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CONTENTS

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THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

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The Field Trial of Two Small Electronic Exchanges at Leamington and Peterborough

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The salient features of two small space-division electronic exchanges which are to be given field trials in the British telephone network during 1965 are described. Both exchange systems employ dry-reed relays for switching the speech path and have a potential application to public exchanges in the size range of 200–2,000 subscribers.

INTRODUCTION

TWO small electronic telephone exchanges have been installed at Leamington and Peterborough in the Midland Region for public field trials during 1965. Both exchanges have been developed under the auspices of the Joint Electronic Research Committee (J.E.R.C.) which was formed in 1956 to co-ordinate the electronic exchange development between the Post Office and the five principal British manufacturers of telephone switching equipment: Associated Electrical Industries, Ltd. (then Siemens Edison Swan, Ltd.), Automatic Telephone & Electric Co., Ltd., Ericsson Telephones, Ltd., The General Electric Co., Ltd., and Standard Telephones & Cables, Ltd. The development studies undertaken by J.E.R.C. have covered several forms of time-division and space-division switching. The two small exchange installations described in this article are examples of space-division switching* and represent part of the recent contribution to the J.E.R.C. program by Ericsson Telephones, Ltd. (E.T.), The General Electric Co., Ltd. (G.E.C.), and the Post Office.

Both small exchanges are register-controlled and employ new trunking and control concepts. The majority component in each system is the dry-reed relay, described elsewhere in this Journal,[1] which is used for speech-path switching and certain control functions. The two manufacturers' systems have broadly the same capabilities, but the detailed trunking arrangements of each trial exchange are different and these differences are reflected in the methods adopted for the speech-path selection. The major purpose of the present trials will be to prove the new control methods and associated circuit techniques pending the finalization of a production system.

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*The term "space-division switching" refers to any exchange system in which the established speech-path connexion occupies a discrete physical path in the exchange. Electromechanical step-by-step and crossbar systems are examples of space-division switching methods.

[1]Reed Relays in the Small Electronic Exchange Systems at Leamington and Peterborough. (In this issue of the *P.O.E.E.J.*)

FIELD-TRIAL ARRANGEMENTS

Each field-trial exchange is of a 200-connexion capacity; the G.E.C. exchange is installed at Leamington, and the one by E.T. at Peterborough. These small exchanges would normally be installed in unattended buildings in urban or rural areas, but, to obtain close control over the field-trial conditions and to expedite development, each small exchange has been housed within a large main-exchange building as a satellite to the main exchange. They have been integrated into the Leamington and Peterborough numbering schemes by replacing a group of 200-outlet final selectors and the associated subscribers' calling equipments. Normal 2-wire junction working conditions exist between the electronic satellite exchange and the electromechanical main exchange. These arrangements are shown in Fig. 1.

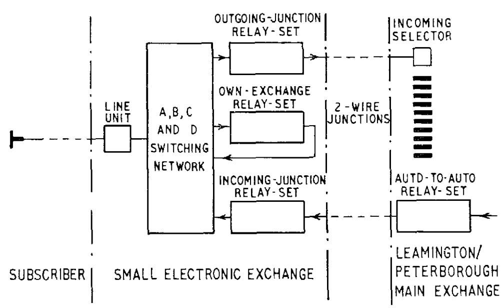
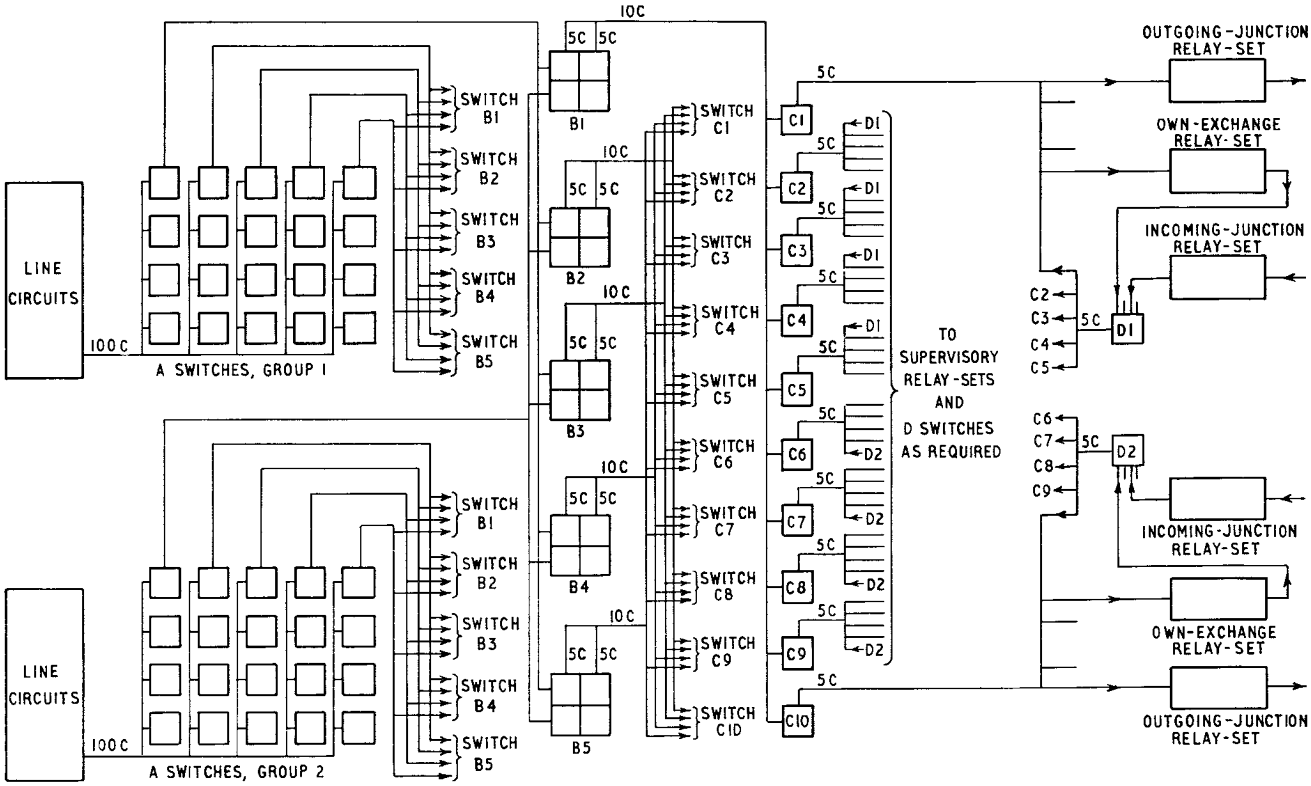


FIG 1—FIELD-TRIAL EQUIPMENT ARRANGEMENTS

Both electronic exchange installations are self-contained, but for convenience the trials use the existing Leamington and Peterborough main distribution frames and ancillary pulse feeds. Normal Strowger-type exchange facilities are provided by both systems, and, prior to the commencement of both trials, a representative distribution of exclusive, shared-service, private-branch-exchange (P.B.X.) and coin-box subscribers was chosen for the selected 200 directory multiple-numbers.

Exchange faults will be dealt with by the local exchange maintenance staff who have received special training on the respective systems. The assessment of the degree of



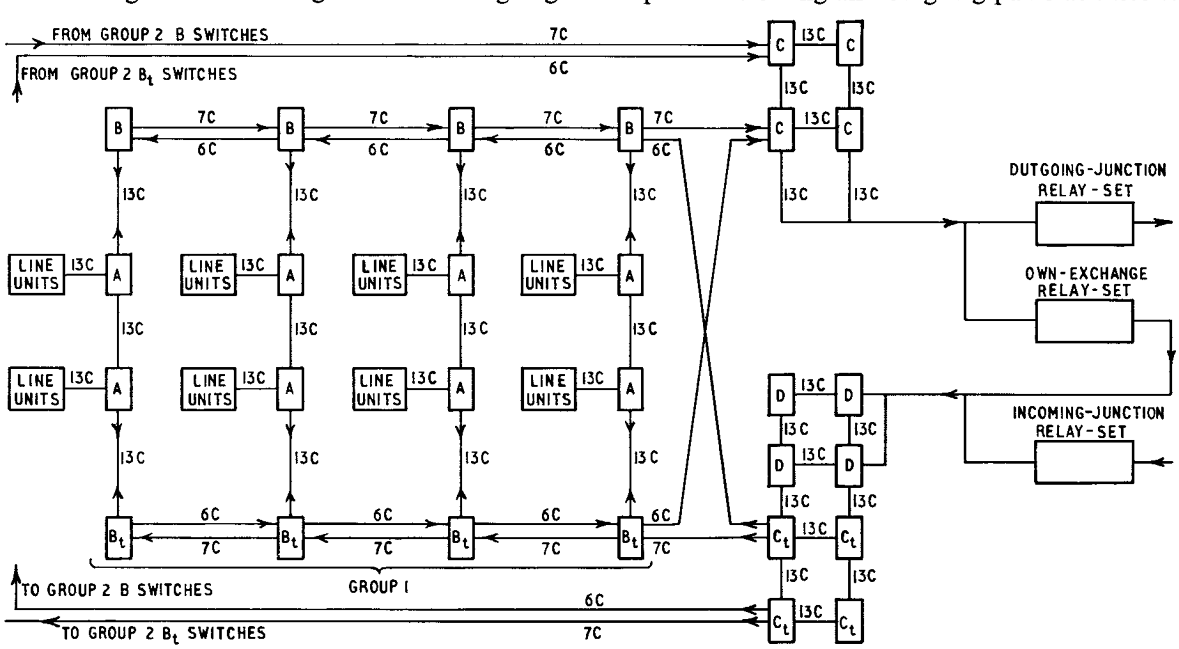
B1, B2, etc., are 10 × 10 matrices each formed from four 5 × 5 matrices. 5C, 10C and 100C indicate 5, 10 and 100 circuits, respectively

FIG. 2—SPEECH-PATH TRUNKING—E.T. SYSTEM

reliability and the ease of maintenance of the two systems will be a feature of the field trials.

