceiling cabling in exchanges without cable lofts, and in exchanges where cabling has previously been supported on conventional runways. This has now been achieved by the use of the grid cable-platform which has been introduced as the standard method of supporting cables in all exchanges other than those designed for over-ceiling cabling.

The grid cable-platform is a wire grid which, in a new exchange, covers the whole of the equipment area. It is fixed to the top of the twin tie-bars which support the equipment racks, and cables are laid on it in a manner similar to over-ceiling cabling. It is provided and fixed by the equipment contractor, but erection is simpler and quicker than that of cable runways. Engineering of the grid takes less time than the engineering of cable runways, because the contractor is able to present the information for an exchange in the form of standard drawings. The grid can also be applied on extension contracts where the new racks are grouped together in a part of the apparatus room which is not already equipped with cable runways.

The grid platform is subdivided into sections for ease of handling. The sizes of the sections vary between equipment contractors to suite their individual schemes. The smallest panel used is about 3 ft square and the largest is 6 ft × 4 ft 6 in. The grid is made of $\frac{1}{4}$ in. diameter steel wire, and the mesh size is approximately 6 in. square. Several types of finish are being investigated, but that which appears to be most economical and readily available is a coating of zinc applied by plating or hot-dip galvanizing.

The twin tie-bars which support the grid, and also rack lighting, travelling ladders, etc., are raised $3\frac{1}{2}$ in. above the rack top-angle to accommodate lighting fittings on the underside and to give headroom for the maintenance of equipment on the top shelves of racks. This increased height of the tie-bars makes the overall height of the grid nominally 11 ft. It is intended that travelling ladders will be modified to extend an extra $3\frac{1}{2}$ in. so that the ladder track can be fitted directly on to the tie bars. During the development period, however, ladders of standard lengths have been used and, by using packing pieces, the ladder track has been lowered to maintain the original height. All sundry apparatus and fittings, such as alarm lamps, bells and conduits, are mounted below the tie-bars to avoid projections above the grid. The inter-rack bus bars are fixed to the horizontal projection of the detail used to raise the tie-bars (Fig. 4).

Holes are provided in the grid at regular intervals to give access above the grid for cabling and cleaning operations. The minimum size of the hole is 1 ft 3 in. × 1 ft 6 in., and is sufficient to enable a large man to work with head, shoulders and arms through it whilst standing on a trestle or similar support. A maximum size of hole, 2 ft × 2 ft 3 in., is also specified to limit the amount of cabling space which would otherwise be lost due to the over-provision of holes. Normally, the access holes are formed either by arrangement of the grid panels so that suitable spaces are left between them, or by the use of a special panel of the grid which has an access hole already provided in it. The edges of access holes provided by these methods are thus free from sharp edges which would have resulted from cutting the wires to form the hole, and also the wire ends are coated with the normal finish. In some circumstances it may be necessary to provide additional holes on site, and these can be cut by means of a hacksaw, the cut-wire ends then being filed smooth or covered to prevent damage to personnel or cables. Any wires cut on site are painted with a zinc-rich paint to prevent corrosion. The access

[2]ROBERTS, W. G., and POVEY, J. A. Over-Ceiling Cabling for Telephone Exchanges. *P.O.E.E.J.*, Vol. 54, p. 82, July 1961.

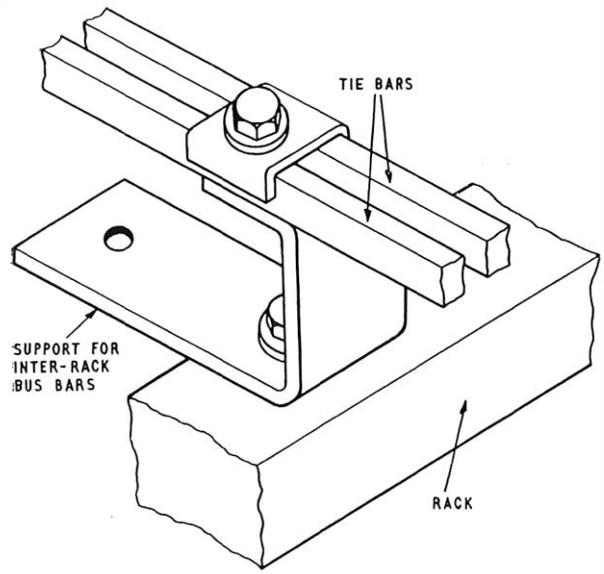

FIG. 4—BRACKET USED TO RAISE TIE-BARS AND TO SUPPORT THE INTER-RACK BUS BARS

holes are always formed in the grid so that the grid wires create a boundary and no wire ends project into the hole.

Cabling is carried out by feeding cables, from one end of the run, up through the grid and by passing them from hand to hand between access holes (see Fig. 5). Various devices have been tried in attempts to extend the distance that cables can be passed between workmen, but, in practice, it has been found that the inherent stiffness of most cables enables them to be manoeuvred over distances of 10–15 ft without additional assistance. The mesh size is such that cables can be manoeuvred over short distances by reaching through the grid and passing the cable from one hand to the other. Cable staff normally do their work standing on a trestle, so that the weight of the individual is not borne by the grid. Where, however, circumstances are such that working on top of the grid cannot be avoided, a temporary superstructure is provided to support the workman and to prevent damage to the grid and cables.

FIG. 5—CABLES BEING PLACED INTO POSITION ON THE GRID CABLE-PLATFORM

Cables are run on the grid from point to point, but it is essential that they should not be drawn so tight that they cannot be moved to give access to racks beneath the runs. Most cable runs will deviate from straight lines to avoid holes, obstructions, or specified areas which have to be left clear of cables, but where a run does follow a straight line extra cable, usually about 1 ft, is left in the length to permit movement of the cable at a later date. It is intended that cables should not be deliberately formed into runs, although in most instances these will naturally occur. At the same time, it is essential that cable routes should not grow into enormous piles so that cleaning and future cabling is made difficult.

Cables are not secured to the grid at any point, otherwise movement of any cable might be limited by cable ties buried out of sight. An occasional tie to other cables is permitted where this will prevent a cable slipping across an access hole or off the edge of the grid, but these ties are restricted to the vicinity of access holes or the edge of the grid. Fig. 6 shows the cable concentration on the grid platform over an I.D.F., where the cables leaving the grid are supported by ties to the top cable brackets on the I.D.F. verticles.

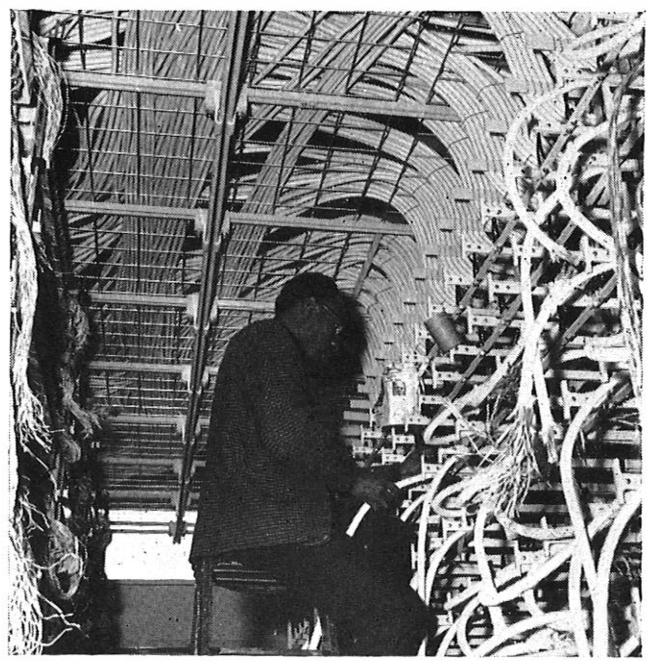

FIG. 6—HEAVY CABLE-CONCENTRATION ON THE GRID CABLE-PLATFORM OVER AN I.D.F.

The effect of the pressure of a pile of cables on a cable underneath which is pressed against a grid wire is being investigated. Sufficient information is already available to show that there is no danger of insulation breakdown or damage to the wires in a cable that is subjected to a weight equivalent to a pile of cables 12 in. deep.

The ventilation of an exchange which has cables supported on a grid platform presents similar, but no greater, problems to those of ventilating an equivalent exchange that has cables on conventional runways. In both types of exchange, air must be able to circulate through and around equipment. Where forced ventilation is provided air is normally distributed via trunking and discharged from inlets which should be clear of obstructions. In many new exchanges where the grid is being used there are large quantities of equipment which have a high heat dissipation, and special arrangements are required to ensure adequate ventilation. In principle, it has been agreed that ventilation inlets should be extended from the trunking to the level of the grid and a hole should be provided in the grid to give access to the inlet for maintenance. Where the clearance between the grid and the ceiling is very limited, ventilation inlets would be fitted into the underside of the trunking and the area of grid below the inlet will be left clear of cables.

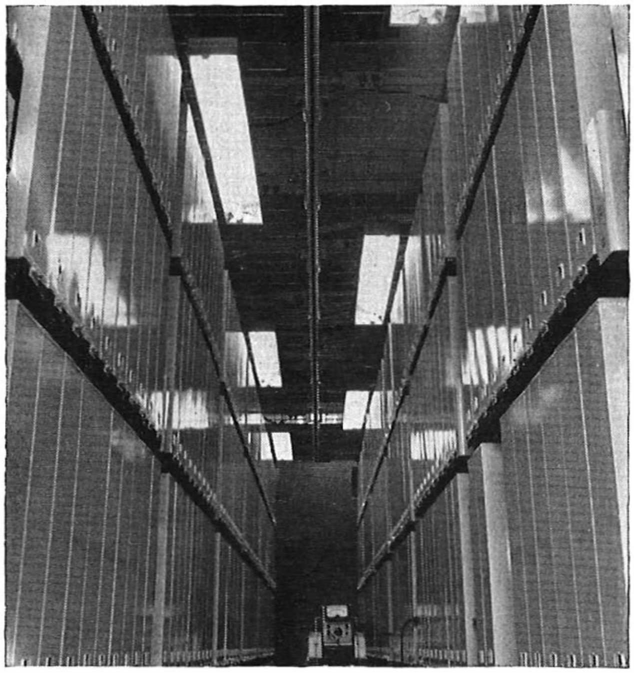

FIG. 7—APPARATUS GANGWAY WITH GRID CABLE-PLATFORM AND WITH NEW LIGHTING FITTING

A new fluorescent-lamp fitting has been designed for lighting apparatus gangways of exchanges where the grid is fitted (see Fig. 7). There is adequate headroom for the maintenance of equipment at the top of a rack because, although the fitting is fixed to the underside of the twin tie-bars, the fitting's overall depth is only $3\frac{1}{8}$ in. and the tie-bars are $3\frac{1}{2}$ in. above the rack.

CONCLUSIONS

The current emphasis on new installation methods is, primarily, intended to reduce the engineering and installation periods of a telephone-exchange provision program. The methods described in this article contribute to this purpose, and, by their application, a marked saving in materials and manpower has also been achieved without reducing standards of workmanship or appearance.

ACKNOWLEDGEMENTS

Acknowledgement is made to the telephone-exchange equipment manufacturers for their close co-operation in the work described. Acknowledgements are also made to the co-operation, advice and assistance of colleagues in Power Branch, Engineering Department, and in Regions and Telephone Areas where trials were carried out.

Book Review

"Audio Systems." J. L. Bernsteain. John Wiley and Sons, Ltd. xii+409 pp. 219 ill. Cloth 60s., paperback 34s.

The author defines the basic function of any audio system as "to deliver audible and recognizable sounds to a listener." One is therefore entitled to expect the book to explain the basic principles of uni-directional audio-transmission systems. Unfortunately, the treatment is almost entirely concerned with descriptions of certain elements of complete audio connexions and practically not at all with assembling them together or with the overall performance.

Only 12 pages are devoted to any description of the signals that need to be transmitted. This is slightly mathematical, mentioning Fourier series, but is devoid of vital statistics such as the ratios of peak to r.m.s. sound pressures. No mention is made of acoustical environments nor are the characteristics of the listener considered.

A chapter of 29 pages is devoted to decibels and volume units, but this contains no information on the method of using decibelmeters or vu-meters. Indeed, the conspicuous absence of any attention to measuring methods or test gear is inexcusable.

The main bulk of this book consists of 237 pages (out of 361 pages of descriptive text) of exercises relating to attenuators, mixing devices, amplifiers and attenuation equalizers. The information given should enable the reader with some technical background to design such devices for many applications, but he would require extra guidance, not included in the book, if he wished actually to construct and test the items. Characteristics of power supplies are not mentioned.

Recording methods are surveyed briefly, both disk and tape being covered in 24 pages. Information on audio transducers occupies 55 pages, but this is mainly concerned with the design of loudspeaker enclosures and dividing networks; microphones are dealt with in only 6 pages.

Clearly, the book is not intended for those who require a treatment of the subject in depth, but the author, in attempting to avoid difficult aspects, has introduced several erroneous, or at least misleading, statements. He has, furthermore, not assisted the reader as much as he might to avoid pitfalls that beset the inexperienced when they set up chains of audio elements each having a limited dynamic range and each possibly having different input and output impedances, balanced or not to earth. The book might have use as a well-indexed source of design information on attenuators, mixing devices, attenuation equalizers, certain types of amplifier, loudspeaker enclosures and loudspeaker dividing networks. There remains, however, the need for a good text-book on audio systems in the broad sense of the term.

D.L.R.

Designing a Voice-Switched Loudspeaking Telephone—Loudspeaking Telephone No. 4

B. COPPING, B.Sc., C.Eng., M.I.E.E., and R. G. FIDLER†

U.D.C. 621.395.721.1 : 621.395.623.7

The problems of circuit design and the factors affecting the physical design of a voice-switched loudspeaking telephone are discussed. The design of the Loudspeaking Telephone No. 4 is described, together with a brief description of the operation of the electronic circuit which controls the voice switching.

INTRODUCTION

TELEPHONE-CIRCUIT design is, of necessity, the result of a series of compromises. The problems encountered are, however, considerably greater in the design of a loudspeaking telephone: one of the major problems is avoiding the unwanted oscillation (howling) due to acoustic coupling between loudspeaker and microphone and the signal leak across the hybrid transformer, the latter remaining because of the difficulty in achieving an accurate impedance balance at the point of connexion of the send and receive channels to the line. Loudspeaker-to-microphone coupling cannot be accurately controlled in other than laboratory conditions, whilst impedance unbalance will be recognized as the principal cause of sidetone in a conventional telephone. Howling not only is an impediment to conversation but can also cause misoperation of voice-frequency signalling systems.

A simple loudspeaking telephone is illustrated in the schematic diagram of Fig. 1. During sending, with a

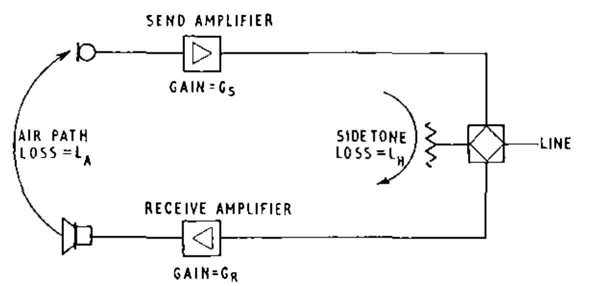

FIG. 1—SCHEMATIC DIAGRAM OF A SIMPLE LOUDSPEAKING TELEPHONE

perfect hybrid transformer and balance, all the power would be dissipated in the line and balance, and none in the receive path. However, due to balance imperfection, a finite loss, L_H, is introduced between the sending and receiving paths via the hybrid. If the air-path loss between the loudspeaker and microphone is L_A, then for stability

$$G_S + G_R < L_H + L_A.$$

For the Loudspeaking Telephone No. 1[1] a balance-control unit was used, the balance impedance varying with variations in line current. However, the impedance at the line terminals of a subscriber's instrument may vary widely, not only with the line length but also with the type of physical construction used for the line, quite apart from other impedance influencing factors such as transmission bridges, signalling equipment and the distant termination. The line current is not, therefore, a reliable guide to the impedance seen at the subscriber's instrument, and the automatic balance control fails to cater fully for all the possible routings of telephone connexions.

In theory, if an infinite loss is introduced into the receive channel any required gain can be inserted in the send channel, and vice versa. Practical difficulties, however, such as the users' objections to vivid aural contrasts, make complete switching undesirable. For the circuit of a new loudspeaking telephone a method of voice-controlled switching of attenuators has been used, the attenuators (L1 and L3) being inserted automatically in either the send channel or the receive channel, as shown in Fig. 2. The stability equation for this arrangement is

$$G_1 + G_2 + G_3 + G_4 < L_1 + L_H + L_3 + L_A.$$

In the send condition, attenuation $L_1 = 0$, and in the receive condition, attenuation $L_3 = \infty$. The decision to switch the attenuation from one channel to the other is taken by the comparator, which, after comparing signals

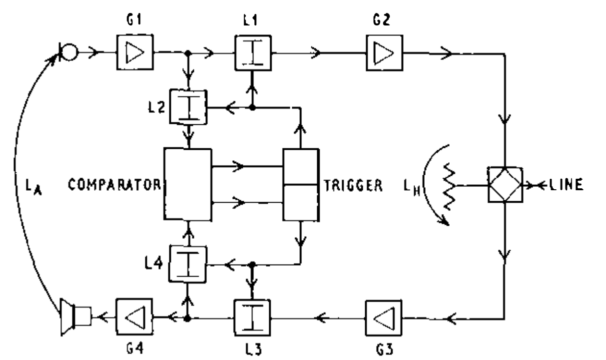

FIG. 2—SCHEMATIC DIAGRAM OF A VOICE-SWITCHED LOUDSPEAKING TELEPHONE

from the send and receive channels, switches the attenuators accordingly, via the trigger circuit. The transition from one state to the other must be closely controlled and, because of the difficulty in distinguishing between noise and the beginning of soft consonants, the switching must be rapid without producing transients. On the other hand, switching times must be slow enough to bridge inter-syllabic pauses and combat room reverberation. Attenuators L2 and L4 are also necessary to reduce the sensitivity to signals on the attenuated channel. This hysteresis is necessary to prevent the comparator hunting when the connected subscribers both talk at the same time or when the troughs in the speech envelope fall below the noise level on the other channel.

It is desirable to keep the acoustic loss L_A as high as possible since it forms part of the acoustic feedback loop. In the Loudspeaking Telephone No. 1 this is arranged

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by mounting the transducers in separate housings and asking the user to keep them about 1 yd apart. The electrical voltage loss between the input to the loudspeaker and the output of the microphone, when the transducers are mounted 12 in. apart in the same ideal housing, is about 58 dB in anechoic conditions. This is a degradation of 10 dB at 1 kHz, compared with separate transducer housings resting 2 ft 6 in. apart on a table top and with an included angle between their faces of about 100°. Most of this decrease in loss is due to the shorter path length, but, in practice, the figure will be worse due to coupling via the case.

The correct acoustic environment is essential for loudspeaking telephones. Hard-surfaced rooms are highly reverberant and make subscribers sound as if they were talking in a bathroom; the customer may combat this effect by speaking at a very close distance from the microphone. He could be aided by having a special microphone stand to bring the microphone nearer his mouth, or, if the conference potential of the set were not required, a directional microphone could be provided. Another disturbing effect of non-voice-switched loudspeaking telephones experienced by the distant subscriber is that, when he speaks, he hears an echo aided by the room reverberation enhancing his normal sidetone. The user of a voice-switched telephone does not suffer in this respect, but it is possible for the room reverberation to actuate the attenuator-switching circuit so that each time the distant subscriber pauses, he receives a burst of room reverberation. The maximum receive level permissible is, thus, necessarily limited to below the average talker level measured at the microphone.

Noise will not only mask speech—in a voice-switched telephone it can cause false operation. The worst possible circumstances can occur when two loudspeaking telephones in the same building are connected together and an aircraft passes overhead: both telephones will lock on the send channels and misunderstanding will arise because neither party will be aware that he cannot be heard. To some extent a microphone cut-off key overcomes noise problems, and, if both parties are prepared to use radio-telephone operating procedure, they may converse with its aid in quite bad conditions.

In general, loudspeaking telephones must not be fitted in noisy or reverberant situations. Customers may need to be advised that their offices need acoustic treatment: double glazing, if the office overlooks a busy thoroughfare, and absorber or resonator boards on the walls or ceilings. The average office in which a loudspeaking telephone might be fitted should be sufficiently damped by carpets and curtains.

SWITCHED DEVICES

There is an increasing number of voice-switched devices in the telephone network, e.g. T.A.S.I.,[2] echo suppressors and conference amplifiers.[3] Experimental work is also proceeding on special telephones for use in noisy situations and over long lines. In general, switching times of these devices will be additive and, together with the considerable transmission time delay of circuits routed via transoceanic telephone cables and satellite systems, make it imperative that switching times are minimal. However, on short-distance calls to a subscriber with a standard telephone the distant-end user finds the contrast of fast switching objectionable, due to changes in background noise and room reverberation. A 20 ms operate time is only just acceptable, and even this can be disturbing at first. A hangover time of about 300 ms copes with the average talker, but there are indications that something nearer 400 ms would be desirable for some speakers.

FACTORS AFFECTING THE PHYSICAL DESIGN

Number of Units

Ideally, the microphone and loudspeaker should be spaced well apart for the reasons already given. Wide separation means, in practice, the provision of at least two apparatus units, and possibly three if the electronic circuit cannot be housed conveniently with one of the transducers. Market research reveals, however, that there is a marked preference on the part of subscribers to have only a single unit on the desk, and, therefore, it was on this form of unit that development proceeded. As a result, the transducers were brought closer together, and additional feedback paths were introduced via the air coupling inside the container and also via the structure itself. Coupling through the front air path cannot be eliminated, so every effort had to be made to reduce the remaining couplings as far as possible, e.g. the interior of the loudspeaking telephone has been divided into two approximately equal compartments, one for the loudspeaker and one for the microphone, and the loudspeaker compartment is completely lined with $\frac{1}{4}$ in. acoustic felt to absorb as much as possible of the rearward radiation from the loudspeaker; in addition, the microphone is acoustically insulated from the front panel. Even with these precautions the margin of stability is reduced from that obtainable with widely-separated transducers, and greater care has to be exercised in the circuit design.

Consideration was first given to the possibility of locating the electronic circuit remote from the desk instrument in an endeavour to reduce the size of the latter. If the desk unit and electronic-circuit unit were to be supplied interconnected by a short standard length of cabling this would present problems for installation in situations envisaged for a prestige instrument, e.g. on an expensive desk (to which nothing may be screwed) situated on a large expanse of fitted carpet. In such circumstances the electronic-circuit unit would have to remain under the desk, and, apart from the unsatisfactory aesthetic aspect, it would probably receive damage in use.

The alternative of locating the electronic-circuit unit on a nearby wall presented further complications. The cable would have to be specially manufactured to contain several screened wires for the volume-adjustment circuit, the associated trigger-control circuit and the microphone circuit, and a variety of unscreened wires for the loudspeaker circuit, the telephone circuit and, possibly, the d.c. power supply. Provision would have to be made not only for a variety of ready-made lengths of cable but also for various numbers of conductors, to cater for all systems from a simple direct-exchange-line installation to a multi-wire house-exchange system. These factors lead to an undesirable multiplicity of types of cable. Furthermore, bearing in mind that the cables would include a mixture of diverse circuits, such as the high-level circuit to the loudspeaker, the low-level circuit to the volume-control circuit, and the very-low-level circuit from the microphone, as well as the exchange-line pair and unbalanced single wires on certain extension-plan arrangements, it seemed unlikely that satisfactory results could be maintained in view of the crosstalk that would most certainly occur. Such an arrangement was therefore abandoned.

On the other hand, because a cavity of not less than 800 cm^3 had to be provided behind the loudspeaker to preserve its front radiation characteristic, a practical solution was secured by placing the whole of the electronic unit within this cavity. The volume of the cavity had, however, to be increased a little to compensate for the space occupied by the electronic-unit components.

Compatibility with Existing Installations

The loudspeaking telephone has been designed as a versatile instrument capable of being fitted in as many types of subscribers' installations as possible. It was realized at an early stage that its potential versatility could not be fully exploited for a very long time if it had to await the drawing up and introduction of a completely new range of fitters' installation diagrams covering all possible station arrangements, many of which might rarely, if ever, be required. It was apparent that an enormous advantage could be gained if uniformity could be preserved with the existing library of fitters' installation diagrams, and the aim was to present the same electrical conditions and terminal numbering as the four-button Telephone 710[3] and to retain, as far as possible, the identical facilities of that telephone by making provision for the addition of the standard range of components such as spring-sets, adaptors, buzzers, etc. This policy would have the additional advantage of not requiring the introduction of special components.

The objective has been achieved by using the basic electrical circuit from the Telephone 710 in a very slightly modified form, and causing the change-over from loudspeaking operation to handset operation to occur by switching the circuit beyond the bell-capacitor-dial section and not on the line terminals. During dialling, the off-normal springs in the standard 700-type telephone short-circuit the receiver, and the remainder of the receiver circuit is used, in conjunction with the bell-circuit capacitor, as a spark quench for the pulsing springs. For loudspeaking working, the handset is out of circuit, so the wire from the junction point between the bell and the capacitor has to be re-routed via additional contacts to a resistive dummy load so that the spark-quench circuit is maintained for dialling. This is an important feature from another aspect: certain extension plans, e.g. Extension Plans No. 1 and 1A, use a 3-wire interconnexion system, and if the standard electrical conditions were not maintained at all times standard 700-type telephone installation-practice could not be followed.

Method of Operation

Operation of a key or bar was envisaged for switching the instrument on and off for loudspeaking operation. For handset operation the following two possible methods were then examined.

(*i*) Assuming the on/off key to be operated, lifting the handset would transfer the call to the handset and also restore the on/off key automatically. On replacement of the handset the call would be cut off, so that, if it were desired to revert to loudspeaking operation, the on/off key would again have to be operated and held operated during replacement of the handset.

(*ii*) Assuming the on/off key to be operated, lifting the handset would transfer the call to the handset but would not interfere in any way with the on/off key. On replacement of the handset the call would simply revert to loudspeaking operation.

In a normal telephone it can be arranged that any of the button-operated spring-sets may be released by replacement of the handset. The equivalent operation has to be performed in a loudspeaking telephone by the restoration of the on/off key. If method (*i*) were adopted a cross-link mechanism would have to be provided from the handset switch hook so that control could be exercised from both the on/off key and the handset gravity switch. This might involve using a stronger switch-hook restoring spring and possibly a heavier handset.

Furthermore, in a normal telephone it is possible to fit an additional auxiliary gravity spring-set. The equivalent operation in the loudspeaking telephone would be the addition of a spring-set to the on/off key for method (*ii*), but with method (*i*) two spring-sets, one for the on/off key and one for the handset switch hook, would be required and every operation duplicated; this would mean, for example, a single break contact-unit on the fitters' diagram would have to be interpreted as two break contact-units in series, and a single make contact-unit as two make contact-units in parallel. Auxiliary sketches would be needed to interpret change-over or make-before-break circuit configurations. A large number of extra terminals would be needed for the cross-connexions between the spring-sets, and the resulting circuit, although functionally feasible, would be untidy and not very easy to service because of the departure from the declared principle of adhering to the standard fitters' diagrams. Method (*ii*) was clearly preferable since the only interpretation needed from fitters' diagrams would be to substitute "auxiliary on/off key spring-set" for "auxiliary gravity spring-set."

Method (*i*) had an advantage that the handset might be picked up initially to engage a call without the need for any further switching. Equally, however, it suffered from a disadvantage in that, if a call were on loudspeaking operation and the handset were picked up in a careless manner so that it dropped back momentarily on to the switch hook, there would be a danger of an initiated call being lost. With method (*ii*) the call would be safeguarded, the only danger being that the call might not be finally cleared owing to the subscribers' omission to restore the on/off key. This objection was overcome by providing a reminder lamp. Experience has shown that not everyone can reliably master the technique for reverting from handset to loudspeaking operation using method (*i*) without occasionally losing a call.

It was, therefore, decided in view of the foregoing factors to adopt method (*ii*).

Received-Signal Sensitivity Adjustment

The circuit provides for three receive gain settings, under the control of the user, to allow for variations in received-signal strengths. As will be described later, the set normally remains switched in the direction of the last talker but the maximum gain setting, intended for faint calls, causes the gating attenuators (a.c. gates) to switch in a monostable mode, always reverting to the receive channel to favour the weak incoming signal. It follows, therefore, that under this condition the loudspeaking-telephone user should ensure that his own speech is directed clearly and reasonably loudly towards the instrument, because each speech train is required to open the send-channel a.c. gate. For simplicity, the received-signal sensitivity-adjustment control has been marked VOLUME CONTROL, since it does, in fact, control the loudspeaker volume. Unless warned against the practice, however, subscribers have a tendency to set the gain at maximum even on local calls, and then settle well back and lower the voice, so that opening of the send-channel a.c. gate becomes erratic. This should be regarded as misoperation of the instrument: the high-gain setting should be reserved for faint calls only.

Since the instrument was to be capable of being fitted with four pushbuttons, as in the Telephone No. 710, an aesthetically pleasing design was obtained by adding four more pushbuttons in a parallel row: three of these buttons are used for signal-sensitivity adjustment and the fourth is designated MICROPHONE OFF.

Power Supply

If a built-in power unit were provided for the derivation of the necessary 21-volt d.c. supply from the mains, external connexions to the loudspeaking telephone would have to be provided over two separate cords: one for the telephone line and one for the a.c. power supply. For protection and other reasons it is not possible to combine these into a single cord. If, however, a remote power unit is provided, not necessarily in the same room as the loudspeaking telephone, d.c. power can be supplied over two conductors in the telephone-line cord, and the installed equipment presents a neater appearance.

Loudspeaking telephones are frequently used on large private automatic branch exchanges (P.A.B.X.s), especially in conjunction with direct-access key-calling equipment, and in such circumstances it is often convenient to use the 50-volt P.A.B.X. battery instead of a mains unit. The loudspeaking telephone was, therefore, designed to operate from a 50-volt d.c. supply and to incorporate a 50/21-volt regulator circuit which corrects voltage fluctuations caused by the state of charge of the P.A.B.X. battery and also allows for the potential drop in the house wiring.

LOUDSPEAKING TELEPHONE No. 4

There are variants of the basic Loudspeaking Telephone No. 4; these are indicated by suffix letters, as follows.

(*i*) 4A: standard model with rotary dial.

(*ii*) 4B: experimental model, not proceeded with.

(*iii*) 4C: model with push-button keyboard for d.c. signalling.

To the above codes are added hyphenated numerals to denote specific types, e.g. Loudspeaking Telephone No. 4A-1 is complete with feet, and back with switch hook and handset, whereas Loudspeaking Telephone No. 4A-2 has feet and a plain back.

Except where otherwise stated the descriptions that follow are applicable equally to Loudspeaking Telephones No. 4A-1, 4A-2 and 4C-1.

General

The Loudspeaking Telephone No. 4A-1 is illustrated in Fig. 3. The unit, excluding feet, has the following dimensions: height $4\frac{1}{2}$ in. (11·5 cm), depth $8\frac{3}{16}$ in. (20·8 cm), and width $17\frac{1}{8}$ in. (43·5 cm).

(*a*) Front View

(*b*) Rear View

FIG. 3—LOUDSPEAKING TELEPHONE No. 4A-1

The height is increased by 2 in. (5·1 cm) by the addition of the feet, or by the matching plinth which can be fitted in the place of the feet and used to accommodate apparatus required for specialized purposes. The complete instrument weighs 15 lb 9 oz (7·1 kg).

The main unit is vinyl stove-finished in two-tone elephant grey and light French grey, with plastic fittings in the same colours to match the standard 700-type grey telephone.

The Loudspeaking Telephone No. 4C-1 is similar to the No. 4A-1 except that in place of the rotary dial a pushbutton keyboard for d.c. signalling is provided (see Fig. 4). It is expected that demand for this telephone will

FIG. 4—LOUDSPEAKING TELEPHONE No. 4C-1

be almost exclusively for large P.A.B.X.s with facilities for pushbutton signalling, and, in most instances, direct-access key-calling plinths will be required as well.

Front Panel

The moving-coil loudspeaker (Loudspeaker No. 6A) is located behind the plastic grill on the extreme left of the front panel, and the electrodynamic microphone (Microphone-Inset No. 2A) on the extreme right behind the perforated circular metal plate with plastic surround. Adjacent to the loudspeaker is the rotary dial, conventional in all respects except that the dial ring has white characters on an elephant-grey background. The ON/OFF push-bar located in the centre of the panel is positioned vertically; a spring, fitted internally, ensures that the bar always returns to its fully extended position. It is not, therefore, possible to establish by looking at the bar whether the set is on or off, and for this purpose a reminder lamp (Lamp No. 41B) is fitted behind an amber window set into a black-acrylic strip running along the length of the panel and immediately below it.

Between the ON/OFF bar and the microphone are located the control buttons in two horizontal rows of four, one row directly above the other. The lower row of buttons is provided as standard for volume control; from left to right these buttons are as follows:

(*i*) Button 1: Local-call position—indicated by a single dot.

(*ii*) Button 2: Medium-position—indicated by two dots.

(*iii*) Button 3: Faint-call position—indicated by three dots.

(*iv*) Button 4: Microphone off.

Buttons 1–3 are interlocked so that depression of any one button restores any other previously depressed. Dots were chosen to symbolize the volume-control positions in order to achieve a cleaner effect on the panel, uncluttered by excess lettering. Button 4 is non-locking and causes complete suppression of voice signals to line; it is provided for confidential local consultation.

The upper row of four button positions is fitted initially with dummy buttons, which are removed and replaced during installation by buttons and spring-sets in accordance with local-facility requirements. Two additional lamps may also be fitted below the front panel. When it is necessary to fit additional components for the more complex installation arrangements, they can be accommodated in the matching plinth (Case No. 148A) fitted in place of the two feet.

Handset

The handset is suspended on a switch-hook bracket and a plain bracket on the rear panel, and is largely hidden from view of the user. A standard Handset No. 3 is used, but a lead weight is fitted inside the receiver moulding to enable the handset to overcome the additional force of the switch-hook springs. Alternatively, the rear panel with the brackets and handset may be removed and replaced by a plain back, and a remotely situated telephone provided.

Internal Layout

The lid of the instrument is held down by two concealed snap fasteners under the back edge, the front edge of the lid engaging with a protruding lip along the top edge of the front panel. To remove the lid, it is necessary to pull the rear of the lid upwards, and then pull it forward to disengage it from the front panel.

The main body is constructed in two compartments, the one on the left (see Fig. 5) housing the loudspeaker,

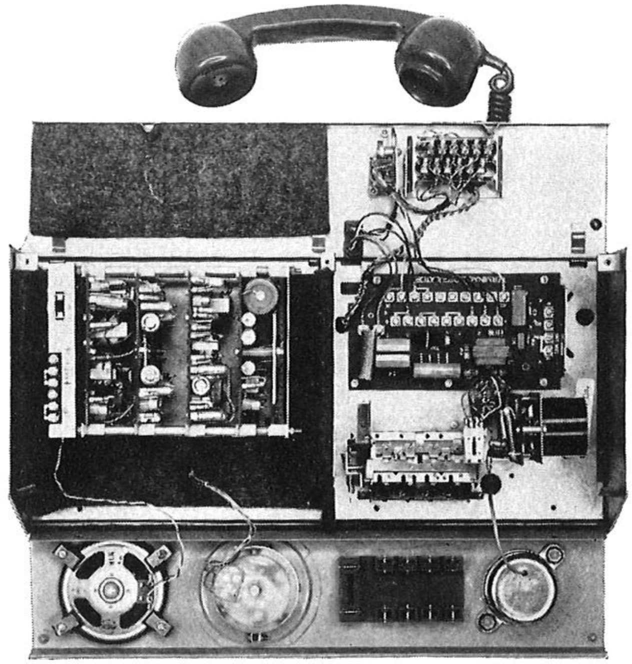

FIG. 5—INTERNAL LAYOUT OF LOUDSPEAKING TELEPHONE No. 4A-1

dial and electronic-circuit boards, and the one on the right housing the microphone, telephone circuit and control switches.

The interior walls and lid of the loudspeaker compartment are covered in ¼ in. moth-proof acoustic felt. The electronic circuit has been constructed on four printed-wiring boards, which are mounted vertically and adjacent to each other. The permanent wiring of the instrument is soldered to connexion blocks in the base of the unit, and the tags of the printed-wiring boards are arranged to slide over the corresponding connexion-block tags, each pair of tags being tightly bound with copper wire as for a solderless wrapped joint. A small six-way terminal strip is provided for the connexion of a matching external loudspeaker (Loudspeaker-Unit No. 4A) which may be used in addition to, or in place of, the internal loudspeaker. When the internal loudspeaker is not in use it is possible to increase the normal output by operating the loudspeaker attenuator-pad switch from MEDIUM to HIGH, thus giving an additional 6 dB gain in the receive direction.

The right-hand compartment houses the basic telephone circuit on a printed-wiring board, the microphone, the ON/OFF push-bar and button mechanisms, the tone-ringer (Tone-Ringer No. 3A) and the switch hook with its associated terminal strip. The basic telephone-circuit board has four additional terminals so that a matching extension microphone (Microphone-Unit No. 1A) may be used in addition to, or in place of, the internal microphone.

Microphone-Inset No. 2A

The Microphone-Inset No. 2A has a rising response slope of 7 dB per octave which, when mounted in the case, is modified to 4 dB; this is a little more than the optimum required to assist with the room reverberation.

Tone-Ringer No. 3A

Tone-Ringer No. 3A comprises a separate sub-unit with a printed wiring-board. The circuit and operation are similar to those already described for the Telephone No. 712[5] except that no provision is made for variation of output level or for build-up of tone. Sensitivity is set at the maximum, and further acoustical amplification is achieved by coupling the modified rocking-armature receiver to a nylon horn. The volume of the calling signal is considerably attenuated because the device is totally enclosed within the instrument, but, nevertheless, it is comparable with the volume emitted by the tone-ringer of a Telephone No. 712 set to the SOFT position. This volume should be adequate for the quiet locations essential for voice-switched loudspeaking telephones, but, if more volume is demanded, a separately-mounted variable-volume tone-ringer or extension bell can be provided as alternatives.

Loudspeaker-Unit No. 4A and Microphone-Unit No. 1A

The extension loudspeaker and microphone have been designed as attractively styled matching auxiliary units (see Fig. 6) containing the same transducers as those in

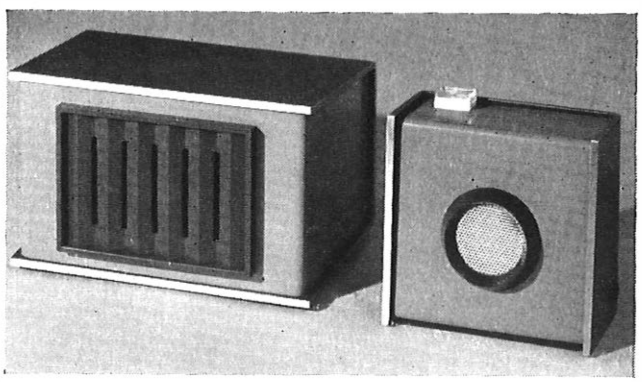

FIG. 6—LOUDSPEAKER-UNIT No. 4A AND MICROPHONE-UNIT No. 1A

the main instrument, and finished to the same standards and colours. The microphone unit has been provided with a cut-off button to duplicate the function of the main instrument button.

Special Arrangement of Electronic Circuit

Occasionally a large organization may request physical integration of the loudspeaking facilities with other communication services. The electronic circuit has, accordingly, been so constructed that it can be supplied, to special order, as a separate entity enclosed in a box. It can, thus, be incorporated in the customer's furniture, requiring special controls and transducers externally fitted as part of the comprehensive communication system.

ELECTRONIC-CIRCUIT DETAILS

Fig. 7 shows a block schematic diagram of the Loudspeaking Telephone No. 4.

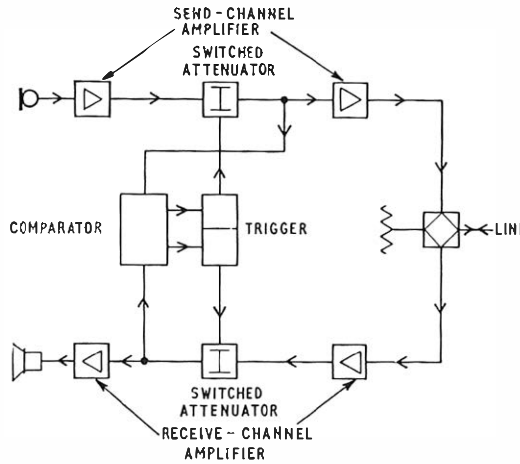

FIG. 7—SCHEMATIC DIAGRAM OF LOUDSPEAKING TELEPHONE No. 4

A.C. Gates

The a.c. gate circuit, shown in Fig. 8, is balanced to prevent switching noise from being introduced into the signal circuits. The diodes are forward biased in the signal-through condition and reverse biased in the attenuated condition. Resistors R1 and R2 have two purposes: to limit the load on the switching trigger and

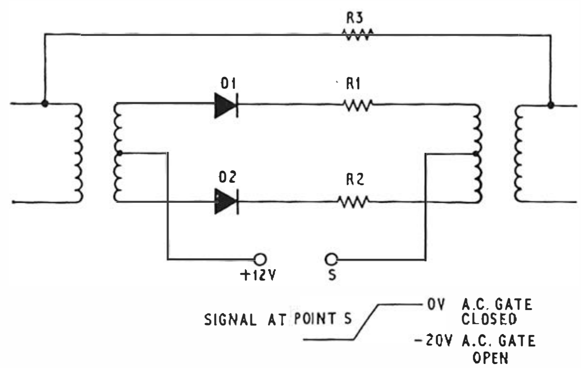

FIG. 8—CIRCUIT OF A.C. GATE

to reduce non-linearity of the diode characteristics. Resistor R3 provides a signal leak through the a.c. gate, and its value controls the loss of the gate.

Send Amplifier and Hybrid

The send amplifier has three conventional transistor stages. The amplifier stage which follows the a.c. gate acts as a buffer and a phase splitter, the phase-splitter second output being part of the input to the send side of the comparator. The hybrid is a conventional 2-wire/4-wire terminating unit with a 600-ohm balance. A more complex balance network is available, but it was thought that any improvement could be more easily achieved by increasing the switching loss. The channel has a preset voltage gain of 57 dB between the 2,000-ohm microphone and a 600-ohm resistive line. The 1 dB points are 150 Hz and 6 kHz.

Receive Amplifier

The four-transistor receive amplifier is of a conventional type, with a push-pull output stage. The voltage gain of the amplifier is 18 dB between a 1,200-ohm source and a 3-ohm load. The peak-power capacity is about 600 mW, and the 1 dB points occur at 250 Hz and 11·0 kHz. The received-signal sensitivity control precedes the amplifier and gives two 10 dB steps; the control also readjusts the signal input to the comparator so that the gain between the line and the comparator remains constant for all positions of the sensitivity control. The faint-call position, i.e. maximum gain setting, also changes the switching circuits from being bistable to monostable as explained below.

Comparator and Trigger

The amplifiers on each side of the comparator use two conventional stages for which the gain is pre-set by adjusting the negative feedback. At the output of each amplifier the signals of differing polarities are separated, and the positive send signal is coupled via resistors to the negative receive signal, and vice versa (see Fig. 9). These two signals are then applied to the two inputs of the trigger: one signal may be regarded as setting the pedestal-voltage level, while the other operates the trigger when that level has been exceeded. Thus, the switching is operated by the difference of the differences; this rather elaborate procedure is necessary because of the asymmetric nature of speech wave-forms.

The output impedances of the input transformers are low to obtain quick charging of capacitors C1, C2, C3 and C4 and a fast operating time of the switch (20 ms). The discharge of these capacitors, via resistors R8, R9, R16 and R17 and the base circuits of the next stages, leads to a hang-over time of about 300 ms.

It was decided to make the trigger normally bistable to avoid unnecessary switching operations and, thus, minimize speech mutilation; bistable switching also prevents the possibility of drop-out during quiet periods. On high-loss calls, the receive signal would have difficulty gaining control of the circuit, but, on the high gain setting, the set becomes monostable with the bias in the receive signal direction. Thus, the distant-end subscriber will have no difficulty in making himself heard during the near-end user's pauses in speech. The bistable-monostable control is by means of resistors R1, R2, R3 and R10 in conjunction with contacts RLA1 and RLA2 which pre-bias the trigger. Silicon transistors have been used for the trigger circuit to obviate variations of operating conditions with temperatures up to 80°C.

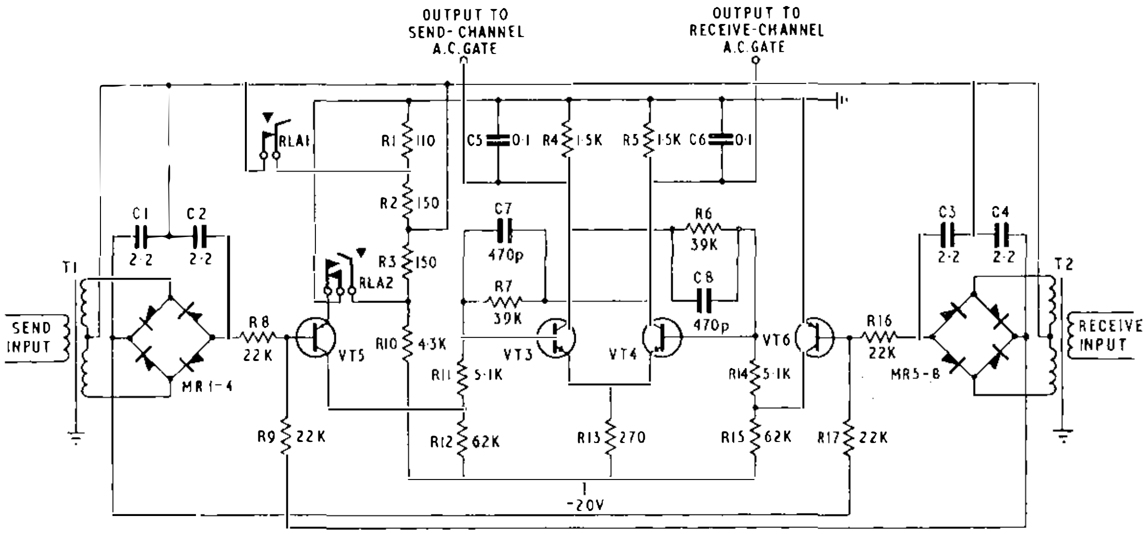

FIG. 9—COMPARATOR AND TRIGGER CIRCUIT OF LOUDSPEAKING TELEPHONE No. 4

FIELDS OF APPLICATIONS

The Loudspeaking Telephone No. 4A-1 provides facilities equivalent to those required for many of the existing Telephone No. 710 installations. However, the Loudspeaking Telephone No. 4C-1 has its prime application with large P.A.B.X. installations, individually engineered to special order.

CONCLUSIONS

Loudspeaking Telephone No. 4, an advance on previous loudspeaking telephones, is a versatile and useful addition to the steadily expanding range of modern instruments currently offered to the public by the Post Office. Its design represents a compromise between mutually conflicting requirements, one of the most significant being the necessity to maintain a good performance on the public switched network. In this respect, the Loudspeaking Telephone No. 4 possesses a performance markedly superior to the Loudspeaking Telephone No. 2, which it now supersedes.

ACKNOWLEDGEMENT

Acknowledgement is made to the General Electric Co. (Telecommunications), Ltd., who co-operated with the British Post Office to bring this development to a successful conclusion.

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Notes and Comments

New Year Honours

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

City Area, London Telecommunications Region	L. G. Pond	Technician I	British Empire Medal
Dundee Telephone Area	A. T. Kay	Technical Officer	British Empire Medal
Engineering Department	S. Welch	Lately Assistant Staff Engineer	Officer of the Most Excellent Order of the British Empire
Engineering Department	W. C. Ince	Assistant Executive Engineer	Member of the Most Excellent Order of the British Empire
Factories Department	T. Bradley, B.E.M.	Factory Manager	Member of the Most Excellent Order of the British Empire
Liverpool Telephone Area	E. M. Ward	Technician IIA	British Empire Medal
Post Office Research Station	H. T. Mitchell	Staff Engineer	Companion of the Imperial Service Order
South East Area, London Telecommunications Region	J. R. G. Smith	Area Engineer	Member of the Most Excellent Order of the British Empire
Tunbridge Wells Telephone Area	R. A. Evans	Inspector	British Empire Medal

Retirement of Mr. R. H. Franklin, E.R.D., B.Sc.(Eng.), C.Eng., F.I.E.E.