TRUNKING ARRANGEMENTS

The speech-path trunking arrangements for the E.T. and G.E.C. systems are shown in Fig. 2 and 3, respectively. They are broadly similar in that both use a three-stage switching network for originating calls and four stages of switching for terminating calls. An outgoing call is routed from a calling subscriber via an A switch, B switch and a C switch to an outgoing-junction relay-set. The path of an incoming call is from an incoming-junction relay-set, via a D, C, B and A switch, to the wanted subscriber. In both systems the A stage is used to switch combined originating and terminating traffic. The E.T. system also switches bothway traffic through the B and C stages, whereas the G.E.C. system uses separate incoming and outgoing paths at these stages.



6C, 7C and 13C indicate 6, 7 and 13 circuits, respectively

FIG. 3—SPEECH-PATH TRUNKING—G.E.C. SYSTEM

In general, the majority of calls originated on these small exchanges will be to the parent exchange and so both systems initially assume that each call will require routing this way. If, however, an originating call requires to be connected to another subscriber on the electronic exchange, advantage is taken of the high setting-up speed of the electronic speech path: the original connexion to the outgoing-junction relay-set is released and the connexion is re-established to an own-exchange relay-set during an inter-digital pause, as described later. When the required subscriber's identity is known, the own-exchange relay-set is connected to the wanted line via the D, C, B, A switching network in the same way as for an incoming call. This discrimination and drop-back for a local call is a feature of the system which greatly simplifies the trunking requirements.

As mentioned earlier, both exchanges are space-division systems, providing a discrete path for each call through the exchange with the interconnexion between trunks achieved by means of dry-reed relays. Each reed relay contains four dry-reed inserts, two of which are used for switching the speech path and two for control and metering purposes. Fig. 4 shows how, in a simple

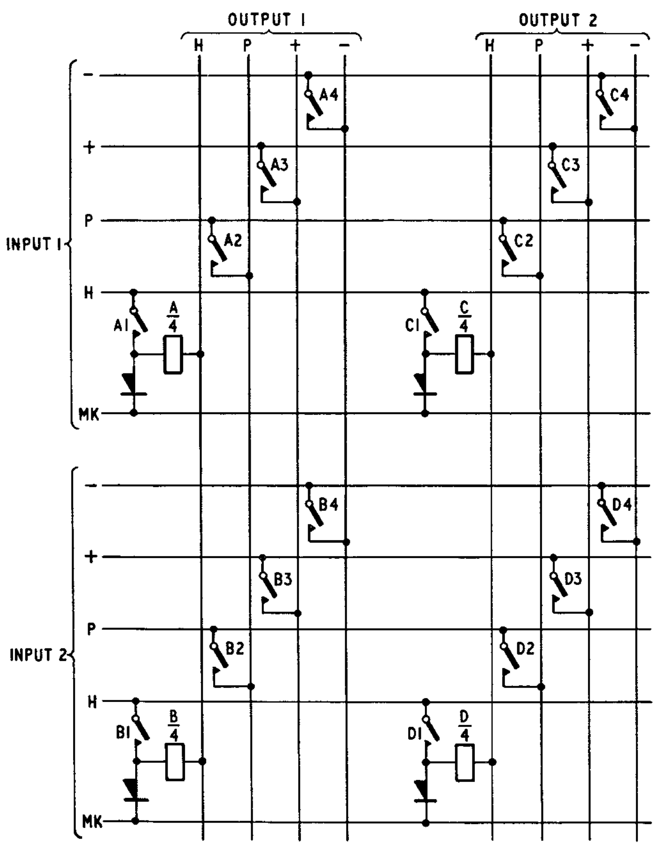
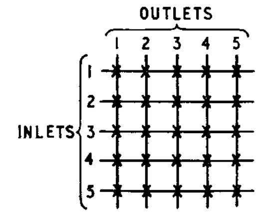


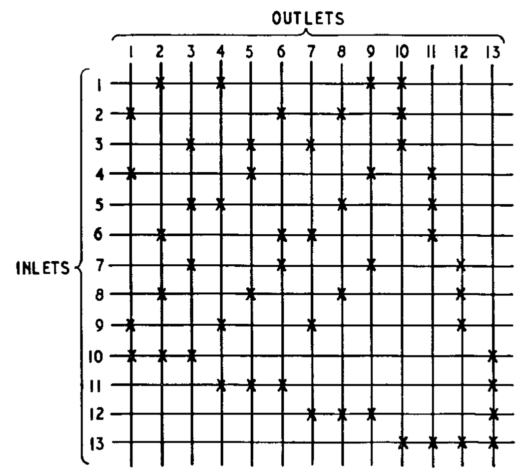
FIG. 4—A 2 × 2 CO-ORDINATE SWITCH

co-ordinate array, four such reed relays may be connected as a 2 × 2 full-availability switch having two inputs and two outputs; for example, if relay B is operated, input 2 would be connected to output 1. Devices used in the manner of these relays at the co-ordinate switching points are referred to as "cross-points."

In the E.T. system the switching matrices are made up of multiples of a small basic full-availability 5 × 5 switch, i.e. 25 reed relays or cross-points, whereas the G.E.C. system uses a switch having 13 inputs and 13 outputs, but with limited availability between inputs and outputs such that any input can be connected to only four of the outputs. The two basic switches are shown in Fig. 5 (*a*) and (*b*), respectively, where each cross represents a four-insert reed relay.



(*a*) Basic Switch—E.T. System



(*b*) Basic Switch—G.E.C. System

FIG. 5—REPRESENTATION OF BASIC SPEECH-PATH CO-ORDINATE SWITCHES

The G.E.C. switch has the following two special properties.

(*i*) No two inputs have common access to more than one output—this is a useful property, particularly for the first traffic-concentration stage of a system, ensuring that if two subscribers with similar telephone traffic habits are connected to the switch their traffic does not interfere severely and cause undue lost-call conditions.

(*ii*) Any two switches when connected simply in tandem permit any input of the first stage to have access to any output of the second stage—thus, under zero traffic conditions there is "full accessibility" between any of 13 inputs and any 13 outputs at a reed-relay cost of $(13 \times 4) + (13 \times 4)$, i.e. 104 reed relays, compared with 169 reed relays which would be required by a single switching stage of 13×13 with full availability. All switches are directly wired in tandem except for a simple wiring interchange between the B, B_t, C and C_t stages (see Fig. 3), which permits removal of a B or B_t switch without removing service from any subscriber.

The E.T. trunking has similar properties but they are achieved in the inter-stage wiring paths rather than in the stages themselves. In the first switching stage, given groups of five subscribers are so interconnected that no two groups have access to more than one common trunk—this property is analogous to property (*i*) of the G.E.C. switching stage. The second and third switching stages are connected as an integrated two-stage network so that under zero traffic conditions there is a path between each input to the B-stage switches and each outlet from the C-stage switches—this is analogous to property (*ii*) of the G.E.C. switch and results in a similar saving in reed relays.

In both cases these savings in cross-points have to be balanced against the blocking introduced, i.e. although free outlets exist it may not be possible to connect a call to them because the available inter-switch paths are "blocked" by other calls in progress. As the calculation of traffic loss through an integrated 3-stage or 4-stage network is complex, both systems have been simulated on computers to determine the extent of this blocking under varying traffic loads. From the results obtained there would appear to be little difference in their "cross-points per erlang" characteristics.

GENERAL DESCRIPTION OF EXCHANGE OPERATION

A schematic diagram applicable to the general control operations of both systems is shown in Fig. 6. For convenience, the operation of either exchange will be described under the following three main headings.

(*i*) Outgoing call—that is, a subscriber wishing to make an outgoing junction call.

(*ii*) Incoming call—that is, an incoming junction call for a subscriber connected to the electronic exchange.

(*iii*) Own-exchange call—that is, a subscriber connected to the electronic exchange wishing to make a local call to another subscriber on the electronic exchange.

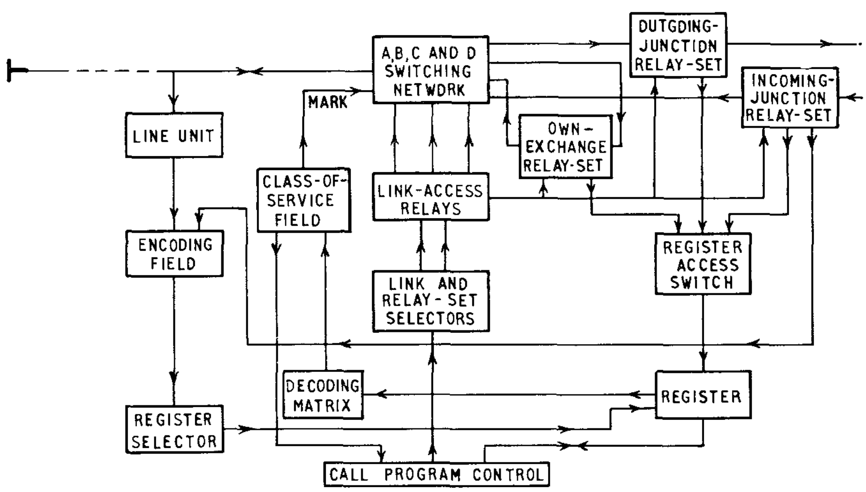


FIG. 6—GENERAL CONTROL ARRANGEMENTS OF BOTH SYSTEMS

Outgoing Call

The subscriber, lifting his telephone off the receiver rest, causes a loop condition to operate a line relay in the subscriber's line unit. A contact of this relay causes the calling subscriber's directory number to be generated in an encoding field[2] in two-out-of-five code form, and this information is then passed to a free register. The register requests the call program control for processing facilities to set up a connexion to the calling subscriber. As only one connexion can be set-up at a time, and as other registers may be making similar demands, the registers are dealt with in turn by the call program control. When the call program control is ready to deal with the demand from the register, the subscriber's coded identity is passed from the register to a decoding matrix, the discrete output of which marks the subscriber's A-stage switch-appearance. The link selectors, via access relays, are then able to choose a free outgoing-junction relay-set, which has access to the calling subscriber via the switching network and to the register via the register-access switch. By end-to-end marking conditions the switching stages are then operated in sequence starting with the C stage. The call program control is released, dial tone is then returned from the register, and dialling can commence. The above sequence of operations takes approximately 50 ms.