Mr. R. H. Franklin, Staff Engineer of the Main Lines Development and Maintenance (LMD) Branch, left Post Office service on 9 February 1967 after a distinguished career in telecommunications, which began at the age of 17 as a Probationary Inspector.

He left Hampton Grammar School in 1924 to enter the Post Office and worked for a few years on exchange design. He was successful in the Open Competition for Probationary Assistant Engineers in 1928 and, after a short time on radio work, moved over to telephone-cable engineering, first in the Test and Inspection Branch and later in the Lines Branch. He then began to build a solid foundation in this field, and to develop a feeling for copper and lead as the raw materials of telecommunications upon which his subsequent career was to be based. His joint paper on telephone-cable design with Mr. F. H. Buckland (I.P.O.E.E. Printed Paper No. 144), although long out of print, remains as a unique contribution to the scanty literature on this subject.

In 1936 he was promoted to Executive Engineering Lines Branch where, until the outbreak of war, he was responsible for cable maintenance and provision of international circuits, and participated in C.C.I.F. activities. He attended the Study Group 3 meeting in Oslo in 1938, and was the United Kingdom delegate at the formation of the maintenance sub-committee. So began his long association with international telecommunications.

He was associated at that time with many important developments and was always appreciative of long-term, overall aspects. Perhaps the most significant was the standardization, internationally and in the Post Office, of the 12-channel carrier group and its adoption as a basic unit for multi-channel systems.

He was mobilized as a Supplementary Reserve Officer and served with Royal Signals in Europe, Middle East and India; he was Deputy Chief Signals Officer in the Arakan until the end of the war. He was promoted *in absentia* to Assistant Staff Engineer whilst serving in Egypt in 1942.

After the war he returned to Lines Branch to take charge of planning of the main-line and local-line networks, and was a major force in setting the scene for the subsequent expansion of the trunk network on coaxial cables.

He attended the Imperial Defence College in 1950, and in 1951 was seconded to serve as Deputy-Director of Signals, Air Ministry, dealing mainly with land-line communications for the Royal Air Force. This period included service as a member of a commission appointed by the Canadian Government under Sir Robert Watson-Watt to evaluate R.C.A.F. communications.

Having been promoted *in absentia* (again!) he returned in 1953 as Staff Engineer to Main Lines (LM) Branch (local lines having been hived-off in the formation of the Local Lines and Wire Broadcasting Branch), and led the Branch into a most intensive and exciting period. This period involved the expansion and reshaping of the trunk network, creation of a second television network, and intensive development in multi-channel coaxial-cable systems. Its culmination was perhaps the introduction of ocean submarine telephone cables, and the unfolding of the possibilities and problems of a world-wide telephone system with ever-increasing international involvement.

In 1958 a separate Branch (Main Lines Planning and Development (LMP)) was created from the planning and provision section of LM Branch, leaving Mr. Franklin in charge of the new LMD Branch and responsible for transmission and main-lines development and maintenance. The work of the LM and LMD Branches during his term of office steadily became more complex and covered widening fields; its ability to cope with these demands has depended upon the personality of its head and his power of commanding respect and affection from his staff. That the exceptional tasks imposed in the planning and systems engineering, as well as in providing teams of transmission experts to serve on cable ships and at remote terminal stations, were met during the TAT-1, TAT-3, SCOTICE, CANTAT, COMPAC and SEACOM projects (as well as many smaller schemes), is a tribute to his ability to organize and devolve (a quip of that period is recalled: "Join LMD and see the world").

Acknowledgement is due also of his ability for selecting and encouraging junior men, and for extending them to their full, often unsuspected, potential, under a firm but friendly guidance.

For many years he was an active participant and respected figure in the international consultative committees; he returned as a delegate to Study Group 3 (Transmission) of the C.C.I.F. in 1953, taking over from Mr. G. J. S. Little as Chairman for the 1954 meeting. He was appointed Vice-chairman of Study Group 3 for the 1954–56 period and of the succeeding Study Group 1 of the C.C.I.T.T. from 1954 to 1960. From 1956 to 1960 he presided over sub-group 1/2, "Use of Lines for Telephony," which, after the 2nd Plenary Assembly of the C.C.I.T.T., became Study Group XVI under his chairmanship, responsible for general studies of the transmission aspects of the world-wide interconnexion plan.

It is appropriate at this stage to mention his long interest in overall transmission standards and performance, his endeavours in LMD Branch to foster the concept that transmission engineers should be concerned with subscriber-to-subscriber performance and not over-concentrate on the beguiling technicalities of particular equipment designs. His chairmanship of Study Group XVI was clearly a most congenial task and revealed his underlying interests, as did his assignment for 3 months in 1963 as an I.T.U. Technical Assistance expert to advise the United Arab Republic on planning their long-distance network. He was awarded the Institution's Silver Medal in 1961 for his paper (I.P.O.E.E. Printed Paper No. 222) entitled "World-Wide Telephone Transmission."

He led the United Kingdom delegation on C.C.I.T.T. Study Group XV and its predecessors (Transmission Systems) throughout his period as Staff Engineer, attended many Plan Committees, and was vice-chairman of the Joint Mixed Committee on Television Transmission (C.M.T.T.) from its foundation in 1960.

It is difficult to imagine LMD Branch without the genial transmission engineer at its head: just as difficult to accept the fact of his retirement. In fact, he has not retired from telecommunications engineering but has joined SHAPE Technical Centre in the Hague for a term of years. The best wishes of his friends and colleagues accompany him.

M.B.W.

J. F. P. Thomas, B.Sc., C.Eng., M.I.E.E.

Mr. Thomas, recently appointed Staff Engineer in charge of the Main Lines Planning and Provision (LMP) Branch, entered the Engineering Department as a Youth-in-Training in 1937. After a short spell in the Training Branch at Dollis Hill he was transferred to Research Branch. His early work in the Physics Group included the development of special testing equipment. In 1942 he became a Probationary Inspector, and subsequently an Inspector carrying out investigations on magnetic materials and contact problems. He obtained his London B.Sc.(Hons.) degree after studying at the Northampton Engineering College, and subsequently studied physics and mathematics at the Northern Polytechnic.

As an Executive Engineer in 1948, he commenced his association with submarine-cable systems, and was initially closely concerned with the design, manufacture and testing of equipment for system monitoring and fault locating. In 1957, as a Senior Executive Engineer, he had added responsibilitities for power-feeding equipment and long-life components. This work brought him in close contact with the component suppliers, who were called on to introduce special manufacturing processes to achieve the high standards required. He played no insignificant part in the success of the first transatlantic telephone-cable project (TAT-1) and of the large number of other submarine cables laid from the United Kingdom to Europe, Scandinavia and North America in the 1950s and early 1960s. He spent some time aboard cable ships on the earlier shallow-water schemes, and was subsequently responsible for shore stations on the major schemes. His duties involved investigations and discussions in the U.S.A. and Canada during this period.

Since 1963 Mr. Thomas has been the Assistant Staff Engineer in LMP Branch responsible for planning the inland trunk network, during a time when it has been expanding at an unprecedented rate. He has done much to foster the introduction of high-capacity transmission systems on small-tube coaxial cables, and of a standard p.c.m. system to meet the extensive requirements within the Post Office network. Although this represented a considerable change from his previous interests, he accepted the challenge with an enthusiasm well known to his many friends within and outside the Engineering Department, who now welcome his translation to head of the Branch.

During the time he spent at Dollis Hill, Frank Thomas was a regular participant in the stage presentations which contributed so much to the success of the annual Christmas parties. He has always been an active sportsman, and is still a very keen tennis player, stimulated by the competitive game, and an energetic organizer within his club.

L.W.J.C.

L. R. F. Harris, M.A., C.Eng., M.I.E.E.

Mr. L. R. F. Harris—Roy—who has been appointed Staff Engineer of RF Division in the Post Office Research Branch, entered the service in August 1947 as a temporary Scientific Officer after securing a double first at Cambridge. By the end of 1947 he had become a Probationary Engineer (old style) and was engaged on research into electronic switching under Mr. T. H. Flowers. Promoted to Senior Executive Engineer in August 1957, he continued to work in the same field until October 1960 when he was transferred to the Telephone Exchange Systems Development (TPD) Branch to take over day-to-day control of one of the current joint electronic-switching developments as Project Leader.

In 1961 he was promoted to Assistant Staff Engineer in the newly formed Telephone Electronic Exchange Systems Development (TPE) Branch, where he became responsible for the day-to-day planning and direction of electronic-switching development—a task that reached fruition with the completion of the design of the TXE3 system during the latter half of 1966 and the opening of the Ambergate TXE2 telephone exchange in December 1966.

In August 1966 Mr. Harris was transferred to the newly formed Long-Range Systems Planning Unit (SPU) as a broadly based expert in the switching field, charged with the task of studying and contributing to the forward planning of the Post Office network for the future, both short and long term, in the light of its requirements for switching on a nation-wide basis. As it happened his stay with the SPU was short, and ended with his promotion to Staff Engineer; he nevertheless succeeded in making a real and valued contribution to the work of the SPU.

He has always been widely known for the fertility of his ideas in both research and development, and has several basic patents in the field of electronic switching to his credit. He is equally at home with both time-division and space-division switching, and has presented several excellent papers on these subjects to international audiences both in the United Kingdom and in the United States. He is well acquainted with work in the switching field in the United States and in Europe, and is widely recognized as an expert in these fields abroad.

Despite the fairly long period on research, his transfer to TPD Branch, and later to TPE Branch, caused him no concern—he rapidly developed a talent for planning and progressing exceedingly complicated development projects with vigour and drive without losing his essentially friendly and cooperative approach to others, especially those who had to carry out the programs he had planned.

Roy Harris has an open friendly manner; he is never loath to take part in an argument, but always constructively, with firm views, fluently expressed. He is, nevertheless, always willing to concede a valid point—a characteristic that makes him an excellent colleague. His views have always been sought and valued by the staff he directs—nothing is too much trouble if it will help.

His many friends in the Post Office and in other countries were all delighted to see him promoted, and wish him continued success in his new activities.

J.A.L.

Circulation of The Post Office Electrical Engineers' Journal

The Board of Editors is pleased to note the continuing increase in the circulation of the Journal, as shown by the following statistics.

Journal Issue	Number of Copies Printed
Vol. 59, Part 1, Apr. 1966	31,870
Vol. 59, Part 2, July 1966	32,000
Vol. 59, Part 3, Oct. 1966	33,180
Vol. 59, Part 4, Jan. 1967	33,200

Approximately 8 per cent of the Journals are sold to overseas readers in more than 50 countries.

Terminology Used in the Journal

The Journal uses the standards laid down by the British Standards Institution with respect to terms, definitions, letter symbols, signs and abbreviations. When changes occur in any of the standards, and as additions are made, they are introduced in the Journal as soon as the new standards have been published, and, if it is considered necessary, a footnote is added on any page of the Journal where any such standard is used.

For this and future issues of the Journal two long-established standards have been replaced by new ones. Firstly, the term "hertz" replaces the familiar term "cycles/second;" the symbol Hz will normally be used, the standard prefixes being added to form the multiples of the basic unit, thus: kHz, MHz, GHz and THz. Secondly, the symbol db has been used for the unit of transmission, the decibel. The British Standard has for long given the symbol dB with a footnote stating "The abbreviation db is generally used in telecommunications." However, in view of the recent increasing acceptance of the international recommendation that dB be the approved symbol for decibel, the British Post Office has elected to change to this standard. It is, therefore, an appropriate time for the Journal to follow suit, the abbreviation dB also being used in all the variety of forms in which it appears, e.g. dBm and dBm0.

Syllabi and Copies of Question Papers for the Telecommunication Technicians' Course.

The syllabi and copies of question papers set for examinations of the Telecommunication Technicians' Course of the City and Guilds of London Institute are not sold by *The Post Office Electrical Engineers' Journal.* They should be purchased from the Department of Technology, City and Guilds of London Institute, 76 Portland Place, London, W.1.

Readers are reminded, however, that books of model answers to certain of the City and Guilds of London Institute examinations in telecommunications are published by the Board of Editors. Details of the books available are always given at the end ofthe Supplement to the Journal.

Journal Binding

It is regretted that, due to the difficulty of getting readers' copies bound, it has been necessary to raise the cost of binding a complete set of Journal parts to 25s.

Institution of Post Office Electrical Engineers

Retired Members

The following members, who retired during 1966, have retained their membership of the Institution under Rule 11(*a*):

J. Brady, 6 Bavington Drive, Fenham, Newcastle-upon-Tyne, Northumberland.
R. N. Renton, Thatched Cottage, Ash Green, Aldershot, Hants.
H. Williams, 65 Tudor Close, Seaford, Sussex.
S. L. F. Fagg, 32 Bouveric Road, Chelmsford, Essex.
E. A. Ching, 39 Hawthorne Avenue, Eastcote, Ruislip, Middlesex.
S. G. Crump, 19 Marlyns Close, Burtham, Guildford Surrey.
R. L. Bull, "Greenfields," Bishops Farm Close, Oakley Green, Windsor.
A. J. Cawsey, 25 Stoberry Avenue, Wells, Somerset.
R. H. Franklin, c/o 2-12 Gresham Street, London, E.C.2.
J. S. Gill, 11 Malvern Drive, Acklam, Middlesbrough, Yorkshire.
R. Grosse, 10 Beechwood Crescent, Compton Place Road, Eastbourne, Sussex.

A. B. WHERRY,
General Secretary,

Book Reviews

"Antenna Analysis." Edward A. Wolff. John Wiley and Sons. xviii+514 pp. 259 ill. 188s.

This excellent book is the culmination of material prepared for a course of lectures on aerials and brings an up-to-date introduction to most aspects of aerial design. It is intended for post-graduates who have a good understanding of electromagnetic and transmission-line theory. The principles of most of the fundamental problems associated with aerial theory are treated individually. If the reader requires to concentrate on one particular subject he can, after studying the appropriate section, prove his knowledge by completing the problems set at the end of the section. He then has a set of references to more complete expositions and to broader applications. In the book, the references could well have been given after the problems.

Typical subjects covered are: system considerations, the point-source antenna followed by many types of wire, slot, travelling-wave, lens, helix and spiral aerials. Open wave-guide and horn radiators are included in the chapter on slot antennas; apertures are treated in a chapter separate from reflector systems.

The analysis would have been more complete if low-noise systems were covered, since these are of particular interest to the radio astronomer, the space-communication engineer and to the scientist studying the troposphere.

Considering the high quality of the book generally, the three-dimensional diagrams could have been portrayed with more skill since they confuse rather than assist the reader.

J.E.R.

"Microelectronics Fabrication Equipment, 1966-1967." Edited by G. W. A. Dummer and J. Mackenzie Robertson. Pergamon Press, Ltd. xi+531 pp. 532 ill. 140s.

The volume contains detailed descriptions of a wide range of specialized equipment used in the fabrication of integrated circuits and micro-miniature assemblies, compiled from descriptions and detailed specifications supplied by the manufacturers, and presents a useful up-to-date cross-section of the equipment currently available in a field which is expanding rapidly in both size and importance. A large number of illustrations have been included which usefully augment the information given on the operation and applications of the majority of the equipment listed. The book is intended to be a guide for electronic engineers and designers concerned with microelectronics research, development, engineering and production. The relative merits of different items of equipment which fulfil the same basic function are not discussed.

D.B.

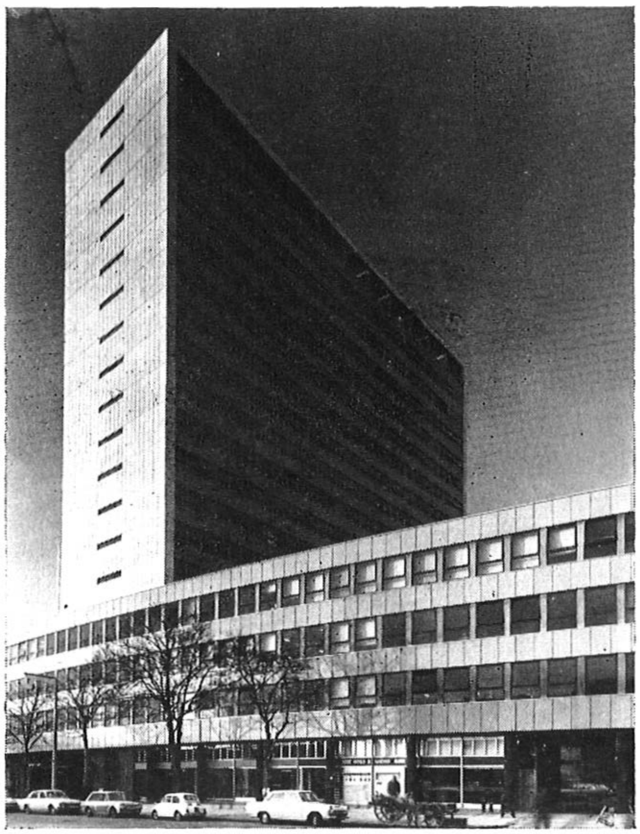
Regional Notes

Northern Ireland

A NEW TELEPHONE MANAGER'S OFFICE FOR BELFAST

On 2 December 1966 Churchill House in the centre of Belfast was officially opened by the Postmaster General. The new building is now the Telephone Manager's Office for Belfast Telephone Area. Having 18 storeys and a height of over 200 feet, it is the tallest office block in Ireland. The accommodation is shared with the Northern Ireland Government Ministry of Finance, who occupy just under 50 per cent of the available floor area. This Ministry carries out, for the Post Office in Northern Ireland, the building and engineering services which are the responsibility of the Ministry of Public Buildings and Works in the rest of the United Kingdom. The building is shown in the photograph.

The heating and the lift installations were designed by the Ministry engineers in conjunction with the Post Office, and the installations were carried out under Ministry contracts. Maintenance of these services will be carried out by the Post Office electric-light and power staff.



The heating load of the building is divided into four zones, each zone being supplied from a calorifier in the boiler room, and there are a further two calorifiers for domestic hot water. The system is powered by three oil-fired boilers each having a maximum output of 3,000,000 B.t.u./h.

The primary circuit between the boilers and the calorifiers operates at medium pressure, using the gravity head available from an expansion tank at the top of the building. The control system in this circuit maintains a flow temperature of 290°F and automatically adjusts the number of burners and the variable firing rate of each burner to meet the requirements of varying load demands. The calorifier secondary circuits to the zones are low-pressure systems operating at 180°F, and each zone is independently controlled by outside compensators and room-averaging thermostats, the zones operating under any one of four modes of operation. The mode of operation can be selected by a switch on the control panel to give the most economical running arrangement to suit the prevailing weather conditions at any time of the year.

A pneumatic control system is used for the secondary zone controls. This operates on compressed air at 15 lb/in^2 and uses pneumatic thermostats controlling diaphragm-operated valve actuators. Churchill House is the first Post Office building where this type of control system is used.

The passenger lift installation consists of a group of five Otis Autotronic lifts having a group-supervisory control system. This system automatically selects any one of four despatching programs to handle the prevailing type of traffic; up peak, up-down or off peak, down peak and automatic zoning, intermittent. The lifts operate at 700 ft/min and are therefore among the fastest in use in Post Office buildings.

The opening ceremony took place in the dining room on the third floor, and the P.M.G. unveiled a plaque in the ground-floor entrance hall by remote control. The guests on the third floor were able to see the unveiling by means of a closed-circuit television link. About 300 of the Telephone Manager's staff were able to see the whole ceremony by means of another television link to six monitor sets on the second floor.

A. N.

Midland Region

FIRE AT WORCESTERSHIRE POLICE HEADQUARTERS

At 09.15 on 18 October 1966 fire broke out on the second floor of the headquarters of the Worcestershire County Constabulary at Hindlip Hall, a former stately home, situated 4 miles from Worcester.

On the ground floor is an apparatus room with a P.A.B.X. No. 2, with nine exchange lines, 16 private wires and 48 extensions. Adjacent is a telegraph instrument room equipped with a telex machine, teleprinter, auto transmitter, and teleprinter switchboard. Next to this, and in the main central part of the building, is the information room with a night switchboard P.M.B.X. 1/4, and three key-and-lamp units fitted into three specially made positions in the control table; there are also WB 400 and WB 600 control unit, the M5 and M50 motorway-telephone control switchboard, and the M5 road warning-sign control panel. The main switchboard, Section Switch SA 7560, is adjacent to the information room near to the main staircase.

The fire was fanned by a stiff breeze and caused the collapse of the roof within minutes. Very soon water from the fire hoses started to flow through the ceilings in ever increasing torrents. Fortunately members of an installation group and the motorway-telephone maintenance officer were working in the building at the time. Very prompt action was taken to prevent equipment being damaged by water and to maintain services. Tarpaulin sheets were brought out from Worcester to cover as much of the equipment as possible. Meanwhile the police headquarters staff were evacuating the building, removing documents and files.

The main switchboard had to be evacuated because of water and falling debris, but the P.A.B.X. continued to give service under night-switching conditions from the information room with a police officer underneath the tarpaulins. As the situation became worse it was decided to transfer the exchange lines to direct exchange lines in an emergency caravan on the car park, and isolate all extensions on the first and second floors.

The motorway-telephone control panel was covered with a waterproof sheet and could not be staffed, and the road hazard signs became inoperative when the electricity mains failed. Teleprinters and other equipment were moved out when the power failed. Apparatus racks, radio equipment and two civil-defence switchboards in the basement were protected from water, whilst arrangements were in hand to use the emergency switchboard should it be necessary.

As it became impossible to use the information room due to flooding, it was evacuated and the headquarters control carried on from the telephones in the caravan. By mid-day the worst of the fire was over, although the fire brigade were still on site several days later. At 14.30 hr the Chief Constable was advised that as far as could be seen all communication systems were intact. Priority was given to the restoration of power to the telecommunications plant, and to the drying out of the information room. By mid-afternoon the telex and motorway services were being staffed, and by early evening the exchange lines were reconnected to the P.A.B.X.

To replace the damaged office accommodation an empty police house 300 yards away on the main drive was connected by a temporary overhead cable to provide six P.A.B.X. extensions. A further three extensions were provided in the main building. This was completed during the evening so that the work of the headquarters could be resumed next morning. During the whole of this time telephone service to Hindlip Hall had been maintained and the only damage by fire and water was to 14 extensions. This incident has highlighted the need for an adequate supply of waterproof sheets, strategically located and readily available in any part of the area.

A. N. C. and J. E. H. H.

AMBERGATE ELECTRONIC EXCHANGE

On Thursday 15 December 1966 a unique ceremony took place in the quiet and solitude of the Derbyshire Peak District with the opening of the new electronic telephone exchange at Ambergate. The opening ceremony was carried out before groups of spectators in Fleet Building, London, and Ambergate telephone exchange, which were linked by closed-circuit television.

The Deputy Chairman of the Post Office, Mr. J. E. Wall, O.B.E., introduced the ceremony from Fleet building, which began with a short film of Ambergate village and the old and new exchanges. The Postmaster General, the Rt. Hon. Edward Short, M.P., spoke of the development of electronic exchanges and the Department's policy for modernizing the telephone system to meet the needs of the 1970s. Mr. Short explained that the Ambergate TXE 2 exchange is the first production electronic unit to be produced in Europe, and it will be followed by about 50 more similar units over the next 18 months. Thereafter, large-scale production will supply rapidly increasing quantities to meet the telephone service expansion and modernization program.

Mr. G. Forshaw, representing Ericsson Telephones, Ltd., who installed the equipment, handed over the exchange to the Post Office, represented by Mr. E. G. Hucker, Director, Midland Region. Mr. Hucker, on acceptance, carried out the change-over from the old manual exchange to the new electronic exchange and invited Councillor B. Boam, B.E.M., J.P., Chairman of Ripley Urban District Council, to make an inaugural call to the Postmaster General.

The initial provision of equipment is for 750 subscribers, but the building capacity allows for an exchange with a 3,000-line multiple.

T.A.B.

Eastern Region

A MINIATURE PUBLIC-ADDRESS SYSTEM

To facilitate the control and location of staff in the Tylers Avenue sorting office at Southend on Sea, the Head Postmaster requested that a temporary public-address system should be installed for the Christmas pressure period. Although the notice was rather short a quotation of £25 was obtained for the hire of a system for a period of two weeks from a local firm. Since the request would be repeated each year it was decided to make one.

The heart of the system was the Sinclair Z 12 transistorized amplifier which, although measuring only 3 in. × 1·8 in. × 1·3 in., is capable of an output of 13 watts with an 18-volt power supply. Two of these were mounted in a Telephone 706 C.B. case and the normal handset was replaced by a Handset No. 6 which includes a non-locking press button. This was necessary because the gravity-switch mechanism had to be removed from the case to allow sufficient space for the amplifiers. The system was powered by dry cells and the press button connected these to the circuit. The normal transmitter was replaced by a Receiver No. 4T. Eight speakers were mounted on baffles, installed in suitable situations, and connected to one or other of the amplifiers.

It was found during testing that instability was present when switching on, and this was thought to be due to induction between the pair of wires in the handset cord to the press button and those to the transmitter. An 8 μF capacitor across the power-supply terminals of the amplifier cured the trouble. It is doubtful if the full 26 watts was delivered to the speaker system since the Receiver 4T, used as a microphone, would not fully load the amplifier input. Nevertheless, the volume was satisfactory.

In practice, the system worked well and had some advantages over a more elaborate arrangement. Being a transistor circuit there was no warm-up time; the Inspector in whose office it was installed merely had to lift the handset, press the button and speak, and of course it took up no more space on his desk than a normal telephone. The press button was a useful safeguard which would have had to be provided since, if the handset had been inadvertently left off, not only would there have been a waste of battery power but conversations in the office would have been broadcast to the whole staff.

The cost of the whole job was less than £15. This represents a worth-while financial saving, particularly as the Head Postmaster confirms that his request will be repeated next Christmas.

South-West Region

SEVERN BRIDGE AND WYE VIADUCT

One of the unique features of the Severn suspension bridge is the employment of a hollow box section to form the road deck. The box is 10 ft high and 80 ft wide, with footway and cycle track cantilevered on each side. This box construction is continued overland on piers across the Beachley peninsula and thence over the River Wye, making a total length of nearly 2 miles from the Aust abutment of the Severn bridge to the west abutment of the Wye bridge.

It had been decided to provide six 4 in. steel ducts along the bridge for Post Office use, and, in spite of the Post Office efforts to have jointing points provided in a position where access could be obtained to their points from the footway or cycle track, the bridge designers insisted on them being provided in the centre of the bridge for structural reasons. As it was intended that the box section of the bridge should be sealed from the atmosphere to prevent corrosion the jointing chambers and pipe network which are open to the atmosphere had to be effectively sealed from the box section in which they are housed.

Steel pipes of 4 in. internal diameter were used, the ends being chamfered internally to prevent damage to the cables. They were joined into a continuous length by welding metal sleeves over the butted ends *in situ*. The complete operation was the subject of two separate contracts: one for the Severn bridge, and one for the Wye bridge and viaduct. For the Severn bridge, alignment of the pipes was achieved by means of a jig which clamped the nest of six pipes in position while the sleeves were fitted and welded. At the Wye bridge and viaduct, packing pieces were inserted between the sleeves and the pipes to align the pipes and wedge the sleeves in position for welding.

There are two sets of six pipes running the length of the structure, one set being for Post Office use and the other for bridge services such as street lighting. The pipes run into common jointing manholes at approximately 500 ft intervals. The manholes are in general 15 ft long, 12 ft wide and 6 ft high between beams, and have a clear height of 5 ft 6 in. The sides and bottoms of the manholes were formed by fitting plates between the transverse diaphragms stiffening the bridge box section. The diaphragms themselves form the ends of the manholes. Inside the manholes there is no separating partition between the two sets of plant, but enamelled plates bearing the words POST OFFICE CABLES in red letters on a white ground have been provided to prevent possible confusion. Post Office wall-type cable bearers are welded to the walls of the chamber for cable supports, and anchor points for cabling are fitted at strategic points.

The considerable expansion of the metal structure is taken up at two points on the suspension bridge, one at each tower, and at one point on the Wye bridge and viaduct. At the towers the cables are laid in a length of trunking fixed on one side of the expansion gap and projecting into a chamber on the other side. The trunking turns at right angles at its free end and from this point the cables will be suspended for about 11 ft on catenaries at right angles to the line of the bridge and thence to brackets attached to the walls of the chamber. An expansion of 39 in. taken up in this way results in a change of dip of the catenary of only $5\frac{1}{2}$ in. At the Wye expansion point the cables are simply suspended across the gap attached to chains in line with the length of the structure. In order to maintain the air seal of the bridge section it was necessary to seal the pipes into funnel-shaped structures built into the bridge. The wide ends of the funnels accommodate the vertical movement of the cables arising from expansion.

Where the pipes pass through the hollow concrete bridge-suspension anchorages changes in line and level had to be accommodated. To facilitate this a gallery was erected to form a jointing chamber within the anchorage. The gallery was made strong enough to carry loading coils and other equipment.

Seven pairs of motorway emergency telephones were installed at the sides of the bridge and conveniently situated adjacent to manholes. Pipes, 4 in. in diameter, were used to connect the emergency-telephone pillars to the manholes in the centre of the bridge. The only cable provided in the bridge at the outset was the emergency telephone cable. This cable was protected in the jointing chambers by locally-purchased flexible aluminium tubing, and anchored against creepage.

Draw ropes were provided in all pipes. Pneumatic "rodding" proved highly successful in the air-tight pipes, the 12 miles of pipe being dealt with in approximately 350 manhours.

N.S.J.

Associate Section Notes

Canterbury Centre

The winter session commenced with a visit to the Port of London docks in August, followed by a visit to a cider works at Smarden.

The annual dinner was held on 20 October and approximately 50 members and guests were given a thought-provoking and, at times, somewhat hilarious talk on communications by the Officer Commanding Manston, Wing Commander D. B. Wills, D.F.C.

On Tuesday, 15 November, a coach containing a Quiz Team and supporters left Canterbury for London, with high hopes of bringing back to the Area the Quiz Trophy (a replica of the Post Office Tower), which is competed for annually by Centres in the London and South East Areas. After being entertained most generously by members of the London Centre, the contest was keenly fought out between a team from London South-West Area and Canterbury. The President of the Associate Section, Mr. E. Hoare, acted as Question Master and presented the trophy to the Canterbury team. Our thanks to all concerned for making this a memorable day.

On Tuesday, 1 December, approximately 86 members and guests were present at a talk given by Messrs. Bluring, Hall and Skinner, Exchange Equipment and Accommodation Branch, Engineering Department, the subject being "An Introduction to Crossbar Exchanges for the Canterbury Area." A visit to the Borg Factory at Whitstable was attended by 12 members.

The Committee would like to take this opportunity of wishing our retiring President and Telephone Manager, Mr. C. W. A. Kent, a very happy and long retirement, and thanking him for the interest shown in the Centre's activities.

B. C.

Reading Centre

The Reading Centre has nearly completed its winter series of talks, most of which were illustrated by slides or films and some included demonstrations of working equipment.

Our program to date has been as follows:

"The Robophone," a sophisticated telephone answering device.

The work of the Central Electricity Generating Board.

Inland waterways.

Microcircuitry, interconnexions and packaging.

Crypton electronic car tuning.

As a follow up to the last item, our members were able to have a practical demonstration of electronic tuning on their own cars.

The annual general meeting was held on 11 April.

P. L. C.

London Centre

"The Problems Posed by Paint" was the subject of our November meeting. The talk was given by Dr. P. E. Taylor of the London Materials Section, Engineering Department. Dr. Taylor described the composition of paint from the time when just basic colouring materials were used up to the modern synthetic varieties. The home decorator was well catered for both in choice of materials and methods of application. The many questions which followed the talk showed how interested the members were in this particular subject.

On 13 December Mr. W. Barker, lecturer for the Consumer Association, who publish "Which" Magazine, gave a talk on "The Consumer Association—What It Means to You." Unfortunately the attendance was very poor but those who did turn up had an interesting evening discussing a variety of subjects with Mr. Barker.

Dr. J. E. Smith, of Shell International Petroleum Co., Ltd., gave an excellent lecture on 24 January entitled "The North Sea Search for Oil and Gas." Dr. Smith explained, with the aid of colour slides, the type of ground where oil is likely to be found and how test drillings are made. Pictures were shown of the various types of under-water drilling rigs which are in use. Their size and shape vary greatly, from the first which stood in 6 feet of water up to the present model which is capable of working in 1,000 feet of water. To the layman the size of the deep-water rigs is fantastic and a credit to those engineers who designed and built them. The work of an oil man can be very difficult and often dangerous. The second half of the evening consisted of a very excellent Shell film called "Underwater Search" followed by a great variety of questions from a very interested audience.

Lunch-time film shows have proved very popular in some areas as have various visits arranged by different areas for their own members.

Visits have been arranged for April to Rank, Bush Murphy at Welwyn Garden City and to Dimplex of Southampton. In November we will pay another visit to Stewart & Lloyds steel works at Corby.

R. W. H.

Exeter Centre

The 1966–67 winter program started with a talk by Mr. C. L. Cload entitled "Pyramids and Tombs of Ancient Egypt." This talk, like all others given by Mr. Cload, was well-attended and enjoyed by all. Requests for a further appearance of this very able speaker are still being received.

The main event of the winter was the return match of the quiz between Exeter and Torquay which was held at the Drive Inn at Newton Abbot on 9 December. About 70 attended the quiz to see Torquay win by 47 points to 37. Both teams did well in answering what was generally agreed to be a difficult set of questions. A humorous break was provided during the interval by the inter-team questions. The Centre is indebted to Mr. E. H. K. Brown (Question Master), Messrs. P. James and R. Powlesland (Score and Time Keepers) and Messrs. G. Strodzinski and N. West ("Sound Effects").

In January Mr. C. L. Chalk, presented his paper "Grid Developments in South West England." Thirty-eight members and visitors attended this meeting which was extended considerably by question time.

Secretaries of other centres may wish to note that a set of general knowledge and technical questions and answers for a 1-hour quiz is available on request.

The summer program has not yet been arranged but it is hoped to organize a mid-week trip to either a B.M.C. car factory or the Esso oil refinery, and evening or Saturday visits to Decca School of Navigation at Brixham, and Hill, Palmer and Edwards (confectioners).

T. F. K.

Bath Centre

In the autumn of last year our meetings included a talk on "Cacti and Succulents" by two of our members, Messrs. R. E. Woolford and R. M. Cohu. This was illustrated by coloured slides and actual examples of plants grown by them. Also, we were visited by Mr. Richard Prior, gamewarden and author who talked on the number and distribution of deer in Great Britain and, in particular, of his observation of deer for the Forestry Commission at Cranbourne Chase.

A visit to Birmingham in November was so popular that members were split into two parties who travelled on separate days. We visited the Rover Company at Solihull and were conducted over their car-assembly lines. We were fortunate in obtaining permission to include on this trip visits to the Birmingham Television Switching Centre and Post Office Radio Tower.

In December a smaller number visited the Post Office Engineering Museum at Taunton Telephone Exchange. This consists of a wide variety of early telephone and telegraph apparatus collected by Mr. P. Povey, who read a paper on the origins and early development of these systems (Mr. Povey would be very grateful to hear of any interesting equipment which should be preserved, and the Engineering Department encourages the transfer of items to him).

Combined with this visit we also were shown over Osmond's Church Organ Works at Taunton. Production of church organs was seen from sheet metal for pipes to the completed organs, which were played for us.

In complete contrast to the Museum, in January we were read a paper by Mr. G. H. Bennett on "Pulse Code Modulation." This system is to be provided for Bath to Bristol junction traffic in the near future, and it proved to be of great interest to the large number who attended.

W. J. R.

Birmingham Centre

The following officers were elected for the 1966–67 session. *Chairman:* Mr. D. F. Ashmore; *Secretary:* Mr. E. H. Howarth; *Treasurer:* Mr. B. W. Headley; *Assistant Secretaries:* Mr. B. Jewkes and Mr. L. W. Baldwin; *Circulation Officers:* Mr. J. R. Smith and Mr. L. Murray.

A varied program has been arranged and includes visits to Stewart & Lloyds steel works at Corby, Webb Corbett Crystal Glass, Stourbridge, and Ffestiniog power station.

Interest in the activities of the Centre has been maintained and membership has increased. We lost 12 members through promotion and to these we wish "Good Luck" in their new jobs.

The annual general meeting will be held on 2 May 1967 and all members are asked, in their own interest, to attend and bring fresh ideas for the future programs.

Due to the long waiting lists, two visits have already been arranged for 1967 after the annual general meeting. These are a visit to the Shell Refinery, Ellesmere Port, on 5 May, and to M.I.R.A., near Nuneaton, in the summer.

B. J.

Aberdeen Centre

We should like to record our thanks to Mr. G. D. Adam for his service to the Aberdeen Centre as Secretary and Treasurer. We congratulate him on his promotion to Assistant Executive Engineer and wish him every success in the future.

Meetings during the session were:

October—a talk by Mr. G. D. Adam on "Network Analysis."

November—a talk by Mr. R. J. Gilbert on "Amateur Telescope Making."

December—an evening visit to Aberdeen City Police C.I.D.

R. M.

Dundee Centre

Our festive-season entertainment took the form of a film show. Two films were shown: "Forth Road Bridge," the prize-winning Shell-Mex account of the construction of this now famous landmark spanning the Firth of Forth, and one entitled "Heather Honey."

The later film was a joint effort by Mr. McGregor Williamson, a Technical Officer at Cupar, Fife, and Mr. Gordon Lumsden, a local hairdresser. Although this was their first venture as film makers the production showed the keen interest both share in their respective hobbies, McGregor as a photographer and Gordon as a producer of honey.

R. T. L.

Inverness Centre

Mr. W. Sheldon, our former External Works Executive Engineer, gave our November talk: his subject was a "Review of B.P.O. A.C. Signalling Systems." He described the development of all types of a.c. signalling systems, starting at S.S. A.C. No. 1 and going on to the latest S.S. A.C. No. 13 system. Afterwards, Mr. Sheldon dealt ably with a variety of questions put to him; the meeting was concluded by Mr. J. W. Innes, Chairman, thanking Mr. Sheldon for his forthright and interesting talk.

(Continued on page 82)

Staff Changes

Promotions

Assistant Staff Engineer to Staff Engineer

Name	Region, etc.	Date
Thomas, J. F. P.	E.-in-C.O.	14.11.66
Harris, L. R. F.	E.-in-C.O.	16.1.67

Regional Engineer to Telephone Manager

Name	Region, etc.	Date
Surman, W. L.	Mid. Reg. to N.E. Reg.	17.10.66

Area Engineer to Deputy Telephone Manager

Name	Region, etc.	Date
Barnsdall, L. G. W.	W.B.C. to N.W. Reg.	21.11.66

Senior Executive Engineer to Deputy Telephone Manager

Name	Region, etc.	Date
Bearham, D. R.	L.T. Reg.	11.2.66

Executive Engineer to Area Engineer

Name	Region, etc.	Date
Knight, N.	S.W. Reg. to S.E. Reg.	24.11.66
Parker, R. J.	E.-in-C.O. to L.T. Reg.	10.11.66
Draper, W. H.	L.T. Reg.	1.12.66
Holdsworth, F.	N.E. Reg.	15.12.66
Cook, F. W.	L.T. Reg.	1.12.66

Executive Engineer to Senior Executive Engineer

Name	Region, etc.	Date
Light, R. A. M.	E. Reg.	28.11.66
Price, C. K.	E.-in-C.O.	12.12.66
Budgen, J. E.	S.E. Reg. to E.-in-C.O.	15.12.66

Executive Engineer (Open Competition)

Name	Region, etc.	Date
Barrett, C. J.	E.-in-C.O.	3.10.66
Pais, A. F.	E.-in-C.O.	1.11.66
Bayfield, R.	E.-in-C.O.	25.11.66
Barnes, D. J.	E.-in-C.O. to Mid. Reg.	5.12.66

Assistant Executive Engineer to Executive Engineer

Name	Region, etc.	Date
Witherow, E.	Scot. to E.-in-C.O.	28.11.66
Shoreland, F.	S.W. Reg. to W.B.C.	21.11.66
Missen, J. O	E. Reg.	17.11.66
Watts, D. G.	S.W. Reg.	14.12.66
Virgin, R. M.	S.W. Reg.	14.12.66
Holder, R. G.	S.W. Reg.	14.12.66
Tetstall, A. A. W.	Mid. Reg.	9.12.66
Leckenby, G.	N.E. Reg.	14.12.66
Stevens, I.	E.-in-C.O.	7.12.66
Perry, E. G.	L.T. Reg.	7.12.66
Mew, L. W.	N.E. Reg.	28.12.66
Webb, A. G.	Scot.	7.12.66
Meredith, L. A.	E.-in-C.O.	7.12.66
Hartley, F.	N.W. Reg.	8.12.66
Williams, F. E.	Mid. Reg.	9.12.66
Underhill, K. C.	Mid. Reg.	9.12.66
Wood, H. E.	Mid. Reg.	9.12.66
Ferrand, J.	Mid. Reg.	9.12.66
Mansfield, W. V. L.	L.T. Reg.	7.12.66
Mason, D. J. H.	E.-in-C.O.	7.12.66
Fagg, D. E.	E.-in-C.O.	7.12.66
Simcox, M. S.	Mid. Reg.	9.12.66
Clement, D. M.	Mid. Reg.	9.12.66
Verdon, A. T.	E.-in-C.O.	7.12.66
Brown, N. W.	E.-in-C.O.	7.12.66
Jones, G. I.	E.-in-C.O.	7.12.66
Hallam, R. H.	E.-in-C.O.	7.12.66
Didcock, F. E.	E.-in-C.O.	7.12.66
Rowe, J. A. T.	E.-in-C.O.	7.12.66
White, P. E.	E.-in-C.O.	7.12.66
Powell, L. A.	E.-in-C.O.	7.12.66
Marsland, D. J.	N.W. Reg.	12.12.66
Slight, J. S.	L.T. Reg.	7.12.66
Line, J. F.	L.T. Reg.	7.12.66
Bass, R. A. A.	L.T. Reg.	7.12.66
Dabbs, E.	L.T. Reg.	7.12.66
Gillan, J. D.	L.T. Reg.	7.12.66
Long, E.	N.E. Reg.	14.12.66
Doble, J. E.	E.-in-C.O.	7.12.66
Smith, F.	N.W. Reg.	8.12.66
Thraves, E. A. J.	L.T. Reg.	7.12.66
Hebden, H. E. G.	L.T. Reg.	7.12.66
Pallett, S. W.	L.T. Reg.	7.12.66
Gillespie, J. M.	L.T. Reg.	7.12.66
Endean, F. C.	L.T. Reg.	7.12.66
Goard, R. E.	L.T. Reg.	7.12.66
Howe, F. L.	L.T. Reg.	7.12.66
Antill, L. A.	Mid. Reg.	9.12.66
Mabey, J. E.	E.-in-C.O.	7.12.66
Drury, C. B.	E.-in-C.O.	7.12.66
Green, G. H. C.	E.-in-C.O.	7.12.66
Elliott, H. F.	E.-in-C.O.	7.12.66
Mitchell, J. T. H.	E.-in-C.O.	7.12.66
Saunders, L. E.	E.-in-C.O.	7.12.66
Daniel, R. E.	E.-in-C.O.	7.12.66
Orridge, G. E. A.	E.-in-C.O.	7.12.66
Stevens, F. W. P.	C.E.S.D.	7.12.66
Baker, W. P.	L.T. Reg.	7.12.66
Pearson, H. A.	L.T. Reg.	7.12.66
Chadwick, E. H.	N.W. Reg.	8.12.66
Solley, S. C.	L.T. Reg.	7.12.66
Hinchcliffe, K. B.	L.T. Reg.	7.12.66
Hedinger, J. F.	L.T. Reg.	7.12.66
Nott, H. C.	L.T. Reg.	7.12.66
Bullen, D. C.	L.T. Reg.	7.12.66
Allan, A. W.	L.T. Reg. to E.-in-C.O.	14.12.66
Roads, B. J.	L.P. Reg.	14.12.66

Promotions—*continued*

Assistant Executive Engineer to Executive Engineer—*continued*

Name	Region, etc.	Date
Pickthorn, P. W. G.	S.W. Reg.	14.12.66
Ford, G. J.	Scot.	29.12.66
Thompson, J. A.	Scot.	30.1.67

Assistant Executive Engineer (Open Competition)

Name	Region, etc.	Date
Hunter, J. J. (Miss)	E.-in-C.O.	3.10.66
Punwani, R. A.	E.-in-C.O.	5.10.66
Storey, M. H.	E.-in-C.O.	24.10.66
Latchu, H. C.	E.-in-C.O.	3.10.66
Davey, B. V.	E.-in-C.O.	3.10.66
Stevenson, I. J.	E.-in-C.O.	24.10.66
Barnes, D. J.	E.-in-C.O.	3.10.66
Gray, D. A.	E.-in-C.O.	15.9.66
Greenwood, W.	E.-in-C.O.	12.9.66
Sharp, A. W.	L.T. Reg. to E.-in-C.O.	3.10.66
Grant, D.	N.E. Reg. to E.-in-C.O.	31.10.66
Bentley, D. F.	L.T. Reg. to E.-in-C.O.	3.10.66
Hayman, G. D.	Mid. Reg. to E.-in-C.O.	24.10.66
Phillips, J. E.	E.-in-C.O.	14.9.66
Springett, R. C. M.	E.-in-C.O.	3.10.66
Hancock, M. A.	E.-in-C.O.	3.10.66
Tite, P. G.	E.-in-C.O.	3.10.66
Davey, L.	E.-in-C.O.	3.10.66
Brentnall, P. G.	E.-in-C.O.	3.10.66
Penney, R. S.	E.-in-C.O.	3.10.66
Wallis, D. R.	Mid. Reg. to E.-in-C.O.	3.10.66
Mathias, G. E.	H.C. Reg. to E.-in-C.O.	3.10.66
Parr, K. G.	Mid. Reg. to E.-in-C.O.	3.10.66
Douglas, H. J.	L.T. Reg. to E.-in-C.O.	26.9.66
Ward, M.	E.-in-C.O.	6.9.66
Coates, S.	E.-in-C.O.	19.10.66
Thomas, C. J.	W.B.C. to E.-in-C.O.	24.10.66
Phoenix, A.	E.-in-C.O.	5.10.66
Childs, M. A.	E.-in-C.O.	12.9.66
McConnell, R. D.	E.-in-C.O.	28.10.66
Collier, N.	E.-in-C.O.	24.10.66
Hockenhull, J. H.	E.-in-C.O.	3.10.66
Thomas, I. L.	E.-in-C.O.	3.10.66
Randell, R. B.	E.-in-C.O.	3.10.66
Richards, R. A.	E.-in-C.O.	24.10.66
Croucher, T. A.	E.-in-C.O.	24.10.66
Yates, C. C.	E.-in-C.O.	24.10.66
Search, E. G.	E.-in-C.O.	24.10.66
Newman, G. L.	E.-in-C.O.	24.10.66
Underwood, D. B.	E.-in-C.O.	24.10.66
Pritchard, A.	E.-in-C.O.	24.10.66
Barber, M. S.	E.-in-C.O.	24.10.66
Hopkins, D. J.	E.-in-C.O.	24.10.66

Inspector to Assistant Executive Engineer

Name	Region, etc.	Date
McGowan, T.	Scot.	10.10.66
Ferguson, J. H.	Scot.	27.9.66
Croker, W.	N.W. Reg.	26.9.66
Caunt, G.	N.W. Reg.	26.9.66
Robinson, J.	N.W. Reg.	26.9.66
O'Neill, T.	S.W. Reg.	17.10.66
Hayes, M.	E. Reg.	3.11.66
Hazeldine, J. M.	N.W. Reg.	21.11.66
Makin, J.	N.W. Reg.	7.11.66
Fisher, A.	N.W. Reg.	7.11.66
Hodges, F.	Mid. Reg.	23.11.66
Moore, C. E. S.	S.W. Reg.	14.11.66
Munro, D.	S.W. Reg.	30.11.66
Procter, F. D.	Mid. Reg.	12.12.66