The subscriber now dials, and the dialled digits are passed over the junction to the main exchange as well as being counted and stored in the register. If any one of the first three digits indicates that it is a main-exchange call the register will discriminate and release, leaving the calling subscriber connected to the distant exchange via the outgoing-junction relay-set. This relay-set has similar facilities to the auto–auto relay-sets used in Strowger exchanges, i.e. transmission feed, pulse-repeating elements, and standard supervisory functions; in addition, local-call timing and metering-over-junction facilities are provided. The remaining digits received are repeated over the junction to complete the call. At the end of the call when the calling party clears, the outgoing-junction relay-set releases the connexion without resort to the common-control equipment.

Incoming Call

Incoming junctions terminate on incoming-junction relay-sets. Seizure of an incoming relay-set results in the incoming-junction identity being generated in the encoding field and passed to a free register. The register requests the call program control to associate it with the incoming-junction relay-set via the register-access switch. As the register must be associated with the incoming relay-set in the remaining period of the inter-digital pause, the register is given priority over other registers in gaining access to the call program control. The remaining digits, representing the called subscriber's number, are received over the junction and stored in the register.

The operations to set up the call from the incoming-junction relay-set to the required subscriber are very similar to those described for an outgoing call. After association of the register with the call program control the subscriber's identity is converted by the decoding matrix into a discrete output which is used to mark the called subscriber's A-stage switch-appearance. The link selectors then choose a path through the A, B, C and D switches, and, with end-to-end marking, the switching stages are operated in sequence to associate the incoming-junction relay-set with the called subscriber's line. The register, register-access switch, and the call program control are then released. The incoming-junction relay-set now acts in a similar manner to a Strowger-type final

[2]British Patent Application No. 5112/63.

selector, applying ringing conditions to the called subscriber's line and providing the transmission feed and supervisory functions for the established call.

Own-Exchange Call

As described for an outgoing call, a calling subscriber's loop condition causes the subscriber's line to be connected to an outgoing-junction relay-set via the A, B and C switches, and the outgoing-junction relay-set is connected to a register via the register-access switch.

When the subscriber dials, the dial pulses are stored in the register and repeated over the junction. At Leamington and Peterborough, receipt of the third digit will determine whether an own-exchange call or a main-exchange call is required. If it is an own-exchange call, the register, on receipt of the third digit, seeks association with the call program control. When the call program control has been allocated, the outgoing-junction relay-set and the path to it from the calling subscriber's line are released, and the calling subscriber is then re-routed to the seized register via an own-exchange relay-set and cross-points of the A, B, C and register-access switches. The switching-path selection and control operation are similar to that described previously and take place during the inter-digital pause following the third digit. When the call has been transferred, the call program control is released. The remaining digits, representing the called subscriber's number, are then passed via the new path and stored within the register. The register again applies to the call program control, and the call is set up from the terminating side of the own-exchange relay-set via the D, C, B and A switches to the called subscriber's line as described for an incoming-junction call. The own-exchange relay-set provides transmission and supervision in a similar manner to a Strowger-type final selector; local-call timing is also provided in this relay-set.

SYSTEM FEATURES

Applications

Although the field-trial installations are each of 200-connexion capacity and function on a discriminating-satellite basis, this is only for trial convenience, the range of applications being much wider. Each system has the ability to cater for exchange sizes in the range 200–2,000 connexions, and can be extended in small and simple steps. The upper limit of a given exchange unit is determined mainly by the traffic that can be handled by the one-at-a-time control equipment. The lower limit is basically one of economics, but exchanges of less than 200-connexion capacity and based on the same principles are being designed.

Both exchanges also have the inherent flexibility of register-controlled systems, which, combined with the "drop-back" re-routing facility, permits them to be used in either self-contained or linked-numbering-scheme applications. In addition, either combined (i.e. level-1, level-9 and level-0 ordinary and coin-box traffic) or segregated junction working may be provided. Although primarily intended as a small local exchange, working to a main and adjacent exchanges, tandem working is also possible.

The system trunking and organization also have potential applications in private automatic branch exchange (P.A.B.X.) fields.

New Facilities

The field-trial electronic exchanges provide existing Strowger-type exchange subscriber and service facilities, and, in addition, some new service facilities are being provided on a demonstration basis. These additional facilities include revertive control of coin and fee-checking equipment on incoming calls to coin boxes from a demonstration manual switchboard, and local application of a howler by remote control from the same position. The exchanges also permit private branch exchange (P.B.X.) groups to include lines in any directory-number order or even outside the local numbering range altogether; this flexibility of allocation is being demonstrated on a service private manual branch exchange (P.M.B.X.).

The basic organization of the system, with the originating caller's identity stored in the register and subscriber's class of service available on a common-information basis offers the opportunity of incorporating a number of new subscriber facilities in later designs, such as the transmission of calling-line identity and class-of-service information to a manual board, the provision of push-button telephone facilities, etc.

Calling-Number Selection

In a common-control exchange special precautions have to be taken to ensure that false calling conditions due to cable breakdown, etc., do not monopolize the common-control facilities at the expense of legitimate calls. The method of calling-number selection adopted in both systems provides this facility in a novel way.

Each line circuit is jumpered to a magnetically coupled encoding field consisting basically of a number of toroidal pulse-type transformers through which encoding wires may be threaded defining the identity of the subscriber connected to the line circuit. The operation of a line relay causes the calling subscriber's identity to appear as a single pulse signal in the output windings of the appropriate toroidal transformers in a two-out-of-five code form. This information is fed into a register and the call is set up as described under "General Description of Exchange Operation." As soon as the calling-line circuit has initiated a pulse condition through the encoding field, the line circuit is "parked," i.e. placed in a dormant waiting state, until the control connects it to the selected register via the switching network. If there is register or link congestion, the subscriber's line circuit will remain parked and a repeat calling condition will have to be made after releasing the line circuit for a defined period of time (1 sec). In this way, fast tapping line faults, a.c. mains contact faults, etc., do not make repeat attempts on the exchange common control equipment.

With this form of calling-line detection there is a slight possibility, perhaps 1 call in 10,000, of two subscribers generating their calling conditions within the same very short period of time. When this happens neither call is set up, both calling conditions are lost, and both subscribers are parked and have to clear and call again. The probability of the same two subscribers' calling signals occurring simultaneously on a repeat attempt is negligible.

If the calling subscriber is not connected to a register due to the reasons given above, plant-busy tone is returned from the line circuit, indicating that the calling attempt has been unsuccessful and that it will be necessary for him to replace the receiver, and call again.

Besides providing the calling subscriber's directory-number identity during the calling selection process, the encoding field can also be used to indicate when a subscriber originating a call requires special register facilities, such as push-button keysending, so that the appropriate class of register may be allocated.

Security

Both systems have been designed to be fault tolerant so that a number of faults can exist while the exchange continues to give satisfactory service. Many of the exchange control functions are provided by equipment common to the whole exchange; such equipment is duplicated, and detected faults cause automatic change-over to take place and appropriate alarm conditions to be given. In addition, to ensure that the duplicate equipment is in working order, periodic change-over of the duplicated items takes place automatically.

Equipment Practice

Each field-trial installation comprises three 8 ft 6 in. high racks for the main electronic equipment. Outwardly the two installations are similar and one of them is shown in Fig. 7. The coin-and-fee-checking equipments, subscribers' meters, and miscellaneous auxiliary equipment are mounted elsewhere within the main electromechanical exchange.

The racks containing the electronic equipment consist of a number of shelves, each shelf containing a number of plug-in units, the plug-and-socket connexions of which have precious-metal surfaces for reliability. These plug-in units contain electronic components such as reed relays, ferrite cores, silicon transistors, diodes, etc., which make up the control and switching network, and the component layout and wiring arrangements having been specially devised for quantity production methods. To facilitate maintenance testing, supervisory lamps, test points and jacks are provided on the front of each unit. Fig. 8(*a*) and (*b*) show close-ups of typical plug-in units.

Because of the different system requirements, and the use of smaller components with a good packing density, the space occupied by the electronic exchanges is less than that for equivalent Strowger-type electromechanical exchanges. The E.T. Peterborough system uses a smaller reed relay than that used in the G.E.C. Leamington

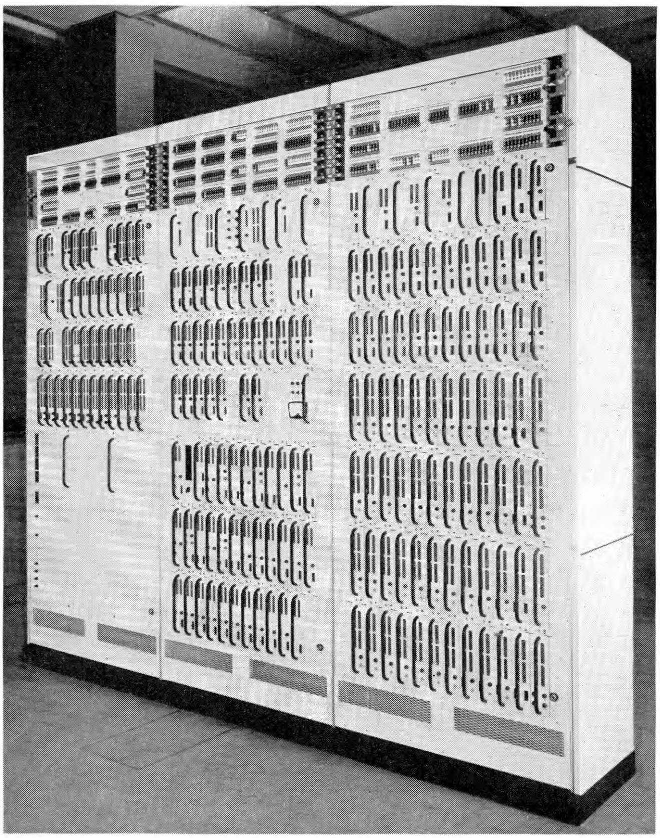
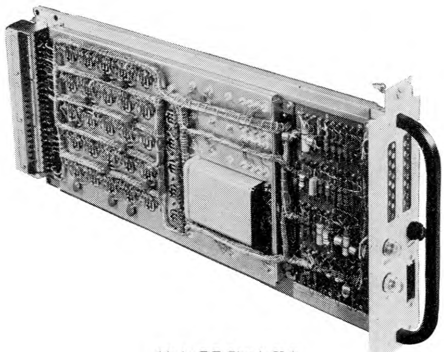
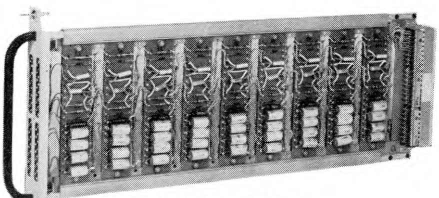


FIG. 7—ONE OF THE FIELD-TRIAL INSTALLATIONS



(a) An E.T. Plug-in Unit



(b) A G.E.C. Plug-in Unit
FIG. 8—TYPICAL PLUG-IN UNITS

installation, and this results in some additional space savings. In the field-trial installation this space saving is not readily evident as E.T. have allowed more space in the racks for the magnetically-coupled encoding fields.