Technical Officer to Assistant Executive Engineer

Name	Region, etc.	Date
Richardson, F. H.	N.W. Reg.	6.10.66
Donaldson, T. M.	Scot.	16.8.66
Jackson, R.	Scot.	7.10.66
Fairfoull, R.	Scot.	26.9.66
Aitchison, A.	Scot.	10.10.66
Bennett, W. L.	N.W. Reg.	14.10.66
Kreutzer, H. R.	N.W. Reg.	7.10.66
Batty, K.	N.W. Reg.	3.10.66
Griffiths, C. P.	W.B.C.	4.10.66
Pointer, E. D.	Scot.	27.9.66
Johnstone, W.	Scot.	27.9.66
Rushton, D.	N.W. Reg.	31.10.66
McAdam, Q. A.	N.W. Reg.	26.9.66
Black, P.	N.W. Reg.	26.9.66
Alford, K.	S.W. Reg.	24.10.66
Woolford, R. E.	S.W. Reg.	27.9.66
Phillips, A. P.	S.W. Reg.	27.9.66
Dent, H.	S.W. Reg.	27.9.66
Harrison, F. O.	N.W. Reg.	24.10.66
Moyle, N. A.	Mid. Reg.	17.10.66
Martin, J. A.	S.W. Reg.	6.10.66
Shea, G. H.	N.W. Reg.	6.10.66
Traverse, G.	N.W. Reg.	6.10.66
Cormack, W. M.	E.-in-C.O. to E.T.E.	5.10.66
Harrison, C. W.	N.W. Reg.	6.10.66
Clark, C. G.	Mid. Reg.	17.10.66
Brown, M. W.	Mid. Reg.	17.10.66
Drummond, A. M.	S.W. Reg.	28.10.66
Wallond, F. P.	S.E. Reg.	28.8.59
James, P.	E.-in-C.O.	2.11.66

Promotions—*continued*

Technical Officer to Assistant Executive Engineer—*continued*

Name	Region, etc.	Date
Carey, G.	Scot.	27.6.66
Campbell, J. P.	Scot.	21.11.66
Swan, W. R.	Scot.	20.9.66
Sinclair, J. D. S.	Scot.	26.9.66
Edwards, J. W.	Scot.	3.10.66
Galloway, W. E.	Scot.	16.8.66
Braid, R. A.	Scot.	12.9.66
Robinson, F.	Scot.	11.11.66
Dye, R. J.	Scot	17.10.66
Tink, R.	E. Reg.	3.11.66
Garrad, P. W.	E. Reg.	3.11.66
Atkins, R. B.	E. Reg.	3.11.66
Dring, R. P.	E.-in-C.O.	1.11.66
McLeod, P. J. A.	E. Reg.	3.11.66
Walton, C. T.	E. Reg.	2.11.66
Gillard, A. T.	E. Reg.	3.11.66
Stratton, M. J.	E. Reg.	3.11.66
Jones, V. D.	W.B.C.	1.11.66
Brown, M. L.	Scot.	11.11.66
Woodward, F. W.	Mid. Reg.	9.11.66
Newman, P. S.	Mid. Reg.	9.11.66
Doherty, P. M.	N.I.	6.10.66
Dorr, F. K.	N.W. Reg.	7.11.66
Blackburn, W. H.	N.I.	19.10.66
Pollock, W. J.	N.I.	19.10.66
Worthington, R.	Mid. Reg.	9.11.66
Lawrence, L. H.	Mid. Reg.	9.11.66
Ball, D. H.	Mid. Reg.	9.11.66
Meyrick, A. H.	W.B.C.	25.11.66
Sheppard, E. B.	W.B.C.	25.11.66
King, H. J. A.	Mid. Reg.	18.11.66
Swain, R. A.	Mid. Reg.	23.11.66
Large, J. W.	Mid. Reg.	23.11.66
Toseland, D.	Mid. Reg.	23.11.66
Whiting, G. A.	Mid. Reg.	23.11.66
Potter, J.	Mid. Reg.	23.11.66
Foster, L.	N.W. Reg.	29.11.66
Lawless, H.	Scot.	5.12.66
Greenan, J. P.	Scot.	27.9.66
Donaldson, R. P.	Scot.	30.9.66
Hancock, D. T.	S.W. Reg.	8.11.66
Rugg, G. J.	S.W. Reg.	14.11.66
Richmond, A.	Scot.	11.11.66
Gault, H. J.	Scot.	11.11.66
Ashman, R. J.	S.W. Reg.	8.11.66
Smith, P. E.	S.W. Reg.	8.11.66
Sear, S. J.	S.W. Reg.	14.11.66
Curwood, J. M.	S.W. Reg.	14.11.66
Rodwell, P.	S.W. Reg.	1.12.66
Spray, C. E.	S.W. Reg.	5.12.66
Shiel, R. N.	Mid. Reg.	2.12.66
Vincent, R. J.	S.W. Reg.	9.12.66
Broom, R. D.	S.W. Reg.	19.12.66
Bromby, D. G.	S.W. Reg.	19.12.66
Martin, R. B.	Mid. Reg.	12.12.66
Burton, C. W.	Mid. Reg.	12.12.66
Spilsbury, R. J.	Mid. Reg.	12.12.66

Technical Officer to Inspector

Name	Region, etc.	Date
Playfoot, R. S.	N.W. Reg.	19.10.66
Pettigrew, J. S.	Scot.	28.11.66
Murdoch, W. C.	Scot.	28.11.66
Huck, R. G.	S.W. Reg.	21.11.66
Watson, A. E.	S.W. Reg.	21.11.66

Senior Technician to Inspector

Name	Region, etc.	Date
Reid, J. H.	Scot.	4.10.66
Forrest, F. R.	E. Reg.	3.11.66
Nightingale, E. L.	E. Reg.	3.11.66
Croot, R. A.	E. Reg.	3.11.66
Kirkham, S. J.	E. Reg.	3.11.66
Young, J. M.	E. Reg.	3.11.66
Brand, C. K.	E. Reg.	3.11.66
Rose, H. D.	E. Reg.	21.11.66
Saunders, D. E.	E. Reg.	21.11.66
Carpenter, D. M.	Mid. Reg.	9.11.66
Milson, F. J.	Mid. Reg.	18.11.66
Millard, S. F.	W.B.C.	25.11.66
Jeffcoate, S.	Mid. Reg.	23.11.66
McCulloch, F.	Scot.	11.11.66
Ewing, W. V.	Scot.	28.11.66
Boyt, F.	S.W. Reg.	31.10.66
Hotson, A. W.	Scot.	11.11.66
Reid, T.	Scot.	11.11.66
Quinn, D.	Scot.	12.12.66
Mair, S.	Scot.	11.11.66
Greenberry, H.	S.W. Reg.	5.12.66
Stevens, H. G.	S.W. Reg.	20.12.66

Technician 1 to Inspector

Name	Region, etc.	Date
Windsor, L.	W.B.C.	12.10.66
Robinson, A.	N.W. Reg.	26.9.66
Stroud, W. L.	S.W. Reg.	27.9.66
Checkley, R. C.	Mid. Reg.	17.10.66
Heraghty, J. P.	N.I.	28.9.66
Slaughter, D. G.	E. Reg.	3.11.66

Promotions—*continued*

Technician 1 to Inspector—continued

Name	Region, etc.	Date
Hammond, H. G.	S.E. Reg.	7.11.66
Acton, R. W.	E. Reg.	3.11.66
Tucker, V. H.	E. Reg.	21.11.66
Ward, K. J.	S.E. Reg.	2.11.66
Stowe, A. S.	E. Reg.	3.11.66
Wilks, F. C. E.	E. Reg.	3.11.66
Hawkins, I. F.	E. Reg.	3.11.66
Hunter, R. D.	E. Reg.	3.11.66
Watts, E. G.	S.E. Reg.	2.11.66
Perring, J.	S.E. Reg.	2.11.66
Wynn, L. P.	E. Reg.	3.11.66
Watkins, K. T.	S.E. Reg.	2.11.66
Clifford, E. R.	S.E. Reg.	2.11.66
Miller, S.	S.E. Reg.	2.11.66
Bull, F. C.	Mid. Reg.	9.11.66
Heames, H. R.	Mid. Reg.	9.11.66
Harris, W. B.	Mid. Reg.	9.11.66
Copson, G. F.	Mid. Reg.	9.11.66
Wright, W. A.	Mid. Reg.	9.11.66
Flewitt, W. J.	Mid. Reg.	9.11.66
Brown, R. S.	Mid. Reg.	9.11.66
Walton, R.	Mid. Reg.	9.11.66
Speller, G. H. J.	Mid. Reg.	9.11.66
Barrett, L. D.	Mid. Reg.	9.11.66
Patterson, J.	Mid. Reg.	9.11.66
Dauncey, T. H.	Mid. Reg.	9.11.66
Pendleton, T. E. R.	Mid. Reg.	9.11.66
Mountford, G. F.	Mid. Reg.	9.11.66
Bowler, P. G.	Mid. Reg.	9.11.66
Roberts, R. K.	Mid. Reg.	9.11.66
Dyer, M. N.	Mid. Reg.	9.11.66
Miller, K. H.	Mid. Reg.	9.11.66
Ringrose, A. H.	Mid. Reg.	9.11.66
Workman, G. F.	Mid. Reg.	9.11.66
Howes, J.	N.W. Reg.	29.11.66
Keith, D. S.	Scot.	28.11.66

Assistant Experimental Officer (Open Competition)

Name	Region, etc.	Date
Grant, L. E.	E.-in-C.O.	1.11.66
Woods, B. J.	E.-in-C.O.	14.12.66

Assistant (Scientific) (Open Competition)

Name	Region, etc.	Date
Harridence, M. (Mrs.)	E.-in-C.O.	1.11.66
Pollock, A. B.	E.-in-C.O.	29.12.66
Valleckanthan, S. S.	E.-in-C.O.	29.12.66

Senior Mechanic to Technical Assistant

Name	Region, etc.	Date
Knight, D. J.	E. Reg. to E.-in-C.O.	9.11.66

Mechanic A to Technical Assistant

Name	Region, etc.	Date
Ferguson, K. G.	Scot. to E.-in-C.O.	9.11.66
Wearing, A.	N.W. Reg. to E.-in-C.O.	9.11.66
Sullivan, M.	Mid. Reg. to S.E. Reg.	9.11.66
Naylor, B. J.	N.E. Reg. to E.-in-C.O.	9.11.66
Shaw, N.	N.W. Reg. to E.-in-C.O.	9.11.66

Leading Draughtsman to Senior Draughtsman

Name	Region, etc.	Date
Paine, G. D.	Factories Dept. to E.-in-C.O.	1.11.66

Draughtsman to Leading Draughtsman

Name	Region, etc.	Date
Whiter, D. W.	E.-in-C.O.	8.12.66

Draughtsman (Open Competition)

Name	Region, etc.	Date
Robinson, A. D.	E.-in-C.O.	13.12.66
Sweatman, D. C.	E.-in-C.O.	16.12.66
Milburn, N.	E.-in-C.O.	19.12.66

Executive Officer to Higher Executive Officer

Name	Region, etc.	Date
Athorn, E. R. (Mrs.)	E.-in-C.O.	19.12.66
Perry, J.	E.-in-C.O.	19.12.66

Clerical Officer to Executive Officer

Name	Region, etc.	Date
Sewell, H. W. A.	E.-in-C.O.	7.11.66
Bates, S. T.	E.-in-C.O.	21.11.66

Retirements and Resignations

Staff Engineer

Name	Region, etc.	Date
R. H. Franklin	E.-in-C.O.	9.2.67

Regional Engineer

Name	Region, etc.	Date
Cawsey, A. J.	S.W. Reg.	9.12.66

Area Engineer

Name	Region, etc.	Date
Buckley, A.	N.W. Reg.	14.12.66

Senior Executive Engineer

Name	Region, etc.	Date
Eagle, R. J. A.	L.T. Reg.	3.8.66
Beatson, H.	E.-in-C.O.	31.8.66
Stevens, E. C. C.	E.-in-C.O.	1.9.66
Mulvey, G. P.	E.-in-C.O.	18.12.66

Retirements and Resignations—*continued*

Executive Engineer

Name	Region, etc.	Date
Hudson, F. S.	E.-in-C.O.	27.7.66
Manning, G. A.	E.-in-C.O.	31.7.66
Deadman, D. J. *(Resigned)*	E.-in-C.O.	31.7.66
Sayers, J. R. *(Resigned)*	E.-in-C.O.	29.7.66
King, A. D. *(Resigned)*	E.-in-C.O.	7.8.66
Ching, E. A.	E.-in-C.O.	3.8.66
Fitton, D. *(Resigned)*	E.-in-C.O.	31.8.66
Byrnand, D. S. J. *(Resigned)*	E.-in-C.O.	31.8.66
Yeates, H. W.	Mid. Reg.	28.9.66
Dudley, D. K. *(Resigned)*	E.-in-C.O.	22.9.66
Evans, A. W.	N.E. Reg.	8.10.66
Regan, D. J.	W.B.C.	30.10.66
Lauderdale, F. S.	N.E. Reg.	13.10.66
Scutt, R. S.	H.C. Reg.	28.10.66
Rogers, J. D. *(Resigned)*	E.-in-C.O.	31.10.66
White, R. L. *(Resigned)*	E.-in-C.O.	28.10.66
Miller, R. W.	E.-in-C.O.	30.11.66
Duff, I. F. *(Resigned)*	E.-in-C.O.	30.11.66
Crump, S. G.	S.E. Reg.	31.12.66
Brown, L.	E. Reg.	5.12.66
Hill, M.W. *(Resigned)*	E.-in-C.O.	8.12.66

Assistant Executive Engineer

Name	Region, etc.	Date
Gardner, G.	N.E. Reg.	1.6.66
Beeby, A. V.	Mid. Reg.	2.6.66
Waite, J. R.	S.W. Reg.	2.6.66
Bond, A. H.	S.W. Reg.	10.6.66
Gill, J. S.	N.E. Reg.	17.6.66
Smethurst E.	N.W. Reg.	27.6.66
Wollard, H. L.	E.-in-C.O.	28.6.66
Pitt, J. J. S.	L.T. Reg.	28.6.66
Flavell, J. A.	H.C. Reg.	30.6.66
Stevens, H. E.	L.T. Reg.	2.7.66
Forrest, J.	E.-in-C.O.	2.7.66
Budgen, F. B.	H.C. Reg.	5.7.66
Weeks, C. R. J.	S.W. Reg.	24.7.66
Bennett, A. V.	L.T. Reg.	25.7.66
Carr, G. W.	L.T. Reg.	29.7.66
Rothwell, L. J.	L.T. Reg.	31.7.66
Digby, W.	E.-in-C.O.	31.7.66
Kitchen, F. T. W.	C.E.S.D.	31.7.66
Stone, C. W.	L.T. Reg.	31.7.66
Taylor, G. H. *(Resigned)*	E.-in-C.O.	10.7.66
Culver, R. C. L. *(Resigned)*	E.-in-C.O.	21.7.66
Geere, R. D. *(Resigned)*	E.-in-C.O.	29.7.66
Alexander, H. L.	L.P. Reg.	29.7.66
Cooper, W. C.	L.T. Reg.	31.7.66
Wickens, S. B.	L.T. Reg.	3.8.66
Clarke, T. M.	S.W. Reg.	11.8.66
Wallace, H. A.	L.T. Reg.	12.8.66
McMullin, J. G.	S.W. Reg.	15.8.66
Leslie, H. F.	E.T.E.	21.8.66
Munnery, W. A. E.	H.C. Reg.	31.8.66
Pinchaud, A. R. *(Resigned)*	E.-in-C.O.	23.8.66
Spilsbury, F. A. *(Resigned)*	E.-in-C.O.	31.8.66
Woollven, A. J. W. *(Resigned)*	E.-in-C.O.	31.8.66
Little, J.	N.E. Reg.	13.3.66
Callan, E. R.	L.T. Reg.	31.8.66
Gray, H.	L.T. Reg.	31.8.66
Ward, J. H.	E.-in-C.O.	2.9.66
Bruce, S. J.	E.-in-C.O.	3.9.66
Greenaway, C. R.	E.-in-C.O.	12.9.66
Townsend, E. E. S.	E.-in-C.O.	30.9.66
Reynolds, W. H.	E.-in-C.O.	30.9.66
Bennett, F. G.	E.-in-C.O.	30.9.66
Morris, L. A.	L.T. Reg.	30.9.66
Smith, A. *(Resigned)*	E.-in-C.O.	16.9.66
Greenhill, S. R. *(Resigned)*	E.-in-C.O.	26.9.66
Harvey, H. D.	L.T. Reg.	4.10.66
Moore, G.	S.W. Reg.	8.10.66
Dean, A. A.	N.W. Reg.	8.10.66
Venmore, C. E.	Mid. Reg.	17.10.66
Lewis, F. L.	S.W. Reg.	25.10.66
Mann, W. H. L.	E.-in-C.O.	28.10.66
Jupp, G. F. *(Resigned)*	L.T. Reg.	30.9.66
Smith, A. J. *(Resigned)*	E.-in-C.O.	14.10.66
Pritchard, R. H.	S.W. Reg.	25.10.66
Seward, W. G.	S.W. Reg.	1.11.66
Warne, F. W.	L.T. Reg.	1.11.66
Davies, J. H.	N.E. Reg.	2.11.66
Hardy, A. M.	N.E. Reg.	13.11.66
Fawkes, A. T.	N.W. Reg.	21.11.66

Retirements and Resignations—*continued*

Assistant Executive Engineer—continued

Name	Region, etc.	Date
Horne, E. G.	L.T. Reg.	30.11.66
Evans, H. T.	S.E. Reg.	30.11.66
Richards, E.	N.W. Reg.	30.11.66
Saunders, H.	N.W. Reg.	30.11.66
Forrest, J. H. *(Resigned)*	Mid. Reg.	30.11.66
Winckworth, S. E.	S.W. Reg.	16.11.66
Jones, H. K. M.	Mid. Reg.	25.11.66
Hollely, H.	N.E. Reg.	1.12.66
Wisdom, T. A.	L.T. Reg.	1.12.66
Hoffmeister, J. M.	L.T. Reg.	4.12.66
Crothers, S.	N.I.	15.12.66
Haythornthwaite, F.	E.-in-C.O.	16.12.66
Bell, L. B.	N.E. Reg.	23.12.66
Hunt, R. H.	N.E. Reg.	31.12.66
Wilson, K. E.	E.-in-C.O.	31.12.66
Hewett, C. H.	S.E. Reg.	31.12.66
Church, W. H.	S.E. Reg.	31.12.66
Bliss, S. W.	E.-in-C.O.	31.12.66
Early, W. F. L.	E.-in-C.O.	31.12.66
Davies, E. H.	E.-in-C.O.	31.12.66
Godfrey, L. A. R.	S.W. Reg.	31.12.66
Williams, W. J.	L.T. Reg.	31.12.66
Read, R. J. *(Resigned)*	E.-in-C.O.	30.12.66
Leach, P. R. *(Resigned)*	E. Reg.	30.12.66
Lorentz, P. J. *(Resigned)*	E.-in-C.O.	31.12.66

Inspector

Name	Region, etc.	Date
Bishop, T. E.	H.C. Reg.	24.5.66
McBride, S. T.	N.I.	8.6.66
Vinn, J. M.	L.T. Reg.	17.6.66
Houghton, A. S.	L.T. Reg.	24.6.66
Newton, L.	N.E. Reg.	30.6.66
Newsome, L.	L.T. Reg.	30.6.66
Woods, G. W.	H.C. Reg.	30.6.66
Hollins, J. S.	Mid. Reg.	9.6.66
Earland, S. W. H.	L.T. Reg.	11.7.66
Sellman, W. T.	S.W. Reg.	27.7.66
Plante, F. R. *(Resigned)*	Mid. Reg.	25.7.66
Neale, G. W.	H.C. Reg.	1.8.66
Brandie, A.	Scot.	4.9.66
Sheenan, J. D.	L.P. Reg.	9.9.66
Lever, F. S.	L.T. Reg.	14.9.66
McDaid, R. A.	N.I.	15.9.66
Marshall, A. R. H.	L.T. Reg.	30.9.66
Welsh, J.	N.I.	30.9.66
Ritchie, H. F. G. *(Resigned)*	Scot.	3.9.66
Kearney, J. *(Resigned)*	Scot.	5.9.66
Lee, W.	Scot.	7.8.66
Read, L. A.	L.T. Reg.	12.11.66
Potts, R.	N.W. Reg.	15.11.66
Hill, A. E.	L.T. Reg.	27.11.66
Knowler, R. A. J.	L.T. Reg.	29.11.66
Arnold, E. H.	S.E. Reg.	10.12.66

Principal Scientific Officer

Name	Region, etc.	Date
New, A. A.*	E.-in-C.O.	6.10.66

Senior Experimental Officer

Name	Region, etc.	Date
Lovett, C. M. (Miss)	E.-in-C.O.	10.10.66

Experimental Officer

Name	Region, etc.	Date
Addley, J. A.	T.S.U.	31.12.66

Scientific Officer

Name	Region, etc.	Date
Fudge, R. E. *(Resigned)*	E.-in-C.O.	31.8.66

Assistant Experimental Officer

Name	Region, etc.	Date
Cole, S. M. (Miss) *(Resigned)*	E.-in-C.O.	26.8.66
Hill, D. A. J. *(Resigned)*	C.E.S.D.	30.9.66
Parker, A (Mrs.) *(Resigned)*	E.-in-C.O.	30.11.66

Assistant (Scientific)

Name	Region, etc.	Date
Sainsbury, C. (Miss) *(Resigned)*	E.-in-C.O.	23.9.66
Baldwin, N. F. *(Resigned)*	E.-in-C.O.	7.10.66
Meadows, D. J. L. (Mrs.) *(Resigned)*	E.-in-C.O.	31.12.66

Motor Transport Officer III

Name	Region, etc.	Date
Fisher, P. E.	E.-in-C.O.	31.8.66
Beeton, F. E.	E.-in-C.O.	30.9.66
Jenkinson, W.	E.-in-C.O.	1.9.66

Retirements and Resignations—*continued*

Name	Region, etc.	Date
Technical Assistant		
Woolley, G. R.	Mid. Reg.	31.7.66
Beveridge, S. R.	E.-in-C.O.	23.8.66
Senior Draughtsman		
Appleton, A. K.	E.-in-C.O.	5.7.66
Westwood, W. S.	E.-in-C.O.	1.10.66
Leading Draughtsman		
Lovelace, T. A. *(Resigned)*	E.-in-C.O.	31.8.66
Beckford, G. E. *(Resigned)*	E.-in-C.O.	16.9.66
Draughtsman		
Isaacs, A. A. *(Resigned)*	E.-in-C.O.	31.8.66
Dawson, D. I. *(Resigned)*	E.-in-C.O.	31.8.66
Gill, E. *(Resigned)*	E.-in-C.O.	28.8.66
Wright, E. J. *(Resigned)*	E.-in-C.O.	26.8.66
Higher Executive Officer		
Bray, S. F.	E.-in-C.O.	22.12.66
Executive Officer		
Lockwood, E. R. (Miss)	E.-in-C.O.	14.8.66
Stern, J. (Miss) *(Resigned)*	B.-in-C.O.	24.8.66
Grosse, R.	E.-in-C.O.	10.9.66
Read, C. W. M. (Miss)	E.-in-C.O.	16.11.66
Fitt, F. J.	E.-in-C.O.	30.11.66
Webb, P. A. (Miss) *(Resigned)*	E.-in-C.O.	20.1.67

*Mr. A. A. New is continuing as a disestablished officer in E.-in-C.O.