The use of silicon transistors and diodes in the electronic parts of the control circuits render the systems insensitive to variation of ambient temperature, thus avoiding the need for ventilation and air-conditioning.

Power Supplies

The electronic circuits have been designed to work from negative and positive 50-volt power supplies. In the Peterborough installation the positive 50-volt supply is derived by means of a converter from the negative 50-volt main-exchange feed. At Leamington, separate negative and positive 50-volt battery supplies have been provided.

CONCLUSIONS

The capabilities of both systems to cater for exchanges ranging in size from 200 to 2,000 lines, coupled with the flexibility of register operation which permits convenient numbering-scheme variations and choice of junction working methods, make these electronic exchanges strong contenders for the eventual replacement of exchanges in this size range, e.g. unit automatic exchanges (U.A.X.s), small automatic exchanges (S.A.X.s), and rural non-director exchanges (R.N.D.s). With this wide range of application the electronic systems also offer considerable space-saving advantages, and, furthermore, have a flexibility for the ready incorporation of new facilities.

It is premature to judge the outcome of these trials; nevertheless, the experience obtained with the equipments during the pre-commissioning stages at the manufacturers' premises is encouraging. The majority component used is the reed relay, and the success of this form of switching in the future will be largely dependent on the cost and reliability of this component.

Meanwhile, the Post Office and associated manufacturers are collaborating to engineer a standard system which is expected to be ready for production in 1966.

ACKNOWLEDGEMENTS

Acknowledgement is made to the large team of manufacturers' and Post Office personnel involved in both projects. Thanks are also due to Ericsson Telephones, Ltd., and The General Electric Co., Ltd., for permission to reproduce Fig. 7 and 8(*a*), and Fig. 8(*b*), respectively.

Book Review

"Worked Radio Calculations." Alfred T. Witts, A.M.I.E.E. Sir Isaac Pitman and Sons, Ltd. viii + 184 pp. 91 ill. 15s.

This third edition would appear to follow very closely the pattern of earlier editions, with the addition of a chapter on transistors. The worked examples are preceded by a list of symbols, units and definitions of unit used in radio. Symbols used in transistors are given separately just before the chapter on transistors. While M.K.S. units have generally been used there is no clarification of this point and it is possible that this may lead to confusion when, for example, centimetre units are changed to metre units without any explanation.

The principle behind the book would appear to be the provision of sufficient mathematical examples on the various formulae used in electrical and radio work to enable the more practical type of radio mechanic or servicing engineer to find a suitable worked example to meet his requirement. This makes it useful to radio mechanics and radio-servicing engineers who find it difficult to master simple mathematics, but limited in value to radio-engineering students. Further, it is not until example number 249 is reached that the examples take on a truly radio character. Hence, for the early chapters the title is really a misnomer.

The solutions are quite well presented and are generally worked out from a statement of the formula, followed in some cases by a brief clarification of the formula in its application to the particular problem. Very few errors have been noted. In some cases, particularly in the transistor chapter, the formulae are complex and are not likely to be of much value to students outside the use made of them in the book. There is a very useful reference index to the various problems.

This is hardly the kind of book which students in the City and Guilds telecommunication subjects will consider a necessity, but for those who may be interested it covers the standard up to third-year subjects.

P.N.P.

Field Trial of the Trimphone—Telephone No. 712

F. E. I. TROKE, A.M.I.E.E.†

U.D.C. 621.395.721.4

A new type of telephone incorporating several novel features and having a very modern appearance is undergoing field trial. The instrument has a handset of unique design and utilizes a tone caller instead of a magneto bell.

INTRODUCTION

IN accordance with its revised commercial outlook the Post Office is to offer an alternative telephone instrument. The modern design, approved by the Council of Industrial Design, incorporates the novel features of dial illumination, tone calling, and a unique handset—features which give rise to its name, Trimphone, from the initial letters of Tone Ringing Illuminated Model. The complete instrument, known as Telephone No. 712, is illustrated in Fig. 1.

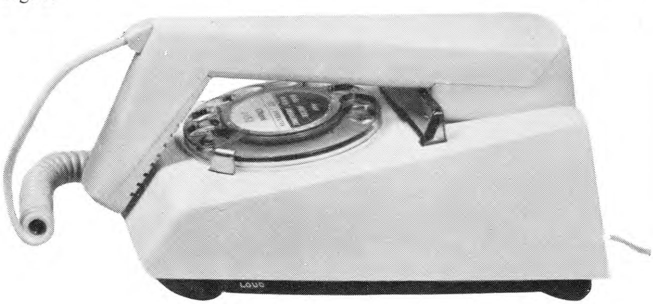


FIG. 1—TELEPHONE NO. 712

DESCRIPTION OF TELEPHONE NO. 712

The Handset

The whole design concept of the new telephone arises from the unique handset (coded Handset No. 8), which in turn is based upon the light-weight headset used by operators and known as Headset No. 1.[1] The small transducers (Inset Receiver No. 3T and Transmitter No. 15) are mounted adjacent to one another in the earpiece cavity, the transmitter being coupled to the mouthpiece by an acoustic horn (Fig. 2). The handset parts are moulded in acrylonitrile butadiene styrene (ABS), a tough thermoplastic with a good surface finish that is currently used for Telephone No. 706 mouldings. The mouthpiece grid is located by a lug and attached by a screw that is then obscured by a polypropylene button; this button also has the function of preventing chafing where the mouthpiece rests on the body of the telephone. The acoustic horn, of toughened polystyrene, is fixed within the handset by adhesive; its lower end is sealed to the mouthpiece cavity, and at the top end the transmitter is held by four lugs, the interface being sealed by a neoprene washer. The horn insert provides acoustic coupling between the mouthpiece cavity and the transmitter, equalizing the frequency response in the same way as the horn in the Headset No. 1. The receiver is retained in position by a metal plate and a rubber-ring seal between the receiver and the earpiece. Two lugs, which are an extension of the metal plate, clip the earpiece on to the handle by engaging behind two moulded bosses; a special tool, which can be inserted in the joint-line, is required to release these clips. A light-weight helical cord, with four conductors and a p.v.c. covering, connects the handset to the body of the telephone.

The Telephone Body

The cover of the telephone body, moulded in ABS, is attached to the toughened-polystyrene base-plate moulding by three screws, which are inserted from the under-side as shown in Fig. 3. The gravity-switch bar, moulded from smoke-tinted polycarbonate to match the dial finger-plate, passes freely through two holes in the cover and is attached by a pivot rod to a bellcrank. The gravity-switch spring-set is mounted on a metal bracket attached to the cover; this bracket is extended to form two knife-edge bearings for the bellcrank, and a helical spring between the two parts keeps them in close contact and provides the restoring force for the gravity-switch bar.

The dial (Fig. 3) is mounted on the base plate and protrudes through a close-fitting hole in the cover; to permit alignment it is flexibly mounted by a three-legged p.v.c. moulding. The pulse mechanism is identical to that of the Dial No. 21, but the body is modified to contain a luminescent tube behind a transluscent number-ring. A thin coating of aluminium is vacuum-deposited on the surface of the cavity within which the tube is fitted; the coating provides a highly efficient reflector to make the best use of the light emitted by the tube. This is a sealed glass tube that has a fluorescent coating on the inner surface and is filled with a small

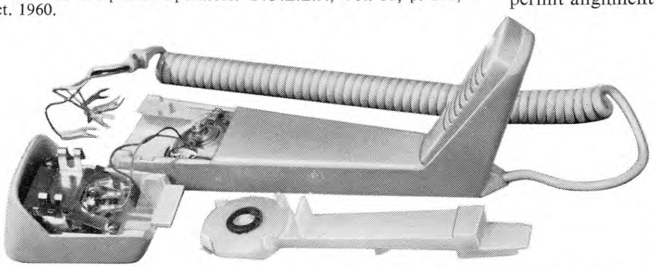


FIG. 2—HANDSET NO. 8 DISMANTLED, SHOWING AN ADDITIONAL ACOUSTIC HORN

†Subscribers' Apparatus and Miscellaneous Services Branch, E.-in-C.'s Office.

[1]SPENCER, H. J. C., and ROBERTON, J. S. P. A Light-Weight Headset for Telephone Operators. *P.O.E.E.J.*, Vol. 53, p. 177, Oct. 1960.

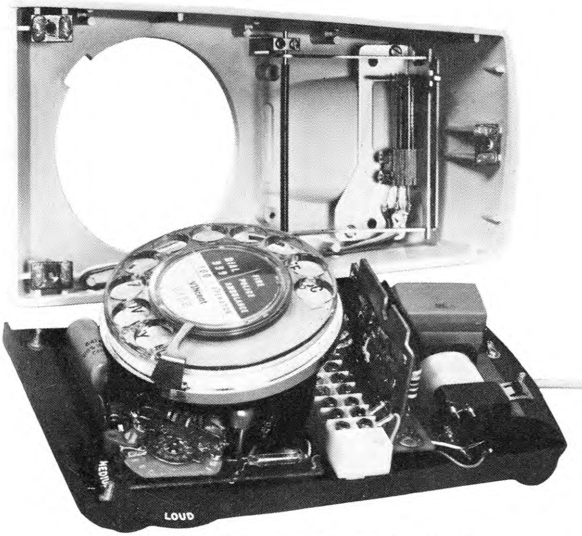


FIG. 3—TELEPHONE NO. 712 WITH COVER REMOVED

quantity of tritium, a low-intensity radioactive gas (an isotope of hydrogen). The low-energy Beta radiation energizes the fluorescent coating and is then absorbed by the glass. The secondary radiation (Bremsstrahlung) which then arises has been confirmed by both the Post Office Radiological Officer and the Radiological Protection Service to be much less than the recommended maximum for luminous wrist watches. The tube is expected to have a useful life of at least 10 years. The illumination, although unnoticeable under normal levels of incident light, is ample to enable the telephone to be located and used in the dark. The fingerplate, transparent to avoid masking the low-level illumination as well as being an attractive design feature, is moulded in smoke-tinted polycarbonate, a tough thermoplastic.

For those installations requiring a single press-button, a micro-switch with a change-over contact can be mounted at the front of the baseplate with its polycarbonate press-bar projecting beneath the front edge of the cover. The 4-way line-cord enters the baseplate at the rear edge, whereas the handset cord enters at the side, conventionally from the left, but it may be transferred to the right if preferred.

The Tone Caller

Beneath the dial is mounted the printed-wiring board of the tone caller (Fig. 4), which is used instead of the more usual magneto bell; it emits a pleasantly-modulated tone, the volume of which is adjustable. The tone-caller circuit (Fig. 5) consists of a single-stage transistor oscillator tuned to about 2,000 c/s, the basic waveform being modulated by the ringing frequency. The output feeds a modified rocking-armature receiver that is positioned by the circuit board above an orifice in the base. The diode D1 acts as a half-wave rectifier of the incoming ringing current, resistor R1 and capacitor C1 smooth the waveform, resistor R3, with other resistors in the circuit, controls the bias applied to the transistor, and the frequency of oscillation of the circuit is determined by capacitor C3 and the inductance of the receiver. Thermistor TH1, diode D2 and capacitor C2 provide a threshold to guard the circuit against false operation by random pulses on the line. Thermistor TH2 in parallel with resistor R4 delays the build-up of the volume if the LOUD or MEDIUM settings of the volume-control are used, and resistors R5 and R6 attenuate the output for MEDIUM and SOFT settings of the volume control. The knurled edge of the control knob projects through a slot in the rim of the baseplate so that it is just visible beneath the edge of the cover. Instead of a bell on/off switch, a locking screw can be withdrawn from the volume control, permitting the knob to be turned to an OFF position. The shunt resistor R2 is incorporated to improve the performance of an additional magneto bell, which may be connected in series with the tone caller if required.

Circuit Arrangement

The circuit of the Telephone No. 712 is the same as that of the basic Telephone No. 706, incorporating the Induction Coil

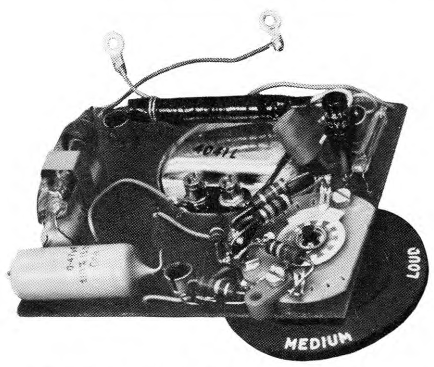


FIG. 4—TONE-CALLER UNIT FOR TELEPHONE NO. 712

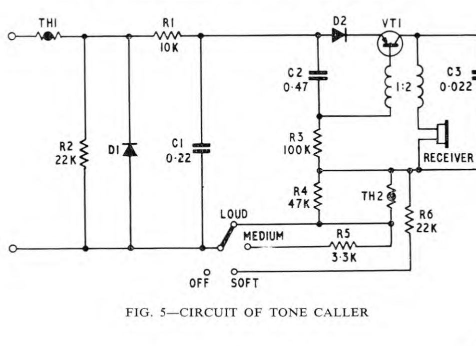


FIG. 5—CIRCUIT OF TONE CALLER

No. 31, and Regulator No. 1A, but, to economize in space, three 0·9 μF capacitors of metallized polyester film encased in polypropylene are used instead of the larger 1·8 + 0·9 μF unit used in the Telephone No. 706.[2] The same 19 terminals are provided to facilitate connexion of the new telephone as an alternative to the Telephone No. 706 in extension plans in accordance with standard arrangements.

PERFORMANCE

It is essential that the transmission performance of the new telephone should be at least as good as that of the Telephone No. 706. Exhaustive tests at the Post Office Research Station, using loudness comparisons by trained crews, measurements of pure-tone sensitivity/frequency characteristics, and conversation tests in which subjects are permitted to hold the handset as they wish, show that the performance of the new instrument is comparable to that of the Handset No. 3.

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

FIELD TRIAL

Production of this new telephone commenced in the early part of 1965, and an initial quantity of 1,000 is to be accepted by the Post Office. These will be offered to selected customers on a trial basis in order that the validity of the radical design can be proven in use by members of the public. The first contract will be completed later in the year with any modifications which the field trial may show to be necessary. It will then become freely available with a choice of three two-tone colour schemes: grey-white, grey-green, and two-tone blue.

ACKNOWLEDGEMENT

The new telephone has been developed for the Post Office by Standard Telephones and Cables, Ltd., under the British Telephone Technical Development Committee procedure.

Book Reviews

"Experimental Radio Engineering." E. T. A. Rapson, M.Sc., A.C.G.I., D.I.C., M.I.E.E., M.Brit.I.R.E. Sir Isaac Pitman and Sons, Ltd. xi + 213 pp. 208 ill. 14s.

This is the fifth edition of this book which was originally published in 1940. Over one hundred experiments are described, together with conclusions which are set out in the rear portion of the book.

Experiments deal with a.c. theory, static and dynamic characteristics of valves, characteristics of amplifiers, demodulators, and oscillators. Audio and r.f. measurements form the basis for a series of experiments, as well as radio receiver tests. In this edition a new chapter has been added dealing with transistor characteristics and amplifiers. In most cases the apparatus required is standard laboratory equipment.

It is obvious in certain chapters that the first edition appeared in 1940, as there are cases of dated terminology being used, such as "detecting triode," and the use of the term "pulsatance" in place of angular velocity. Minor errors occur in several chapters, but the alert student would soon be aware of these. In one diagram an earth has been omitted from a discriminator circuit, which would require a signal generator with an unbalanced output to make it work. This is not mentioned, however, and in later experiments the author assumes that signal generators with balanced outputs are used. In the chapter dealing with transistors, the metering is incorrect in the circuit for measuring output impedance, and capital letters used in the diagrams are sometimes replaced by small ones in the text. The graphs used for certain experiments tend to contain a little too much information, and on at least two occasions reference is made to a logarithmic base, when a linear one has been used.

On the whole, however, the book is good value, and it should prove to be of use to students and those concerned with the planning of technical courses, such as City and Guilds, and National Certificate courses.

L.W.

"Propagation of Radio Waves at Frequencies Below 300 kc/s." Edited by W. T. Blackband. Pergamon Press, Ltd. xii + 478 pp. 261 ill. £7.

With so much attention now being paid to wide-band radio systems operating on frequencies of several gigacycles per second it comes as rather a pleasant change to read of recent progress towards a better understanding of the effects of the ionosphere on radio-wave propagation at frequencies below 300 kc/s. This book is, in effect, a collection of 31 papers presented at the 7th annual symposium of the Ionospheric Research Committee of the Advisory Group for Aeronautical Research and Development, N.A.T.O., held at Munich in 1962. As is to be expected, many of the papers are devoted to problems associated with navigational aids, although a number deal with purely scientific studies especially at the lower frequencies. Nevertheless, there is also much useful propagation information of value in the design of radio communication services.

It is of interest to read about the presence, below the D region, of a C region of ionization believed to be formed by cosmic radiation, but it is pointed out that much more research is required, especially at high and low latitudes, before the influence of this region on v.l.f. propagation can be fully assessed. Another paper describes some measurements of the Rugby standard frequency transmissions operating on 16 kc/s and indicates that over the North Atlantic it should be possible to obtain within any 24-hour period, a precision of frequency comparison of 2 parts in 10^{11}. Further work is in hand to assess the limitations in these frequency comparisons that are imposed by the long-term variations in the lower ionosphere.

Some of the papers bring out the considerable interest shown in propagation problems associated with the Arctic region, while others describe recent research into the non-linear effects of the ionosphere. The effects of the Johnson Island nuclear explosion on the phase of received v.l.f. signals are also discussed.

Without doubt this book is a very valuable contribution to the art of radio communication and, together with its extensive bibliography, is an essential starting point for engineers or scientists concerned with radio-wave propagation at these lower frequencies.

P.J.B.

Low-Noise Solid-State Microwave Amplifiers

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U.D.C. 621.375.9

Low-noise solid-state amplifiers are being increasingly used in radar, satellite communications, radio-relay systems, etc. Some of the more important types of low-noise amplifier are described and their properties, applications and limitations are discussed.

INTRODUCTION

UNTIL comparatively recently, the performance of many microwave systems has been limited by the inherent noise level of the available receivers. The limitations were particularly severe for radio astronomers seeking to measure very weak signals from distant radio sources. However, several types of low-noise microwave amplifiers have now become available, and radio astronomers were among the first to carry out experiments with such devices. Some of these proved most successful, and solid-state low-noise amplifiers are increasingly being used in radar, satellite communications, radio-relay systems, fringe-area reception of television signals and other commercial applications. The purpose of this article is to describe some of the more important low-noise amplifiers, their properties, applications and limitations.

NOISE TEMPERATURE

In order to compare the performance of different amplifiers with respect to noise, it is necessary to have some numerical measure indicating how much noise is generated within the amplifier. It would, of course, be possible to quote a figure for noise power generated by the amplifier in terms of units of noise energy in a unit bandwidth. It is much more convenient, however, to describe the noise by comparison with an external thermal-noise source. In this way, any difficulties and ambiguities due to the definition (and measurement) of the bandwidth can be avoided.

The usual parameter, with which many readers will be familiar, is the "noise factor" (or "noise figure"). For this, the amplifier is supposed to be terminated in a matched load, which is at a standard reference temperature of 290° Kelvin, i.e. 17°C. The noise factor is then given as the ratio of the total noise power per unit bandwidth at the output to that portion of this power which originates in the matched input termination. This parameter, often expressed in decibels, is a very convenient measure of performance for many devices. However, some recently developed amplifiers introduce so little noise when compared with a 17°C termination that the noise figure is always very close to unity. For such amplifiers an alternative much colder reference temperature could be used, but, instead of calculating a new noise factor on such a basis, it is usually more useful to quote the "effective noise temperature" (T_n) of the amplifier. This can be defined as the temperature required for the matched input termination in order to produce an output noise power per unit bandwidth double that which would occur if the input termination were at the absolute zero temperature.