Transfers

Name	Region, etc.	Date
Staff Engineer		
Knight, N. V.	E.-in-C.O. to S. & B.R.D.	17.10.66
Assistant Staff Engineer		
Brown, H. R.	E.-in-C.O. to P.D.	11.7.66
Forster, A. E. T.	S.H.A.P.E. to E.-in-C.O.	18.10.66
Nicholson, T.	E.-in-C.O. to E. Reg.	7.11.66
Rutterford, L. F.	T.S.U. to Dept. of Education and Science	1.12.66
Area Engineer		
Woods, A. S.	W.B.C. to N.W. Reg.	8.8.66
Marsh, R. U. R.	N.E. Reg. to N.W. Reg.	15.12.66
Senior Executive Engineer		
Stoate, K. W.	C.E.S.D. to C.A.S./T.S.U.	22.8.66
Hornsby, H. C	E.-in-C.O. to H.C. Reg.	1.9.66

Transfers—*continued*

Name	Region, etc.	Date
Senior Executive Engineer—continued		
Kynaston, J. A. C.	Mid. Reg. to W.B.C.	30.8.66
Pitham, S.	E.-in-C.O. to E.T.E.	1.10.66
Bennett, T. J.	E.-in-C.O. to E. Reg.	17.10.66
Boag, J. F.	E.-in-C.O. to U.S.A. C.O.M.S.A.T.	1.11.66
Britton, A. D.	E.-in-C.O. to Joint P.O./M.P.B.W./R.D.G.	28.11.66
Executive Engineer		
Bell, C.	E.-in-C.O. to Home Office	20.6.66
Gee, J. A.	E.-in-C.O. to Ghana	1.9.66
Field, R. P.	E.T.E. to Ministry of Defence	1.9.66
Wright, P. J.	L.T. Reg. to Metropolitan Police	21.10.66
Richardson, F. S.	E.-in-C.O. to E.T.E.	1.10.66
Crotchett, S. H.	E.-in-C.O. to L.T. Reg.	14.11.66
Assistant Executive Engineer		
Rice, W. B.	E.-in-C.O. to N.W. Reg.	1.6.66
Whitehall, D. J.	E.-in-C.O. to L.T. Reg.	13.6.66
Bunnis, A.	E.-in-C.O. to N.W. Reg.	27.6.66
Watson, R. J.	E.-in-C.O. to Hong Kong	1.7.66
Hastings, A. D.	Gilbert & Ellice Islands to E.-in-C.O.	4.7.66
Swynnerton, D. C.	E.-in-C.O. to Home Office	11.7.66
Heasman, C. S.	East Africa to E.-in-C.O.	11.7.66
Longman, H. T.	E.-in-C.O. to L.T. Reg.	25.7.66
Millard, D. R.	C.E.S.D. to E.-in-C.O.	1.8.66
Verdon, A. T.	L.T. Reg. to E.-in-C.O.	8.8.66
Gosling, W.	E.-in-C.O. to N.E. Reg.	30.8.66
Lush, W. F.	E.-in-C.O. to G.C.B.	1.9.66
Baker, R. F. E.	E.-in-C.O. to S.W. Reg.	5.9.66
O'Neill, R. T.	E.-in-C.O. to E.T.E.	1.10.66
Oakes, B. A.	E.-in-C.O. to E.T.E.	1.10.66
Lawson, J. S. R.	E.-in-C.O. to E.T.E.	1.10.66
Farr, L.	E.-in-C.O. to E.T.E.	1.10.66
Wiltshire, R. S.	E.-in-C.O. to E.T.E.	1.10.66
Booker, C. F.	E.-in-C.O. to E.T.E.	1.10.66
Daborn, J. F.	E.-in-C.O. to Ministry of Aviation	3.10.66
Piercy, W.	E.-in-C.O. to N.E. Reg.	31.10.66
Male, N. R.	E.-in-C.O. to Ministry of Aviation	1.11.66
Bates, G. W.	New Hebrides to E.-in-C.O.	2.11.66
Lough, J.	N.E. Reg. to N.W. Reg.	7.11.66
Raitt, T. R. K.	C.E.S.D. to E.-in-C.O.	16.11.66
Wright, R. T.	S.E. Reg. to E.-in-C.O.	12.12.66
Inspector		
Downing, R. P.	E.-in-C.O. to Mid. Reg.	15.8.66
Scientific Officer		
Blain, B. J.	E.-in-C.O. to Home Officer	10.10.66
Assistant Experimental Officer		
Smith, M. (Mrs)	E.-in-C.O. to Ministry of Defence	28.11.66

Transfers—*continued*

Name	Region, etc.	Date
Assistant (Scientific)		
Bonterre, B.	E.-in-C.O. to Minister of Health	17.10.66
Abbott, J. R.	E.-in-C.O. to C.O.S.D.	21.11.66
Technical Assistant		
Duncan, W. D.	E.-in-C.O. to N.E. Reg.	6.6.66
Hide, M. G.	E.-in-C.O. to London Reg.	12.9.66
Senior Draughtsman		
Alford, S. B.	Factories Dept. to E.-in-C.O.	15.8.66
Leading Draughtsman		
Clarke, D. E.	L.T. Reg. to H.C. Reg.	15.7.66
Collins, B. V. F.	L.T. Reg. to H.C. Reg.	15.7.66
Draughtsman		
Shelvey, N. P.	E.-in-C.O. to Factories Dept.	21.11.66

Deaths

Name	Region, etc.	Date
Area Engineer		
Charles, F. N.	S.E. Reg.	26.11.66
Executive Engineer		
Boys, H. C.	L.T. Reg.	4.7.66
Cullen, W. E.	L.T. Reg.	14.9.66
Cooper, R. P.	E.-in-C.O.	5.10.66
Assistant Executive Engineer		
Smithson, W.	N.E. Reg.	16.6.66
Watters, T. J. A.	E.-in-C.O.	16.8.66
Warren, H.	N.W. Reg.	17.8.66
Stokes, E. G. F.	S.W. Reg.	19.9.66
Rogers, A. H.	S.W. Reg.	3.10.66
Sizer, V. E.	E. Reg.	7.10.66
Toft, G.	E.-in-C.O.	3.12.66
Payne, K. E. J. E.	L.T. Reg.	3.12.66
Burton, D. L.	S.E. Reg.	4.12.66
Knapp, J. G.	Mid. Reg.	4.12.66
Dawson, B.	N.W. Reg.	27.12.66
Inspector		
Trowbridge, C. W.	H.C. Reg.	2.6.66
Brister, D. A.	Mid. Reg.	16.6.66
Smith, A. E.	N.E. Reg.	3.7.66
Ross, A. E.	W.B.C.	9.7.66
Bailey, E. J.	L.T. Reg.	15.7.66
Gilbert, T.	N.W. Reg.	28.8.66
Adams, E. F.	N.E. Reg.	25.9.66
Russell, G.	N.E. Reg.	3.11.66
Thomson, D. M.	Mid. Reg.	7.11.66
Blann, J. N.	W.B.C.	21.12.66
Principal Scientific Officer		
Bassett, H. G.	E.-in-C.O.	5.9.66

ASSOCIATE SECTION NOTES (*Continued from page 79*)

The December meeting was a cinema night; five films were shown: "From Us to View," "Principles of Ultrasonics," "S.S. British Sovereign," "Enterprise '66" and "Speed the Plough." We are indebted to Shell, Ltd., I.C.I. and Mullard, Ltd. for the loan of films and to Mr. R. I. Thomson for lending and operating the film equipment.

We should like to record our thanks to Mr. D. Neave for his services to the Centre as treasurer. We congratulate him on his promotion to Assistant Executive Engineer and wish him every success in the future.

A. R. H

Liverpool Centre

Since the formation of the Centre in 1965, we have had a most successful year. Our membership is now approximately 220. For our 1966–67 session we had an interesting set of papers suitable for all members' tastes. Our program was as follows:

"External Plant in Canada" by Messrs. W. C. Ward and C. P. Self.

"Lasers and Their Uses" by Mr. J. C. North.

"Engineering Training in the Post Office" by Mr. R. O. Boocock.

"Local-Line Planning—For Service and Satisfaction" by Mr. R. Corbishley.

"An Introduction to the Electronic Exchange" by Mr. C. R. J. Shurrock.

"Integrated P.C.M. Systems" by Mr. C. J. Hughes.

The Liverpool Centre is indebted to the Chester Centre for extending their invitation to attend their celebrity lecture last year, which was on "Colour Television." Again they have given us the opportunity to attend their lecture this year, which will be on "The Practical Uses of Computers."

At our last annual general meeting the following officers were elected: *Chairman:* Mr. R. N. Ross; *Vice-Chairman:* Mr. J. R. Franery; *Secretary:* Mr. W. Brown; *Assistant Secretary:* Miss B. Hughes; *Committee Members:* Messrs. A. D. Bimpson, L. Briggs, G. A. Gallapher, W. J. Hilton, D. J. Lyon and F. J. Windsor.

W. B.

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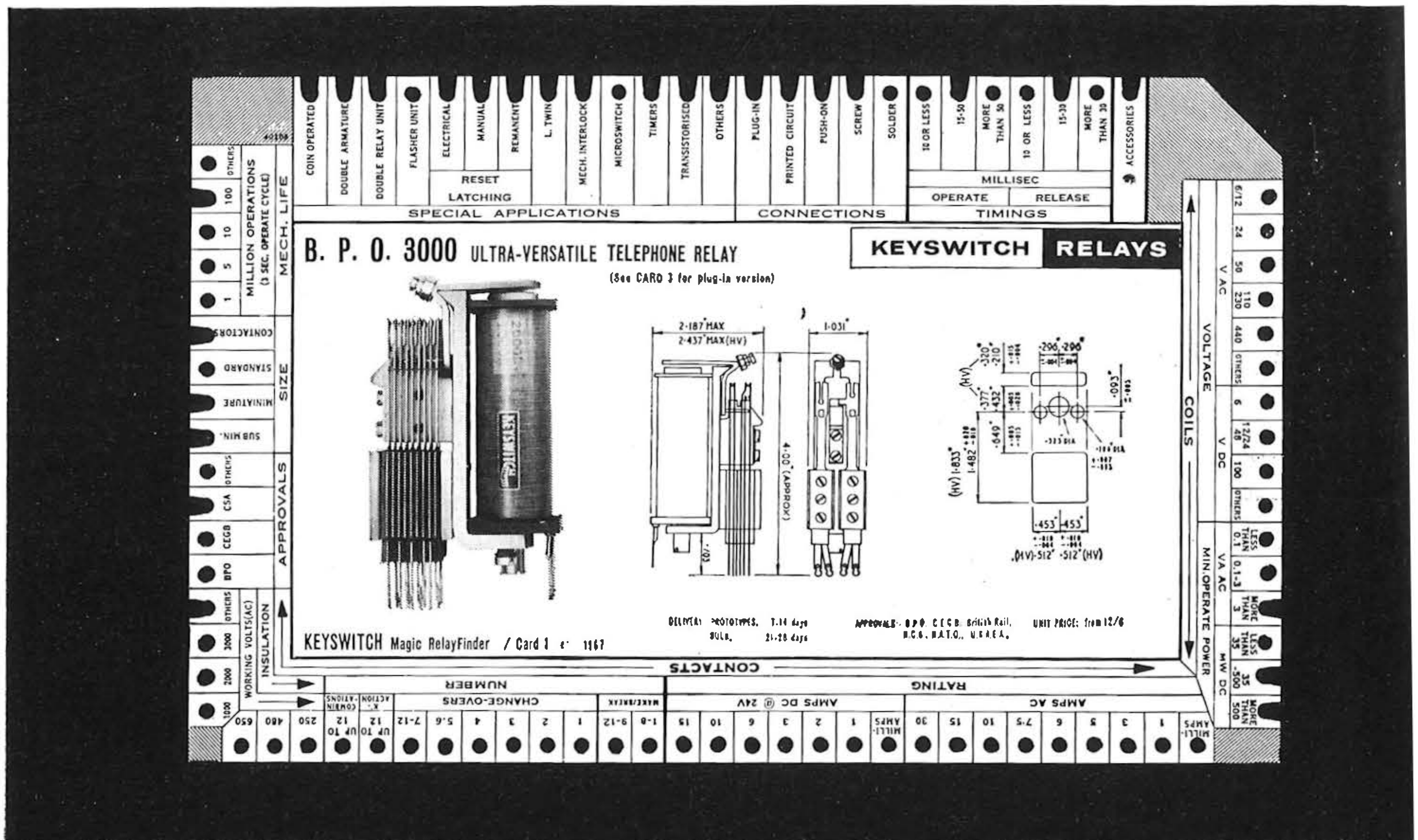
With the exceptions indicated above, all communications should be addressed to the Managing Editor, *The Post Office Electrical Engineers' Journal*, G.P.O., 2–12 Gresham Street, London, E.C.2. Telephone: HEAdquarters 1234.

Model Answer Books

Books of model answers to certain of the City and Guilds of London Institute examinations in telecommunications are published by the Board of Editors. Details of the books available are given at the end of the Supplement to the Journal.


COIN OPERATED
DOUBLE ARMATURE
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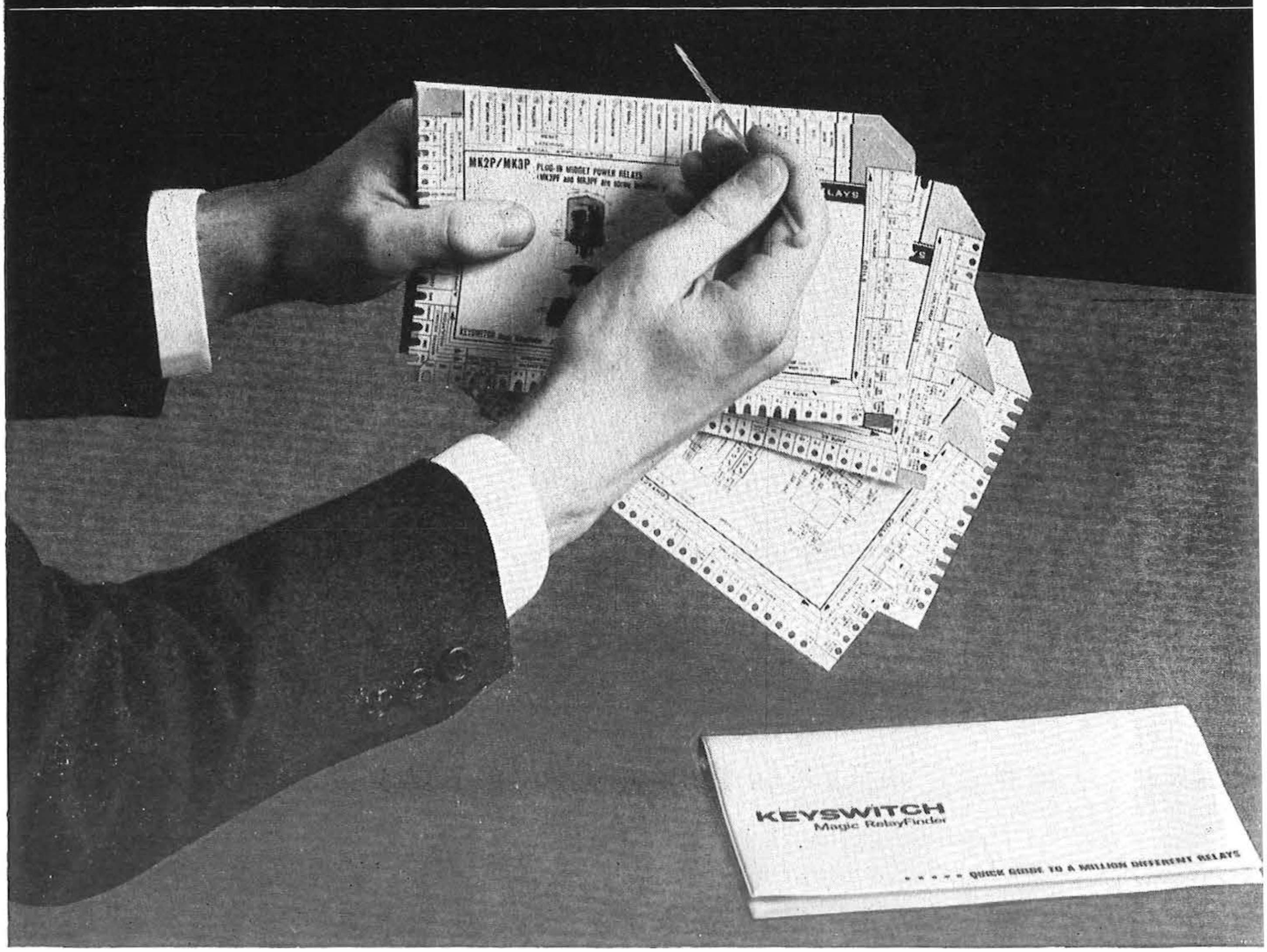
SIZE
BPO
CEGB
CSA
OTHERS
APPROVALS
WORKING VOLTS(AC)
INSULATION
B. P. O. 3000 ULTRA-VERSATILE TELEPHONE RELAY
(See CARD 3 for plug-in version)
KEYSWITCH RELAYS
KEYSWITCH Magic RelayFinder / Card 1
CONTACTS
NUMBER
CHANGE-OVERS
RATING
AMPS DC @ 24V
AMPS AC
V AC
VOLTAGE
COILS
V DC
VA AC
MIN. OPERATE POWER
MW DC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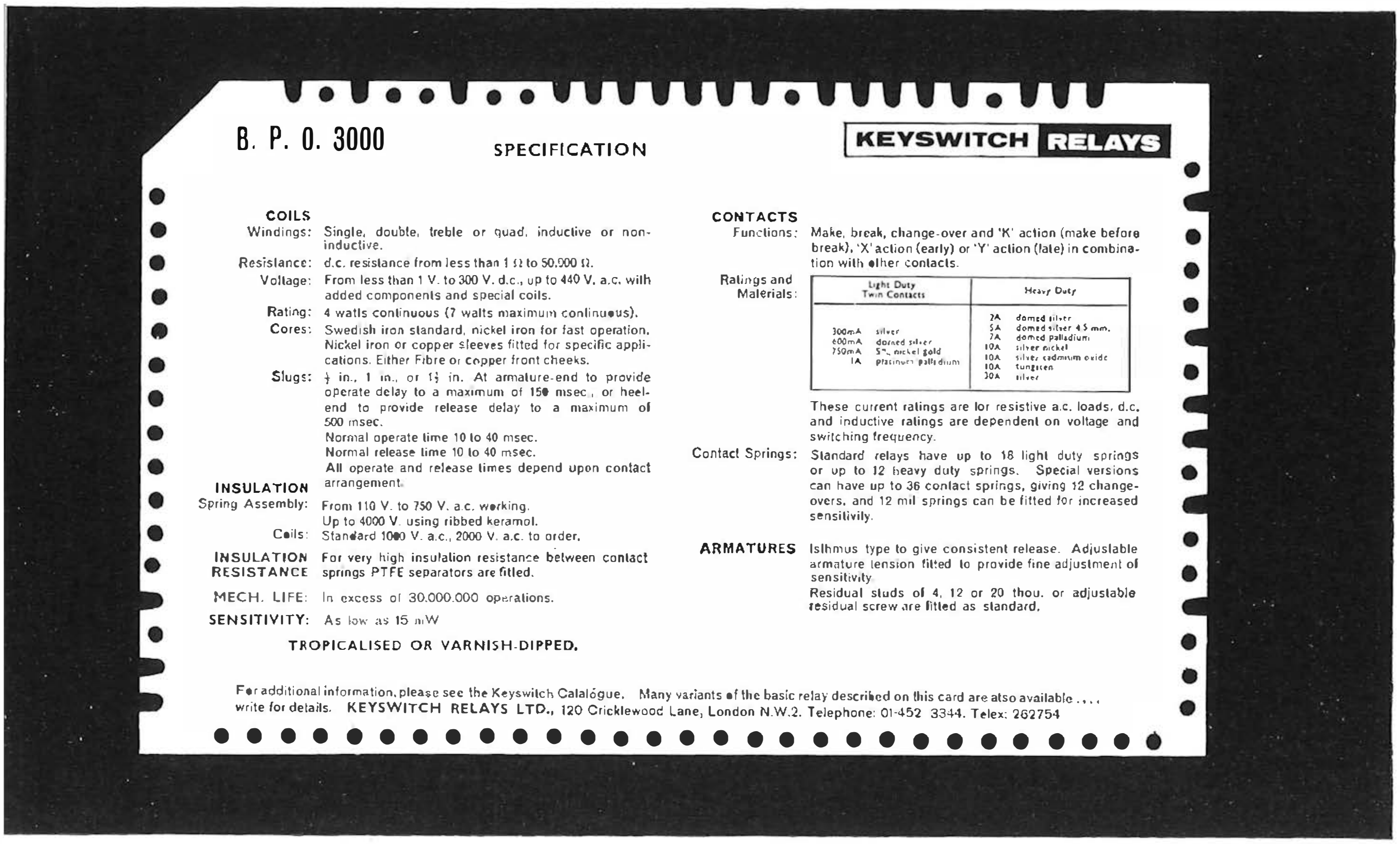

B. P. O. 3000

SPECIFICATION

KEYSWITCH RELAYS

COILS

Windings: Single, double, treble or quad, inductive or non-inductive.

Resistance: d.c. resistance from less than 1 Ω to 50,000 Ω.

Voltage: From less than 1 V. to 300 V. d.c., up to 440 V. a.c. with added components and special coils.

Rating: 4 watts continuous (7 watts maximum continuous).

Cores: Swedish iron standard, nickel iron for fast operation. Nickel iron or copper sleeves fitted for specific applications. Either Fibre or copper front cheeks.

Slugs: ½ in., 1 in., or 1½ in. At armature-end to provide operate delay to a maximum of 150 msec., or heel-end to provide release delay to a maximum of 500 msec.
Normal operate time 10 to 40 msec.
Normal release time 10 to 40 msec.
All operate and release times depend upon contact arrangement.

INSULATION

Spring Assembly: From 110 V. to 750 V. a.c. working.
Up to 4000 V. using ribbed keramol.

Coils: Standard 1000 V. a.c., 2000 V. a.c. to order.

INSULATION RESISTANCE For very high insulation resistance between contact springs PTFE separators are fitted.

MECH. LIFE: In excess of 30.000.000 operations.

SENSITIVITY: As low as 15 mW

TROPICALISED OR VARNISH-DIPPED.

CONTACTS

Functions: Make, break, change-over and 'K' action (make before break), 'X' action (early) or 'Y' action (late) in combination with other contacts.

Ratings and Materials:

Light Duty Twin Contacts		Heavy Duty	
300mA	silver	2A	domed silver
600mA	domed silver	5A	domed silver 4.5 mm.
750mA	5% nickel gold	7A	domed palladium
1A	platinum palladium	10A	silver nickel
		10A	silver cadmium oxide
		10A	tungsten
		30A	silver

These current ratings are for resistive a.c. loads. d.c. and inductive ratings are dependent on voltage and switching frequency.

Contact Springs: Standard relays have up to 18 light duty springs or up to 12 heavy duty springs. Special versions can have up to 36 contact springs, giving 12 change-overs, and 12 mil springs can be fitted for increased sensitivity.

ARMATURES Isthmus type to give consistent release. Adjustable armature tension fitted to provide fine adjustment of sensitivity.
Residual studs of 4, 12 or 20 thou. or adjustable residual screw are fitted as standard.

For additional information, please see the Keyswitch Catalogue. Many variants of the basic relay described on this card are also available . . . . write for details. KEYSWITCH RELAYS LTD., 120 Cricklewood Lane, London N.W.2. Telephone: 01-452 3344. Telex: 262754

the great relay muddle is over!

Anybody who ever needed a relay is only too familiar with The Great Relay Muddle. Finding the right relay has usually been strictly *needle-in-haystack.* There are so many different parameters involved in even the simplest type, you hardly knew where to start looking or when to stop.

Now The Great Relay Muddle is over. Finished. Simply because the boys at Keyswitch tried putting themselves in your shoes, and got corns. So they stopped developing the best relays in the business, just long enough to develop the remarkable new Keyswitch Magic RelayFinder.

The Keyswitch Magic RelayFinder solves the needle-in-haystack problem by letting you put the needle in the haystack yourself—provided it's the Keyswitch Magic Haystack (an edge-punched data-card set).

Each of these unique new cards carries the basic printed matter you'd find on the product data-sheet for a different Keyswitch relay model, *plus* information-retrieval coding that gives you quick access to over a million different relay configurations. A few jabs of the needle into the holes corresponding to whichever parameters concern you most, and up come just the specs, price, delivery and other data you need.

FREE

A Keyswitch Magic RelayFinder is yours free on request—including data-cards, needle, handy wallet and the automatic service that up-dates your data-cards as new and advanced Keyswitch relays are introduced. So ask for yours today, and put The Great Relay Muddle out of your life forever.

Keyswitch Magic RelayFinder

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KEYSWITCH RELAYS

Keyswitch Relays Ltd · 120 Cricklewood Lane · London NW2
Telephone: 01-452 3344 · Telex: 262754

The first armoured miniature coaxial cable to be installed in Britain –made by Pirelli General

The first armoured miniature coaxial cable in the U.K., was laid recently across the River Tamar in the vicinity of the new road bridge. It was manufactured by Pirelli General and forms part of a 54 mile telecommunications link between Plymouth and Truro which has been installed by the Pirelli Construction Company, except for the river crossing which was handled by the General Post Office. Up to 960 conversations can be held over each two tubes, of only .174 inch diameter and the performance is well within CCITT limits for this type of circuit. This installation follows the first of these links (Salisbury-Bournemouth) which was completed in record time by the Pirelli Construction Company.