The two parameters are, of course, merely different ways of expressing the same thing, and are therefore related mathematically:

$T_n = 290(F - 1)$, where F is the noise factor.

Some values have been collected in the table, which covers the range of values that apply to the amplifiers described in this article.

Noise Factor, F (db)	Noise Factor, F (ratio)	Noise Temperature, T_n (°K)
0·00	1·000	0
0·03	1·069	2
0·10	1·023	7
0·20	1·047	14
0·45	1·109	32
0·70	1·175	51
1·00	1·259	75
1·50	1·413	120
2·00	1·585	170
2·50	1·778	226
3·00	1·995	289
3·50	2·239	359
4·00	2·512	438
5·00	3·162	627
6·00	3·981	864

SYSTEM NOISE TEMPERATURE

Having a measure of the noise performance of the amplifier, it is possible to compare this with other parts of the system. There is clearly little value in devising special low-noise amplifiers if their noise contribution is to be only a very small part of the overall noise level.

Many of these amplifiers are installed on aerials directed towards the sky, and the limiting noise level in such a system would be radio noise from the sky. Fig. 1

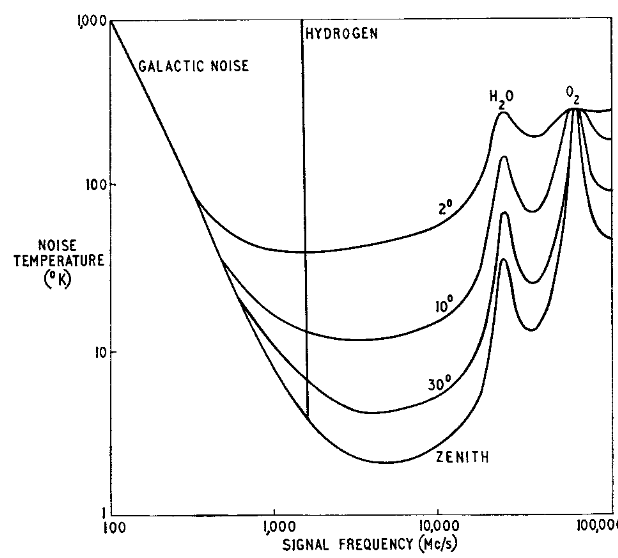


FIG. 1—NOISE TEMPERATURE OF THE SKY AT MICROWAVE FREQUENCIES

shows, as a function of aerial elevation, the noise level entering the main lobe of an aerial pointing towards the sky. At the lower frequencies, this noise originates in the many radio sources in the galaxy. The level of this noise

†Post Office Research Station.

decreases at higher frequencies and also depends upon direction, being greatest when the receiving aerial is directed towards the centre of the galaxy. At the higher frequencies the noise originates primarily in the water-vapour and oxygen molecules in the atmosphere. The water-vapour absorption will obviously depend upon the relative humidity of the atmosphere in the locality of the receiving aerial.

At frequencies in the region of 1–10 Gc/s, and at angles of elevation down to some 5 degrees, the noise level from the sky is very low indeed. For this reason, this part of the spectrum has been used for the reception of signals from the TELSTAR and RELAY satellites. For these applications, the lowest possible receiving-system noise temperature is essential.

At low angles of elevation, such as would be encountered in many radar systems, line-of-sight communications and television broadcasting, the minimum noise temperature is much higher. In addition to noise from the sky, some thermal noise from the earth may enter either the main beam or the side lobes of the receiving aerial in such systems. There would thus be little justification in using an expensive receiver with a noise temperature of only about 5–20°K.

In consequence of the various levels of background noise which are encountered, there are useful applications for amplifiers with an effective noise temperature upwards from the lowest presently achieved ($\sim$ 4°K). There is an additional practical point when using a very-low-noise amplifier: any attenuation between the antenna and the amplifier will introduce additional noise into the system, according to the equation

$$T_s = \frac{T_1}{L} + \left(1 - \frac{1}{L}\right) T_2 + T_n + \frac{T_f}{G}$$

where T_s = system noise temperature,

T_1 = noise temperature of the sky, including noise entering through side-lobes,

T_2 = physical temperature of the feeder between aerial and amplifier,

L = attenuation preceding the amplifier,

T_n = noise temperature of the first stage of the amplifier,

T_f = noise temperature of succeeding stages of the amplifier, and

G = first-stage gain.

Numerically, the additional noise due to the attenuation of the input connexions amounts to about 7°K for an attenuation of only 0·1 db. Consequently, in all systems using very-low-noise amplifiers, the amplifier must be located as near to the primary feed of the aerial as possible so that the interconnecting waveguide is kept short.

The value of T_s obtained from the above equation is referred to the input port of the amplifier. If the value is required with reference to the input plane of the aerial, aerial, the value must be multiplied by L.

In the remainder of this article, some of the recently-developed microwave amplifiers having noise temperatures below about 500°K will be described.

VARACTOR-DIODE PARAMETRIC AMPLIFIER

The essential feature of a parametric amplifier is a non-linear reactance. A reactance may be defined as a circuit element which stores and transfers electromagnetic energy, as opposed to a resistance which dissipates energy. In a capacitor the energy storage is in the electric rather than the magnetic field. If the capacitance is non-linear, i.e. if the stored electric charge is not linearly related to the applied voltage, then, if several alternating voltages are applied simultaneously, frequency mixing takes place and the reactance is capable of transforming energy from one frequency to another.

In the parametric amplifier the purpose of the non-linear reactance (usually capacitive rather than inductive) is to abstract energy from an a.c. source (the "pump" at frequency f_3) in order to use some of this energy to amplify a weaker a.c. signal at another, lower, frequency (the "signal" f_1).

It is necessary to maintain the proper phase relationship across the capacitance, and, except in the special case when the pump frequency is exactly twice the signal frequency, this can only be achieved by permitting power to flow at, at least, one other frequency. This is the "idler" frequency, f_2, which is equal to the difference between signal and pump frequencies.

The amplifier therefore consists of a series of tuned circuits which will permit power to flow only at these three frequencies. The non-linear capacitance forms the common element between the tuned circuits, as shown in the schematic equivalent circuit in Fig. 2.

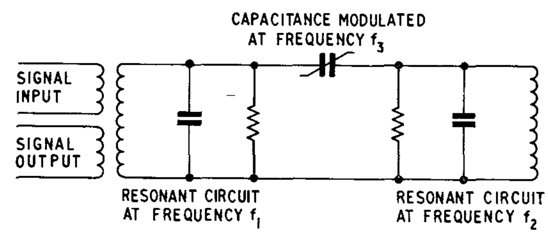


FIG 2—EQUIVALENT CIRCUIT OF PARAMETRIC AMPLIFIER

In most low-noise applications, the input and output are both at the same frequency f_1, but if the output is taken at f_2 the amplifier can be used simultaneously as a frequency converter. In some circumstances the gain could be increased to infinity, i.e. until oscillation occurs. For stability in practical applications the gain is usually limited to 15–20 db for a single-stage amplifier.

When the input and output signals are at the same frequency an additional non-reciprocal circuit element, usually incorporating a ferrite material in a magnetic field, is necessary to separate the input and output signals.

Although in theory the non-linear reactance could be inductive or capacitive, the most successful practical amplifiers depend upon a non-linear capacitance. The capacitance must be suitable for modulation at the pump frequency; for convenience, simple electrical modulation is preferable to electromechanical or other forms of modulation. It has been found that a reverse-biassed p–n semiconductor junction can perform as an almost ideal electronically-variable capacitor. Diodes can be manufactured whose capacitance can be modulated at frequencies up to, and even above, 100 Gc/s.

Such a junction is formed inside a small piece of a semiconducting material, such as silicon, germanium or the inter-metallic compound gallium arsenide. In such a material the electrons within the crystal have energies which lie within a series of permitted energy bands. The highest occupied energy band contains the valency electrons, which bind the crystal together, and in a semiconductor or insulator this band is full. There is then a forbidden energy gap between the valency band and the next, empty, conduction band. A flow of current would imply a slight increase in electron energy, and as this would require electrons entering the forbidden gap, the crystal has a low conductivity. This can be increased markedly by introducing small amounts of certain impurities into the crystal lattice.

If the impurity has the ability to donate electrons to the crystal lattice, these electrons can enter the empty conduction band, where they are available as negative charge carriers. Such material is called n-type. On the other hand, if the impurity has a high affinity for electrons, some electrons are removed from the valency band, leaving "holes." Such holes act as if they were positively-charged carriers, and this type of material is called p-type.

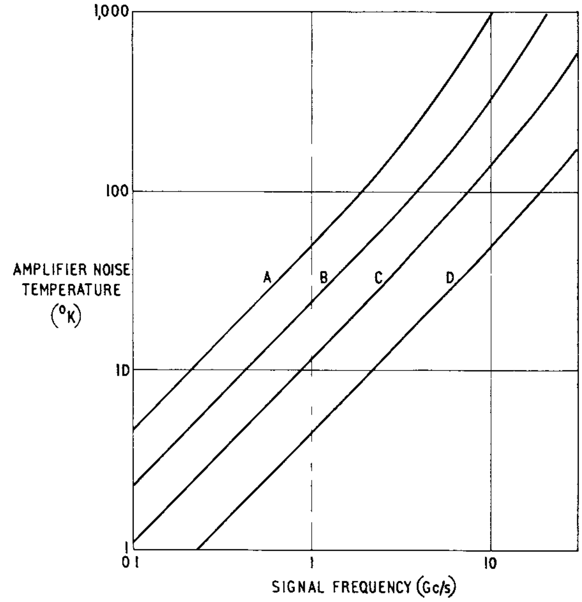
In a gallium-arsenide diode, for example, the donor impurity in the n-type portion of the material might be sulphur, selenium or tellurium, and in the p-type the acceptor impurity might be zinc or copper. At the junction between the p and n materials, charge carriers will diffuse across the boundary. This movement of charge will create an electric field opposed to the further flow of carriers. In the equilibrium conditions, the field is just great enough to prevent further diffusion of carriers across the junction and sweeps all the carriers out of a narrow layer of material at the junction. The p and n zones may now be considered as the plates of a capacitor, with the carrier-free material forming the dielectric. If a small external potential is applied the width of the carrier-free layer will either increase or decrease, depending upon the direction of the applied field. Thus, an external alternating potential would modulate the width of the layer and hence the capacitance of the junction.