PIRELLI GENERAL

PIRELLI GENERAL CABLE WORKS LIMITED SOUTHAMPTON TELEPHONE: SOUTHAMPTON 20381

P8105


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REGD

with the rugged **PROVED** reliability of the

PYE 'VANGUARD' mobile radio

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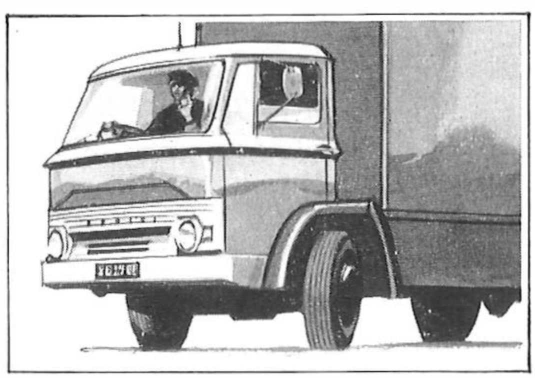


Pye Telecommunications Limited, Cambridge, England
Telephone Cambridge 61222. Telex 81166

MR 14

FERRANTI High Power V.H.F. and U.H.F. Transistors

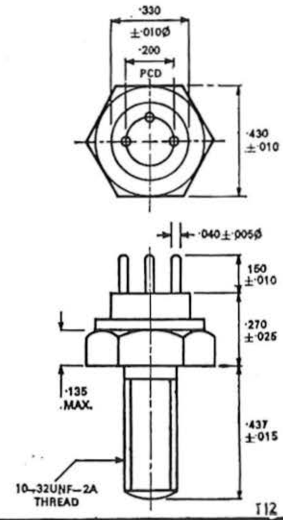
MAIN FEATURES

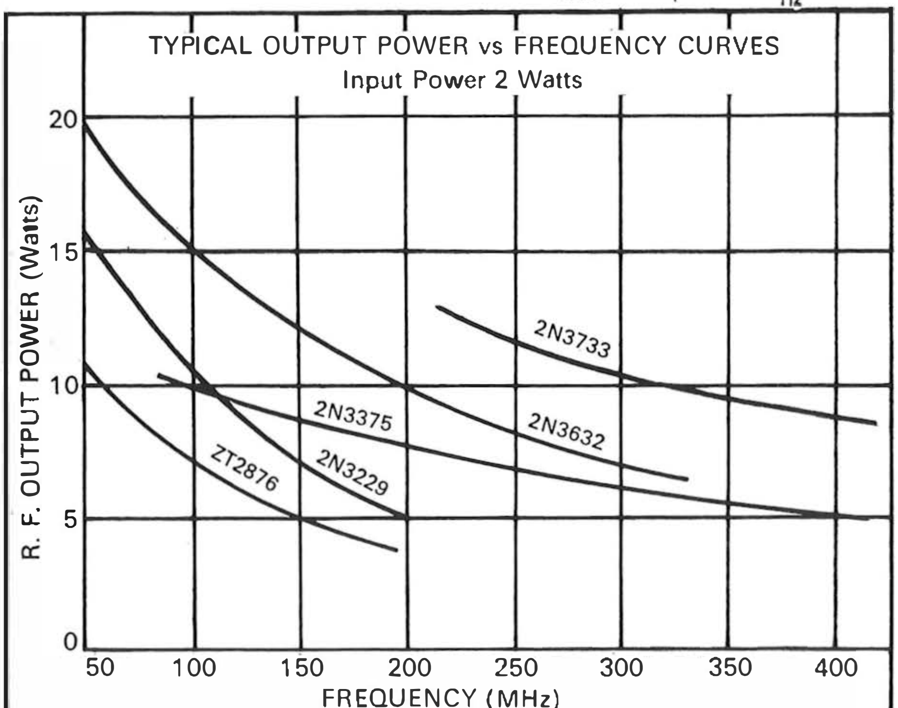
☐ *For use in A.M., F.M., or C.W. Communications Equipment as Class A, B or C Amplifiers, Power Driver and Output Stages, Oscillators and Frequency Multipliers.*

☐ *Typical transition frequencies up to 500 MHz.*

☐ *JEDEC TO-60 Encapsulation.*

DIMENSIONS OF JEDEC TO-60. (Inches)





Examples of performance of a typical device under different operating conditions.

TYPE 2N3375

V_{cc} = 28 volts

CLASS C UNNEUTRALIZED AMPLIFIER

AT 100 MHz : INPUT POWER = 1W : OUTPUT POWER > 7·5W : EFFICIENCY > 65%

AT 400 MHz : INPUT POWER = 1W : OUTPUT POWER > 3·0W : EFFICIENCY > 40%

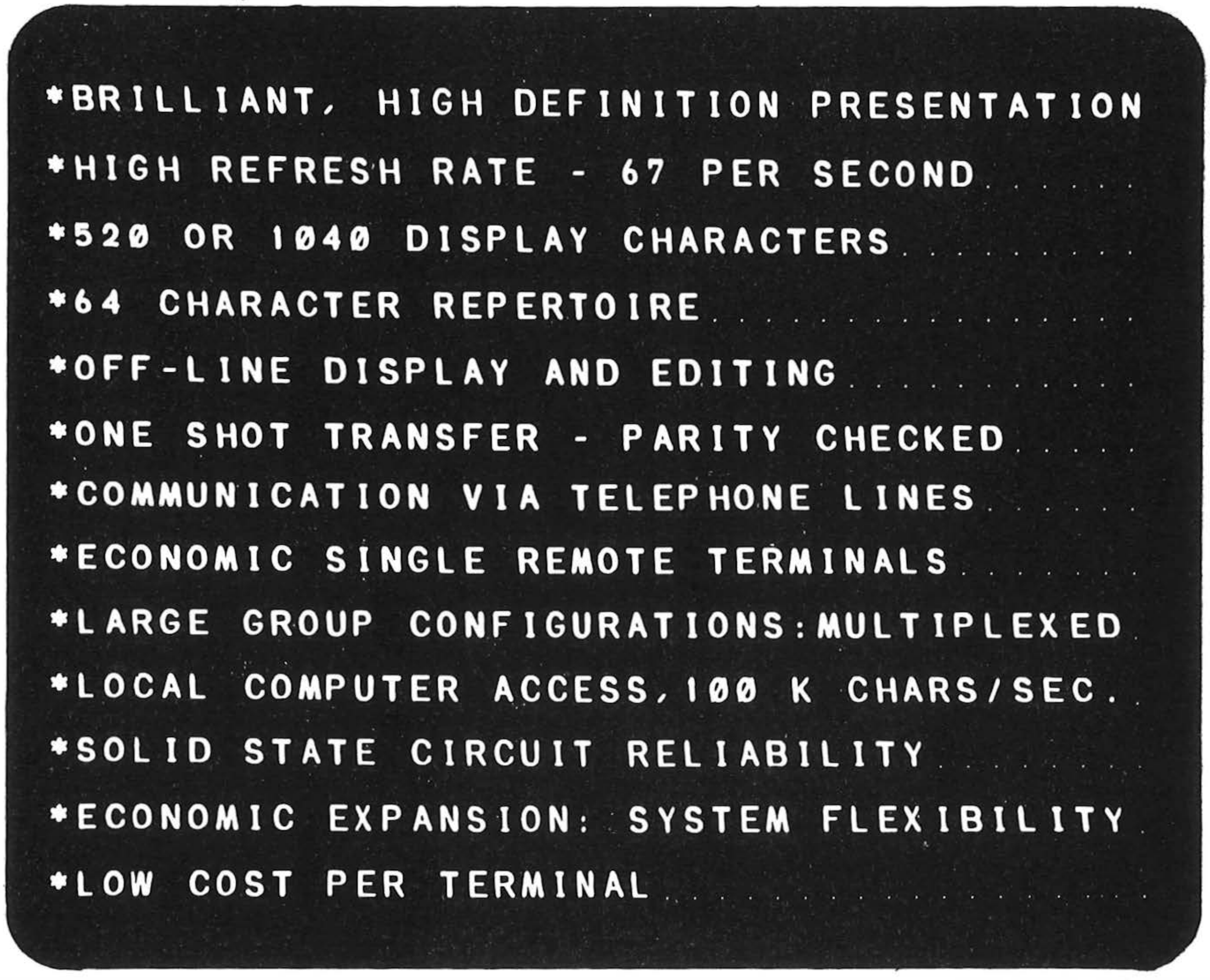
OSCILLATOR

AT 500 MHz : OUTPUT POWER (TYPICAL) = 2·5W : TYPICAL EFFICIENCY = 40%

13 Reasons why you should know about—

DIDS 400

Tabular CRT input output/data terminal.



Unretouched Photo of a DIDS 400 screen.

COSSOR DATA SYSTEMS DIVISION PROVIDES

★ Systems Engineering ★ Development Capability ★ Installation, Service and Maintenance
DIDS 400 offers direct communication between user and data via normal telephone lines, presenting the information in plain unambiguous characters.

For a demonstration of **DIDS 400** *or more information please contact:*

Data Systems Division · Cossor Electronics Limited,
The Pinnacles, Elizabeth Way, Harlow, Essex Tel: Harlow 26862 Cables: Cossor Harlow. Telex: 81228

COSSOR

STC Telecommunications Review

Bringing people together is our business

Through Step-by-Step, Crossbar and Electronic Switching Equipment

Nearly five million lines of STC 'Step-by-Step' equipment are already in world service. Today, over 10,000 skilled workers are employed in its production.

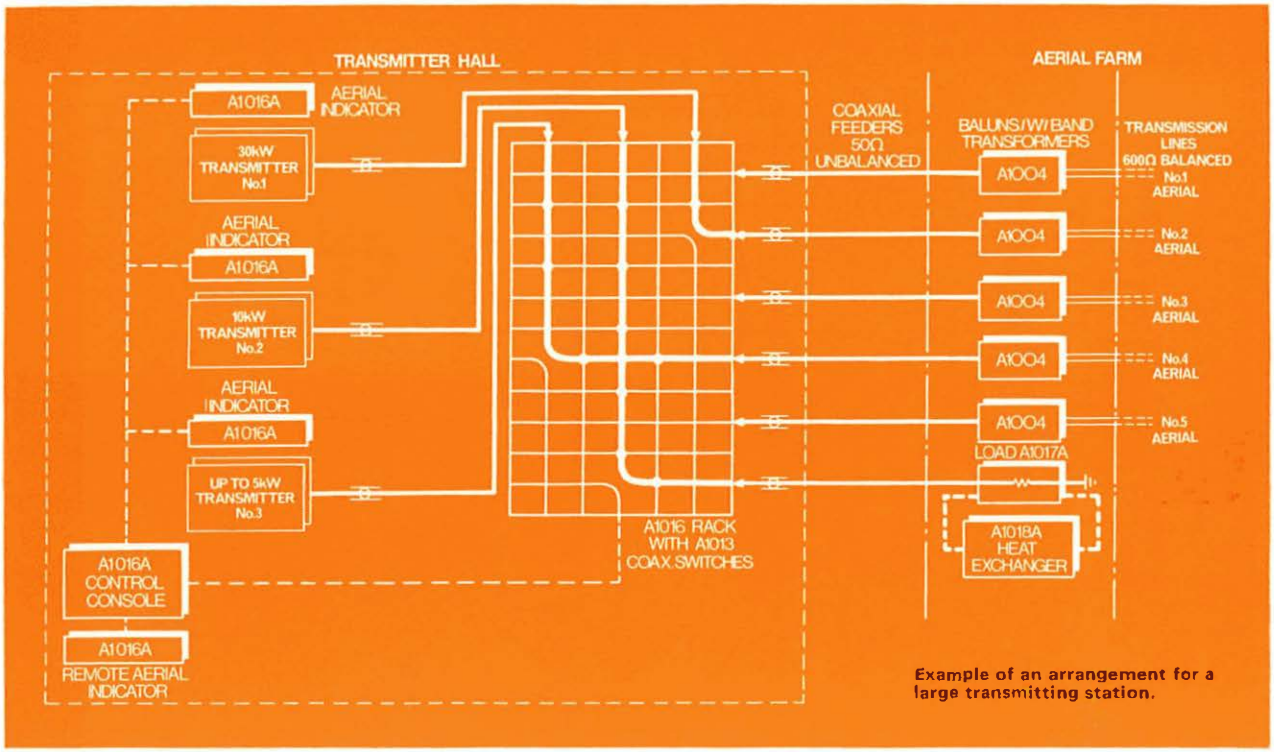
Complete development and manufacturing facilities are now being established for the world's most successful Crossbar system. At present, over $1\frac{1}{2}$ million lines of this system are operating in 65 countries.

As an equal member of the Joint Electronic Research Committee, STC is well to the fore in the field of electronic switching—the system of the future.

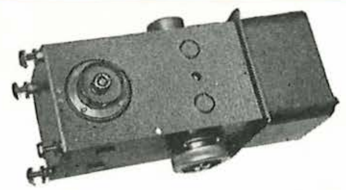
Through these activities, STC is maintaining its world-wide lead in telephone engineering. Advice on the supply of equipment is available through STC consultancy services. And the installation of new exchanges is carried out by expert teams of engineers. It's a world-wide service, too. STC have associate companies in 51 countries.

Standard Telephones and Cables Limited, Telephone Switching Group, Oakleigh Road, New Southgate, London, N.11. Telephone: ENTerprise 1234. Telex: 21612.

G



Example of an arrangement for a large transmitting station.



Coaxial Crossbar Switch Type A.1013B

Wideband Matching Unit (Balun) Type A.1004

5kW Wideband Aerial Matching Transformer Type A.1003

Aerial Ancillaries for STANFAST* transmitter systems

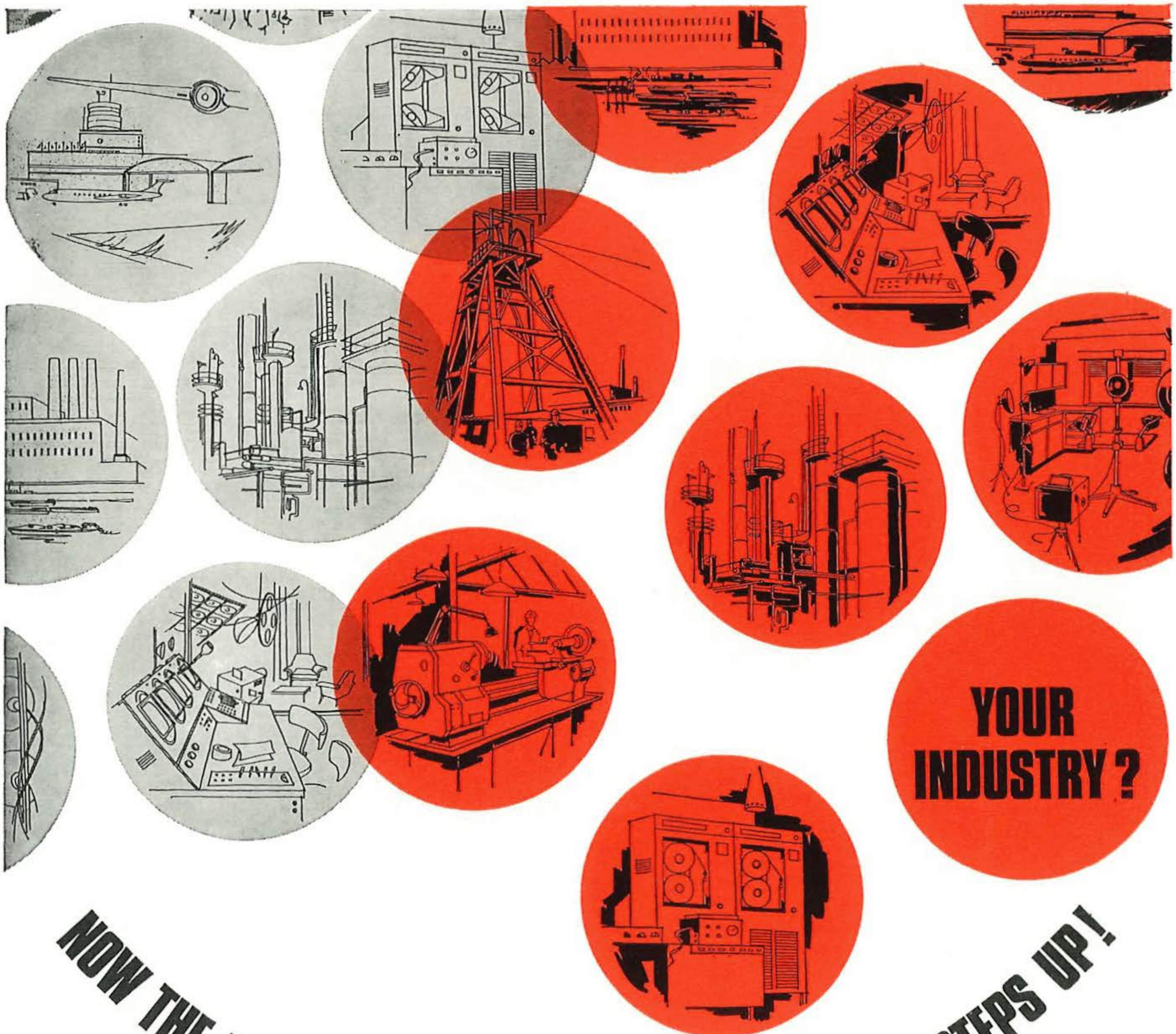
STANFAST* automatic tuning and supervisory techniques enable the modern transmitting station to be operated with a minimum of attendance. The aerial systems for use with these stations must, of necessity, embody components designed specifically for this form of operation. STC can supply a complete range of aerial ancillaries for this purpose.

- 5kW and 10kW wideband aerial matching transformers A.1003 and A.1012
- 20/30kW baluns A.1004
- Coaxial crossbar switch A.1013
- 2 and 4-way coaxial switches A.1014-A and A.1015-A
- Crossbar aerial exchange A.1016-A comprising switching rack, crossbar switches, control console and lamp indicators.

STANFAST* The STC concept of automated radio stations.

**Registered Trade Mark.*

For further details, write, phone or telex Standard Telephones and Cables Limited, Radio Division, Oakleigh Road, New Southgate, London N.11. Telephone: ENTerprise 1234. Telex: 261912.



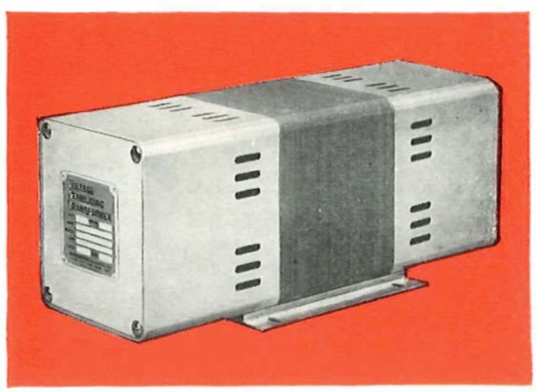
NOW THE BIG SWING TO ASTRALUX V.S.T. REALLY STEPS UP!

Everywhere Astralux Voltage Stabilising Transformers outperform and outdate conventional C.V.T. systems

HERE'S WHY ASTRALUX V.S.T. IS REPLACING C.V.T. IN INDUSTRY AFTER INDUSTRY:

Better Performance. That means improved Output Voltage Stability—output voltage maintained within ± 0.5% for input voltage changes of + 10% —20%. Even when the voltage fluctuation is as great as + 10% to —30% the V.S.T. will maintain the output voltage to within ± 1%. ● **Latest Materials.** High temperature (Class F) materials give optimum reliability and increased safety margins on operating temperatures. ● **Low external field** The latest techniques in magnetic core design give improved performance, coupled with high efficiency, while still offering low external fields. ● **Stable Voltage—Stable Prices.** ASTRALUX prices remain stable over long periods, so costing a job ahead is facilitated with this advanced system. ● **Over 10,000 models!** The ASTRALUX V.S.T. Standard Range consists of ten basic models with over a thousand variations on each. *No other manufacturer* offers such a choice, or can offer such economical prices. ● **Low Cost Specials.** You can order V.S.T. 'specials' at little more than the cost of standard units. Our design department will be happy to prepare prototypes to your specification, for incorporation into equipment under development.

Free illustrated booklet giving full details of ASTRALUX V.S.T. from



ASTRALUX *dynamics limited* TRANSFORMER DIVISION · BRIGHTLINGSEA · COLCHESTER · ESSEX TEL. BRIGHTLINGSEA 2517/8.

'. . . it's the newest Voice Telegraph equipment,
the least expensive, the most compact, most reliable'

'O.K., O.K., cut the sales talk and let us have the facts'

'Five 24 channel terminals on a standard 9′ rack'

'Alright, so it's compact'

'Each channel directly modulated'

'That's worth having'

'Speeds up to 96 bauds'

'Now I am impressed'

'62 Type construction gives flexibility as well as easy maintenance'

'Sure, sure, but you're dodging the price'

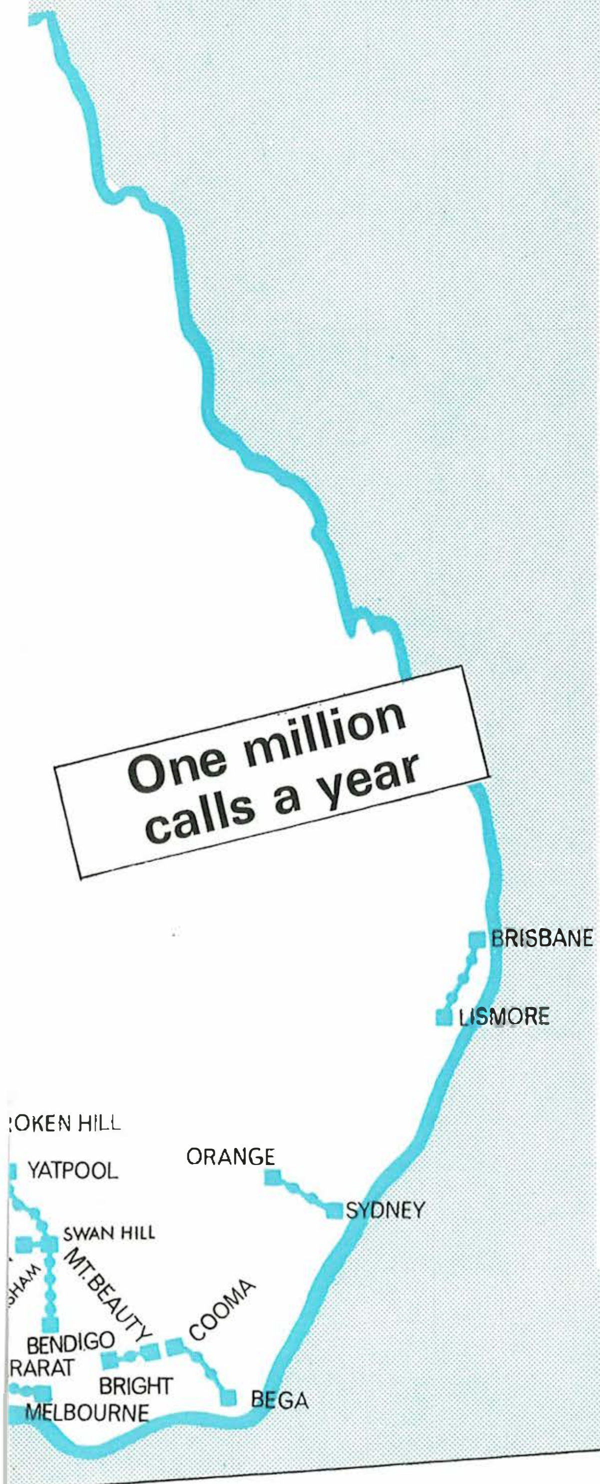
'Get TMC to quote . . .'

Everybody's talking about the new VF Telegraph Equipment Type T24P from TMC. The low price isn't the only surprising thing about this outstanding development; for full details write to:

TMC

Telephone Manufacturing Company Limited
TRANSMISSION DIVISION
Sevenoaks Way St Mary Cray Orpington Kent
Tel: Orpington 27020 Cables: Bubastis London
A member of the group of companies Telex: 28115

latest techniques Telecommunications.