The resistivity of the semiconducting material away from the neighbourhood of the junction is not negligible. Consequently, there is always a series resistance R_s associated with the capacitance C_o. The variable-capacitance property is possessed by all semiconductor diodes, but special diodes are manufactured for use in parametric amplifiers. The performance of these diodes depends not only on the internal series resistance but also upon the parasitic capacitance of the capsule containing the diode and upon the inductance of the leads. In order to minimize the parasitic effects, special encapsulations of very small size must be used for the highest-quality diodes. Such diodes may have a volume of only a few cubic millimetres.

There are a number of possible "figures of merit" by which the quality of such diodes can be described. The simplest is a resistive cut-off frequency, defined as $1/2\pi C_o R_s$, and diodes are available with cut-off frequencies up to and even above 100 Gc/s.

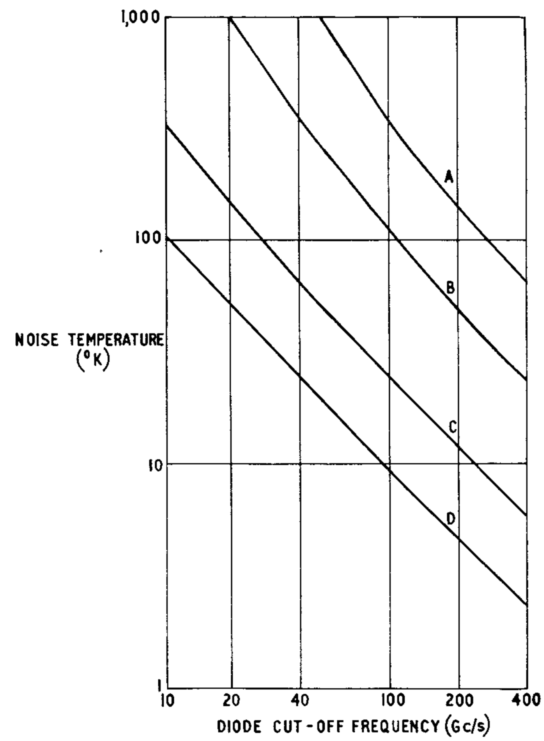
Varactor-diode amplifiers produce no appreciable shot noise because the diodes are operated at or near zero bias, and virtually no current flows across the charge-depleted zone at the junction. Resistance, or Johnson, noise does arise, however, in the inevitable series resistance R_s of the semiconducting material of the diode. On the assumption that this is the only source of noise, it is possible to calculate the effective noise temperature of the amplifier. The noise level will depend upon the signal frequency as well as the properties of the diode and will be a minimum at a particular optimum pump frequency.

Calculated results are shown in Fig. 3 and 4. Of course, these theoretical minimum noise temperatures will not be completely achieved in practice because of additional



A—Diode cut-off frequency 50 Gc/s
B—Diode cut-off frequency 100 Gc/s
C—Diode cut-off frequency 200 Gc/s
D—Diode cut-off frequency 500 Gc/s

FIG. 3—CALCULATED VARIATION OF MINIMUM NOISE TEMPERATURE OF AN UNCOOLED PARAMETRIC AMPLIFIER WITH QUALITY OF DIODE



A—Signal frequency 10 Gc/s
B—Signal frequency 4 Gc/s
C—Signal frequency 1 Gc/s
D—Signal frequency 400 Mc/s

FIG 4—CALCULATED MINIMUM NOISE TEMPERATURE OF AN UNCOOLED PARAMETRIC AMPLIFIER AS A FUNCTION OF SIGNAL FREQUENCY

noise from other components in the amplifier, but experimental values of noise temperature can approach quite close to the theoretical values.

Parametric amplifiers having noise temperatures as shown in Fig. 3 and 4 are quite suitable for many applications. However, for satellite communications and some radio-astronomy experiments, much lower noise temperatures are needed.

The Johnson noise could be reduced by cooling the diode, provided that cooling the semiconducting material does not cause an increase in series resistance R_s. Cooling diodes of silicon or germanium produces little improvement in noise because the value of R_s usually increases as the diode is cooled, but diodes of gallium arsenide and indium antimonide have been successfully used in practical amplifiers cooled to 77°K (by immersing the complete amplifier in liquid nitrogen), and in laboratory experiments when cooled with liquid helium to 4·2°K.

Practical Parametric Amplifiers

From the foregoing sections it will be seen that the parametric amplifier consists of a series of tuned circuits, resonant at the signal and pump frequencies and at the difference between these frequencies. The non-linear capacitance is common to all three circuits. In addition, the one-port amplifier must have an additional element to separate the incoming and outgoing signals.

Depending upon the frequencies involved, the tuned circuits may consist of waveguide cavities, coaxial elements, stripline or lumped components. Although amplifiers have been made to operate at frequencies higher than 10 Gc/s, most commercial amplifiers operate between 400 and 4,000 Mc/s, with effective noise temperatures from 100–400°K, depending upon the signal, pump and diode cut-off frequencies.

The amplifiers have been used for several applications, such as the improvement of long-range radar receivers, tropospheric-scatter-link receivers, for remote reception of u.h.f. television signals, radio astronomy and in some satellite experiments. It is interesting to note that an experimental 960 Mc/s parametric amplifier designed and constructed in the Post Office Laboratory at Backwell, near Bristol, was used at Malvern to receive signals reflected from the ECHO satellite in August 1960.*

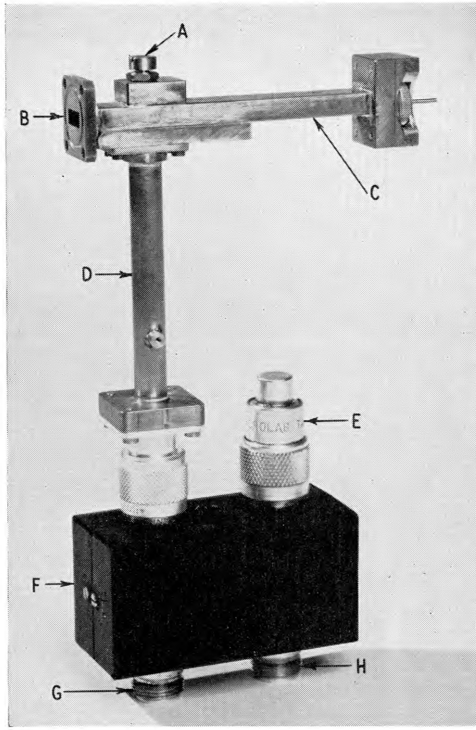
The microwave beacon signal received from the TELSTAR II satellite was amplified at Goonhilly Radio Station by a parametric amplifier designed and constructed at the Post Office Research Station, Dollis Hill.

Cooled amplifiers are not required for as many applications as are uncooled amplifiers, and are mainly used in radio astronomy, although some of the earth stations receiving signals from TELSTAR and RELAY are equipped with liquid-nitrogen-cooled amplifiers, either as the main or stand-by amplifier.

Fig. 5 shows a photograph of an experimental amplifier with a signal frequency of 4·17 Gc/s and a pump frequency of 24 Gc/s. This amplifier has been designed to operate when cooled to 77°K.

Before leaving parametric amplifiers, there is an additional type which should be mentioned. This is the degenerate parametric amplifier, in which the pump frequency has been reduced to just twice the signal frequency. The signal and idler pass-bands now overlap, and instead of the idler circuit being terminated inside the amplifier it is effectively terminated in the sky, via the aerial. Consequently, a signal entering the aerial appears in both idler and signal responses of the amplifier.

*Signal Transmission Across the Atlantic via a Passive Earth Satellite. *P.O.E.E.J.*, Vol. 53, p. 270, Jan. 1961.



A—Diode mount. B—Pump input. C—Idler cavity. D—Signal circuit. E—Coaxial load. F—Coolable co-axial circulator. G—Input. H—Output. Scale: approximately 2/3 full size.

FIG. 5—EXPERIMENTAL PARAMETRIC AMPLIFIER OPERATING AT 4·17 Gc/s

When coherent communication signals are involved, this double response would be unacceptable. However, when the required signal takes the form of noise, as in radio astronomy, it may be possible to use this overlap and to receive in both the signal and idler channels.

Such an amplifier has a theoretical noise temperature of only half the optimum value for the same diode in a non-degenerate amplifier, with the additional advantages of a low pump frequency and a wider bandwidth. The absence of a separate idler circuit makes such an amplifier much simpler than the corresponding non-degenerate version.

THE MASER

The maser is probably the most unusual of the new types of amplifier, depending upon both theoretical concepts and practical techniques hitherto usually found only in the research laboratory. The successful experiments with the passive satellite ECHO and the more recent active TELSTAR and RELAY communication satellites have depended upon the extremely-low noise temperatures which can be achieved with the maser type of amplifier.

The operation of the maser depends upon the laws of quantum physics which control the interaction between electromagnetic radiation and the electrons inside individual atoms. Although the principle is quite general, with many applications, it will be discussed here only in terms of a solid-state microwave amplifier.