The new 2000 Mc/s transcontinental microwave communications system linking eastern and western Australia is to be supplied by G.E.C. (Telecommunications) Ltd., of Coventry, England. The contract, worth well over £3,000,000, was gained in the face of intense international competition. One of the longest civil microwave links in the world, it will be in service in 1969, by which time, telephone traffic over the 1500 mile route linking Perth and Adelaide — as far apart as London and Moscow — will amount to about one million calls a year. Initially, the system will provide two bothway radio bearer channels, one main and one standby, with a capacity of 600 telephone circuits. The standby channel may also be used to provide a television link giving a nationwide T.V. network. In addition a separate T.V. channel will be provided between Northam, near Perth, and Kalgoorlie.

The completely semi conductored 2000 Mc/s equipment will ensure maximum reliability and minimum maintenance of the equipment throughout the mainly virgin country which it will traverse.

For this contract, the standard equipment is being specially modified by G.E.C. to enable wind-driven generators to be used for the main source of power at isolated, unattended repeaterstations. Standbydiesel generators will be provided for use during windless periods. This special feature of the system is of cardinal importance as the repeaters can be as far as 400 miles from the nearest maintenance centre.

The new link will be the biggest single contribution made by G.E.C. to Australia's telecommunications network. Similar links supplied by G.E.C. of England already connect centres in five states. When the Perth-Adelaide system is completed, G.E.C. communication links will span fully threequarters of the southern seaboard.

Takes telecommunications into tomorrow

G.E.C. (Telecommunications) Ltd.,
of Coventry, England.

G.E.C. of England

brings latest techniques to 2000 Mc/s equipment

Specification summary

U.H.F. Completely Semiconductored
Broadband Radio Relay Equipment SPO.5504

Broadband Characteristics

Operating Frequency Bands:
1700 to 1900 Mc/s, 1900 to 2300 Mc/s.

Transmitter Output:
1.6 watts nominal.

Transmitter Output Impedance:
50 ohms unbalanced.

Receiver Input Impedance:
50 ohms unbalanced.

Baseband Input/Output Impedances.
75 ohms unbalanced.

Transmitter Heterodyne:
Oscillator Crystal controlled.

Stability of transmitted frequency:
1 part in 10^4 including modulator.

Receiver Bandwidth:
Does not exceed ± 20 Mc/s (at —3 db points).

Receiver Noise Factor:
Nominally 5.5 db.

Baseband Characteristics

(i) Telephony

Capacity:
Up to 960 channels.

Baseband Input Level:
—45 dbr.

Baseband Output Level:
—20 dbr.

Mean Deviation:
200 kc/s r.m.s. at channel test level.

Pre-emphasis:
As C.C.I.R. recommendations.

(ii) Television

Capacity:
Colour or Monochrome signals with a maximum frequency of 6 Mc/s.

Input/Output Impedance:
75 ohms unbalanced.

Input Level:
Minimum 1 volt double amplitude peak (d.a.p.).

Output Level:
1 volt minimum d.a.p. monochrome and colour.

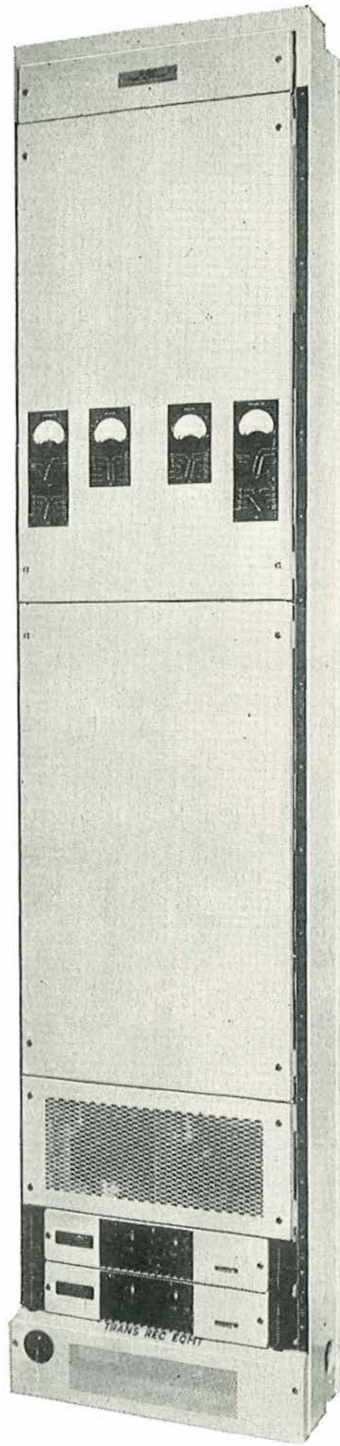
Pre-emphasis:
As C.C.I.R. recommendations.

Deviation:
8 Mc/s peak-to-peak without pre-emphasis

General

Power Supplies:
24 volts d.c. In -built d.c. voltage regulators cater for supply variations of 21.8 volts to 28.15 volts.

Power Consumption:
Each transmitter/receiver 5.5 amps. Each pair duplicated modulators 1.5 amps. Each pair duplicated demodulators 1.5 amps.



Two transmitters and receivers accommodated in one rack 7′ 6″ high x 20½″ wide x 8½″ deep.

For full details write for Standard Specification SPO 5504

ANTENNAS

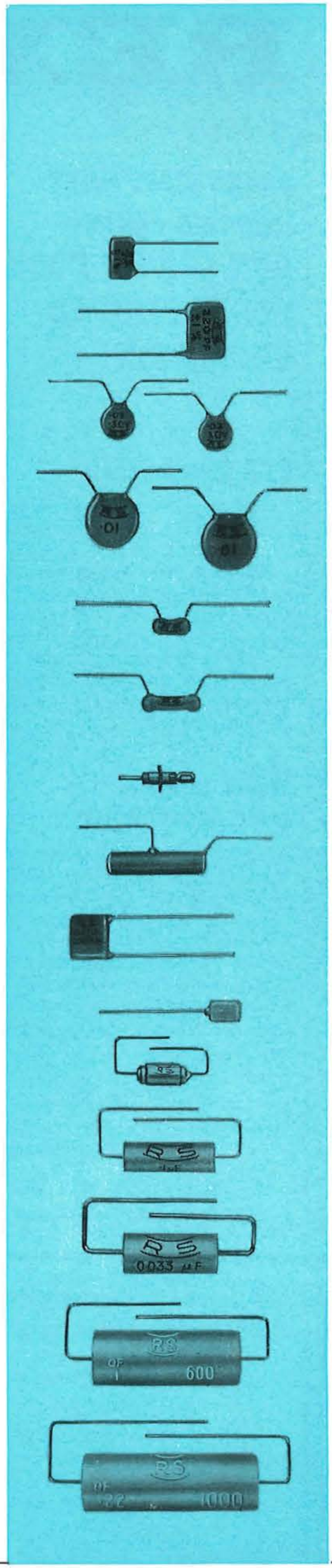
		8 ft. diam.	12 ft. diam.	15 ft. diam.
Forward gain	1800 Mc/s	30.5 db	34 db	36 db
	2100 Mc/s	31.0 db	34.5 db	36.5 db
Beam width to half power points		±2.5°	±1.5°	±1.25°

G.E.C.

Takes telecommunications into tomorrow

G.E.C. (Telecommunications) Ltd., of Coventry, England.

FIXED CAPACITORS



A wide range, to suit practically every application, is listed in our Catalogue. Types included are:-

- ☐ Silvered Mica
- ☐ Ceramic (including Disc, Tubular and lead-through patterns)
- ☐ Foil and Paper
- ☐ Metallised Paper Polystyrene and Polyester
- ☐ Electrolytic (a great variety)

Radiospares Ltd
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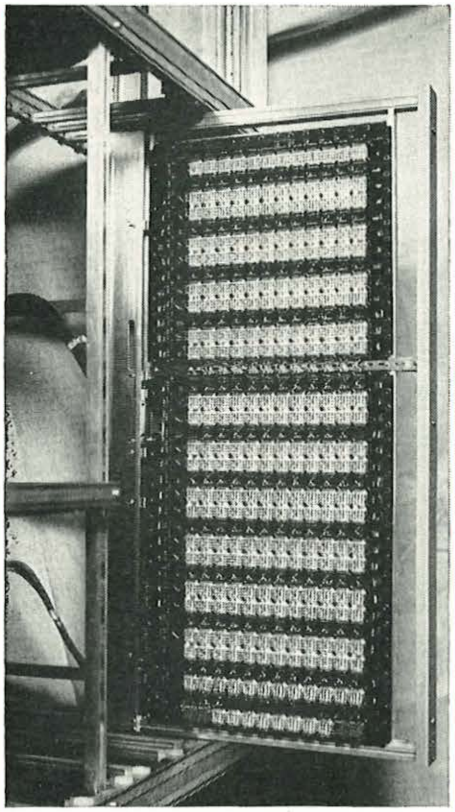
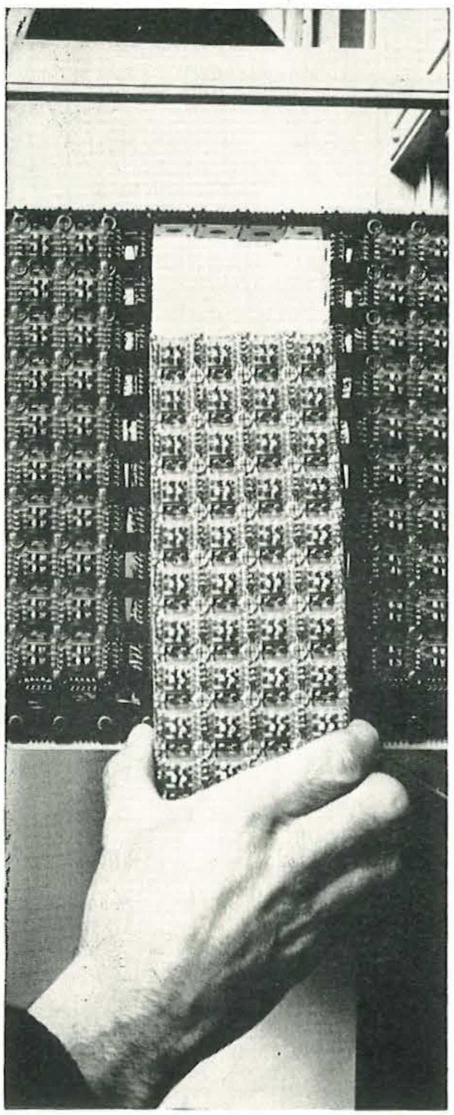
Telephone: 01-387 7232 (8 lines)
Grams & Cables: Radosperes, London, W.1.





REX®

THE REED ELECTRONIC EXCHANGE

No. 18 system

packs more lines into less space— AND LEAVES ROOM FOR UNLIMITED EXPANSION

REX in a nutshell

By providing electronic common control of reed relay spatial switching, the REX system offers an extremely compact and reliable solution to both the switching and control problems of modern exchange design. The REX exchange has been developed by AEI to integrate smoothly with existing automatic networks: its exceptional flexibility ensures full growth capacity for both services and traffic . . .

Wider range— more accessibility

An entirely new Reed & Electronic Modular Apparatus practice (REMA) has been designed by AEI engineers to provide completely compatible mounting of reed relays and electronic circuit components. Combined with a new sliding-frame mounting system, the REMA practice allows more than 20,000 lines of REX switching equipment to be accommodated in the space normally required by a 10,000 line electro-mechanical exchange. In existing buildings this means more space for future expansion: in new exchanges it makes possible great savings in construction and installation costs. And because the REX subscriber's line circuit can tolerate substantially wider line conditions, a REX exchange will serve an area much larger than that of a conventional exchange, with significant reductions in line plant investment.

Designed for expansion

The basic design allows for all future switching requirements, including abbreviated dialling and subscriber's automatic transfer, together with all current standard features such as data for automatic message accounting. A stored programme control is provided to expedite inclusion of these and any other special facilities that may be required during the life of the exchange with virtually no redundancy of initial apparatus.

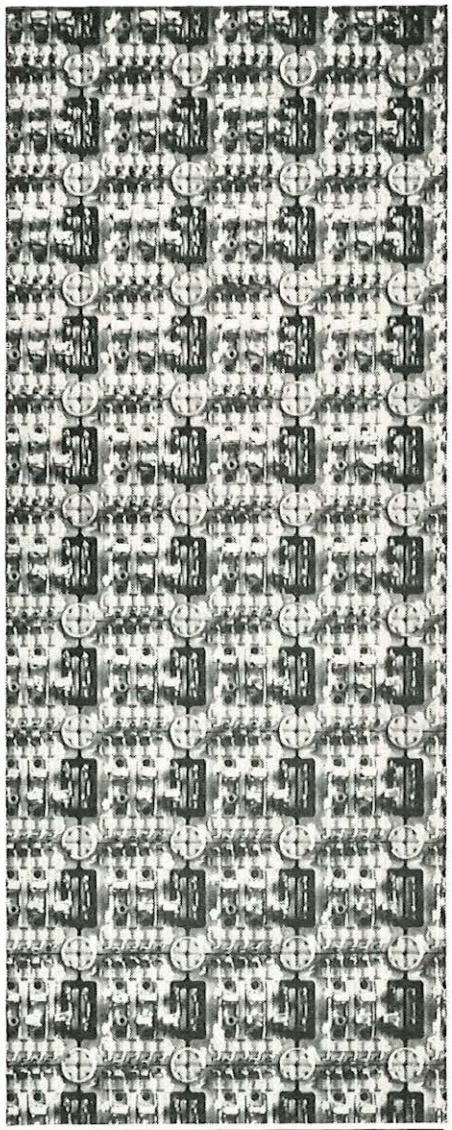
Minimum maintenance

The high-speed electronic control system is programmed to give complete automatic self-checking and self-reporting of fault conditions and at the same time, routes calls away from areas of faulty equipment. A 3,000 (ultimately 7,000) line prototype reed electronic exchange supplied to the BPO at Leighton Buzzard,* has been designed for completely unattended operation and reports all servicing requirements to a remote maintenance control centre.

Maximum service security has been ensured by exhaustive circuit design and testing during the development period and by replication of important items of equipment. The control area is sub-divided into independently switched functional units thus ensuring continued operation in the face of faults. Thanks to the REMA system every part of the REX exchange is accessible for inspection or servicing.

** Developed in conjunction with the BPO under the auspices of the Joint Electronic Research Committee.*

SOPHISTICATED ELECTRONICS— BUILDING BLOCK SIMPLICITY!



The REX switching element

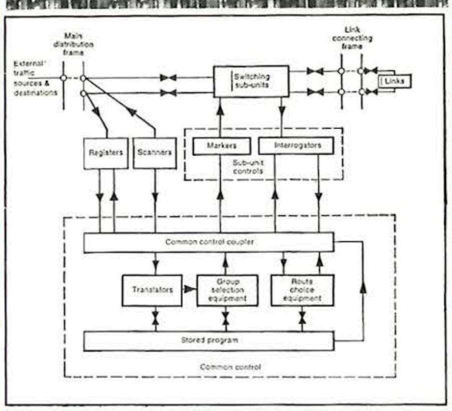
The basis of the REX system is the reed-relay switching element. It contains only nine different piece parts, compared with 200 in a bi-motional selector, and its very simplicity makes it uniquely reliable. There's nothing to wear out and it is sealed completely against dust and atmospheric pollution.

The REX switching matrix

Switching matrices can be built up in any form simply by clipping reed-relay crosspoints together. Thus unlimited provision for the growth of lines and links is built into the REX system.

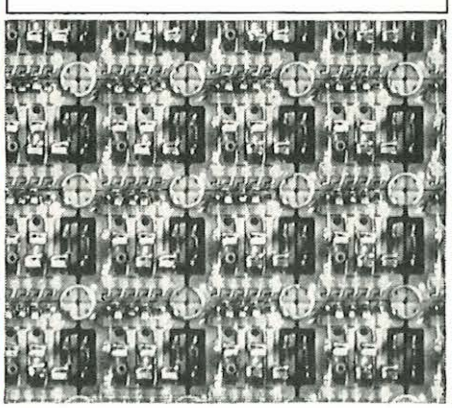
The REX switching unit

Basic switching arrays are built up out of matrices and are arranged in parallel to form a REX switching unit. Typically, a 1,000-line four-section unit would serve a community with an average calling rate of 150 call seconds per line in the busy hour; other calling rates can be accommodated by varying the number of sections.



The multi-unit REX exchange

Switching and linking arrangements are provided for all sections of each unit so that complete crosspoint path interconnection is made between all lines of the REX exchange. The special linking pattern adopted can cater for all traffic patterns whilst retaining simplicity of control.



REX electronic control

The REX electronic control has three main areas of activity:
Scanners and Registers: To determine the source and final destination of a call.
Markers and Interrogators: Concerned with interrogating the state of crosspoint paths and marking these paths through the switching sub-units.
Common Control: Processes the necessary call setting data in accordance with instruction from the stored programme control so that the calls are routed with maximum utilisation of the switching networks.

Information for administrations

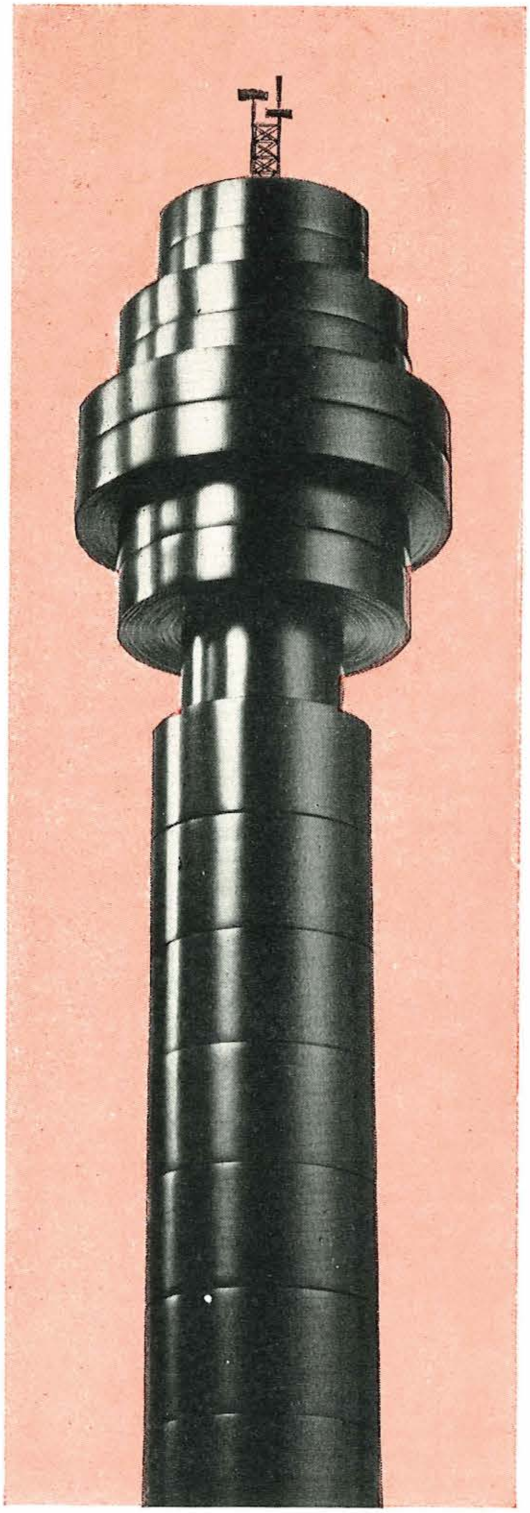
The AEI REX Information Service is one of the most comprehensive programmes ever offered. In addition to brochures and full technical data, AEI will gladly arrange for their lecture team to visit the engineering staff of interested administrations to provide an introductory course on basic REX principles. Later, key personnel would receive full training both at AEI's UK factories and on-site during installation. Training schools staffed and maintained by AEI are also under consideration for territories where reed electronic exchanges are proposed as standard.

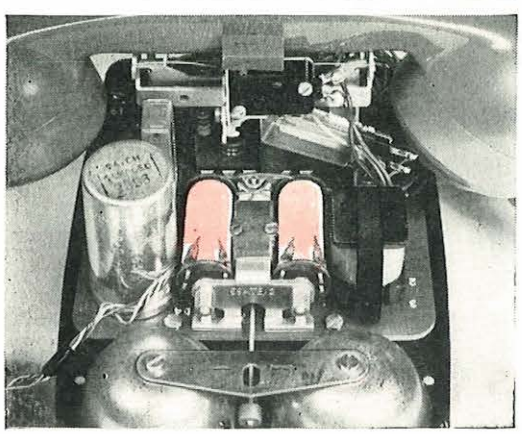
Please write for full details

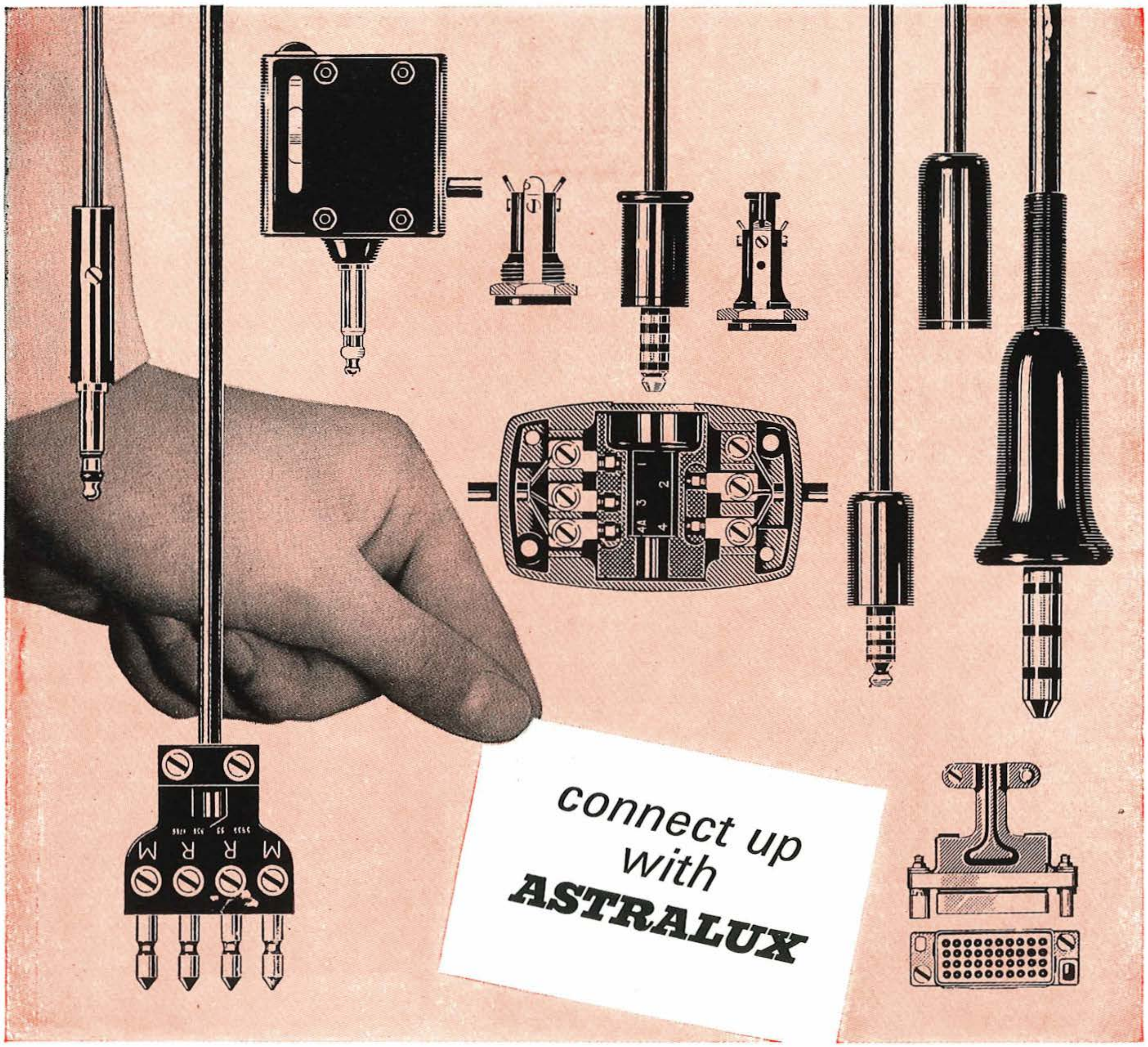
Public Telephone Systems
Department (Electronic)
Telecommunications Group
Associated Electrical Industries Limited
Woolwich, London SE18.
Tel: Woolwich 2020

REX is a UK registered trade mark.

AEI
TELECOMMUNICATIONS



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with
ASTRALUX

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