According to the laws of quantum physics, electrons can exist inside an atom only in particular energy levels. The relative energy values for each level depend upon the nature of the atom and can be modified if the atom is influenced by an external magnetic or electric field, or if electrons are removed from (or added to) the atom to form an ion. Electrons can move from one level to another only if the exact amount of energy is added or taken away from the system. If this amount of energy enters or leaves as radiation, the frequency of the radiation is given by

$$f = \Delta E/h,$$

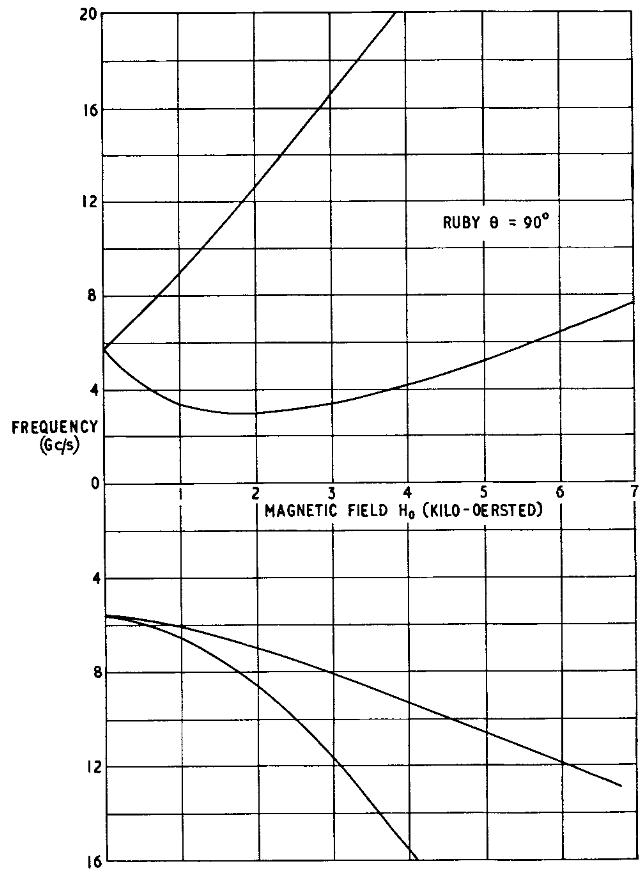
where ΔE is the difference in energy between the two levels, and h is Planck's constant, one of the fundamental constants of nature, with a value equal to $6{\cdot}6 \times 10^{-34}$ joule-seconds.

For every pair of electron energy levels there will be an appropriate resonant frequency at which radiation can interact with the electrons in the atom. In this context microwave frequencies are of interest, and therefore a system is required having energy gaps of the order of 10^{-24} joules.

There are, of course, a number of such systems, but the most suitable for designing a useful amplifier is that of the triply-ionized atom of chromium. The normal energy levels in the ion are modified by dissolving the chromium in a crystal matrix such as titanium oxide or aluminium oxide. The residual electrostatic field of the crystal lattice modifies the energy levels, and these are further modified by applying an external magnetic field. The resulting energy levels are shown in Fig. 6 as a function of the magnetic field for chromium ions in alumina—usually known as ruby. For convenience, the energy levels are expressed as frequency differences from an arbitrary zero.

At any strength of magnetic field there are four energy levels and hence six resonant frequencies. Under equilibrium conditions, the electron population will be greatest in the lowest levels, as shown in Fig. 7. In these circumstances, the crystal will absorb energy at any of the six resonant frequencies. If large amounts of energy are introduced at one of the resonant frequencies, the normal equilibrium conditions will be disturbed, and under these conditions absorption may no longer be possible at one of the other resonances; this is illustrated in Fig. 8. Here, one of the resonances has been "saturated," with the result that the distribution has been distorted, and the resulting relative populations of the lowest two levels have become inverted, i.e. there are now more electrons in the upper than the lower of the two levels. Absorption at this resonant frequency is now replaced by emission. If a small signal is introduced at this frequency it acts as a trigger, stimulating the emission of additional radiation at the same frequency. One packet, or "quantum," of energy (of magnitude $h \times$ frequency) enters the ion, and two leave. These two may encounter further ions which are in the saturated condition and so trigger off more stimulated emission. Thus, a growing wave of radiation at exactly the input frequency travels through the crystal.

If the "pump" power producing the population inversion is removed, the distribution will decay to the normal equilibrium condition and the amplification at signal frequency will cease. The decay will not be



θ is the angle between the crystalline c-axis and the applied magnetic field

FIG. 6—PARAMAGNETIC ENERGY LEVELS IN RUBY

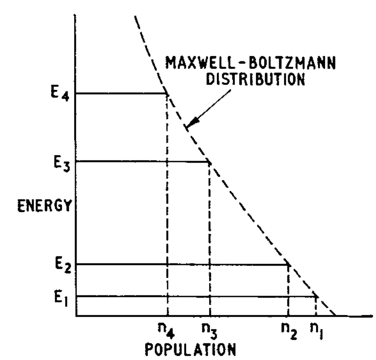


FIG. 7—POPULATION DISTRIBUTION OF ELECTRONS BETWEEN FOUR ENERGY LEVELS UNDER EQUILIBRIUM CONDITIONS

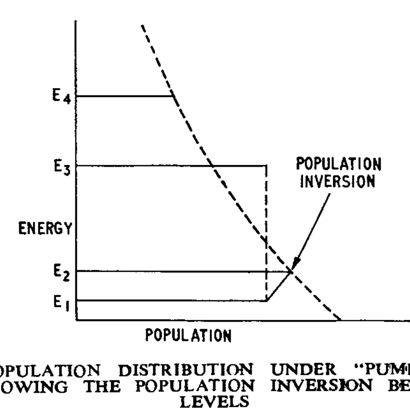


FIG. 8—POPULATION DISTRIBUTION UNDER "PUMPED" CONDITIONS, SHOWING THE POPULATION INVERSION BETWEEN TWO LEVELS

instantaneous, and the time constant, called the "relaxation time," is strongly temperature dependent. The applied pump-power must be sufficient to overcome the relaxation process in order to achieve saturation. At room temperature the relaxation process is extremely fast, and impracticably-large amounts of energy would be needed to saturate the crystal resonance. At the temperature of liquid helium the relaxation time may be several seconds, and a few milliwatts may suffice to saturate every chromium ion in a ruby crystal.

The stimulated emission process described above is free from noise. Some noise will be produced, however, by spontaneous random emission of energy at the signal frequency. The effective noise temperature produced by this spontaneous emission is very low, about 1–2°K. The gain of the maser depends upon the relative numbers of electrons in the various levels, and, according to the laws of thermodynamics, the lower the temperature the greater the population differences and consequently the greater the gain. Thus, both to increase the gain and to reduce the pump power, the maser must operate at a very low temperature. Despite this, the gain/unit-length of crystal is still very low, and unless extremely large crystals are to be used the effectiveness of the ruby must be improved.

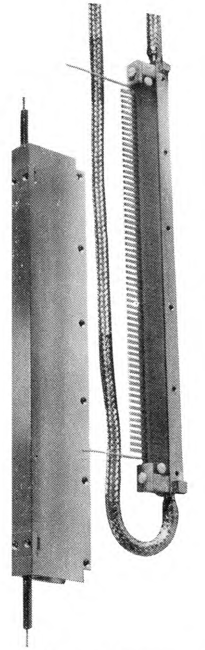
In the cavity-type maser, the ruby is placed in a resonant cavity so that the radio-frequency magnetic field operating on the ruby is increased by virtue of the cavity Q. In the travelling-wave maser a resonant slow-wave structure slows the signal wave down by a factor of 100–150, so increasing the interaction between the signal wave and the chromium ions in the ruby and thus increasing the gain to some 40–50 db in a crystal about 5 in. long.

This description shows some interesting similarities between the maser and the parametric amplifier. Both require a supply of energy at a frequency much higher than the signal. However, in practice, the pump and signal are much more closely related in the parametric device than the maser, and a much greater stability in the pump oscillator is required for the former.

The Maser in Practice

The two types of maser mentioned above have both been used as low-noise amplifiers, but the bandwidth of the resonant-cavity type is generally too narrow for use in a communication system. The description below is therefore of the travelling-wave maser as used at Goonhilly Radio Station. A cavity maser would have many similar constructional features, but would require a circulator to separate the input and output signals.

The photograph (Fig. 9) shows the slow-wave "comb" of the maser used at Goonhilly. The ruby is attached to one side of the comb. The plain alumina on the other side contains disks of ferrite, to act as reverse isolators; without them, the maser would oscillate. The comb and ruby must be cooled by immersion in liquid helium. This is standard practice in low-temperature laboratories, but involves considerable complication where the amplifier must be installed on a large aerial. Because liquid helium has a low latent heat, precautions are essential to reduce heat leaking into the equipment. The comb is mounted on long input and output lines made of an alloy of poor thermal conductivity. These lines (shown in Fig. 10) extend into a vacuum-insulated vessel containing liquid helium. The outer walls of this vessel are cooled with liquid nitrogen. The complete equipment is shown in



Unit partially dismantled to show comb structure, which is 6 in. in length

FIG. 9—COMB AND RUBY STRUCTURE OF THE 4·17 Gc/s TRAVELLING-WAVE MASER USED AT GOONHILLY RADIO STATION

Fig. 11. The various auxiliaries necessary to handle the helium have already been described.*

The magnetic field is supplied by a large permanent magnet with additional coils carrying a stabilized direct current to provide a fine tuning adjustment. The natural bandwidth of the maser depends upon the properties of ruby and is about 15 Mc/s. By introducing soft-iron shims to distort the magnetic field along the length of the ruby it is possible to "stagger-tune" the maser, to increase the bandwidth to 25–30 Mc/s with a net peak gain of about 30 db.

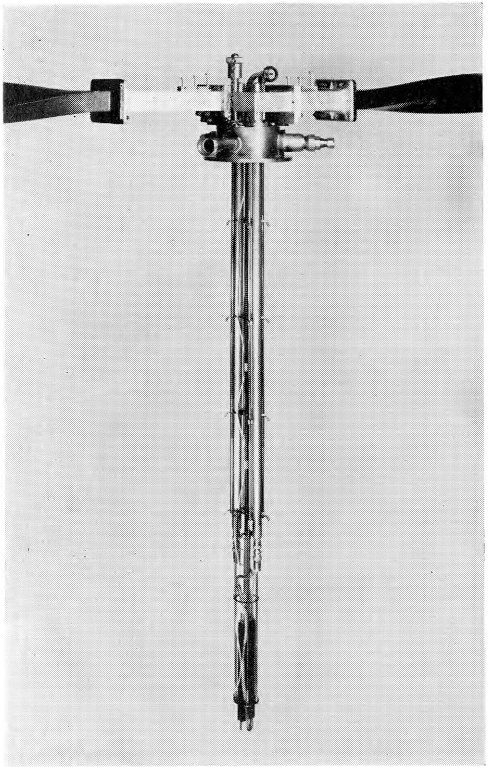
In later designs of maser the permanent magnet and soft-iron shims are replaced by super-conducting coils immersed with the comb structure in the helium bath. This increases the stability and decreases the weight of the whole device.

The cost and inconvenience of the liquid-helium supply (or the alternative closed-circuit refrigerator) tend to restrict the maser to applications requiring noise temperatures of only a few degrees, such as radio astronomy, satellite communications and inter-planetary radar.

COMPARISON OF MASER AND PARAMETRIC AMPLIFIERS

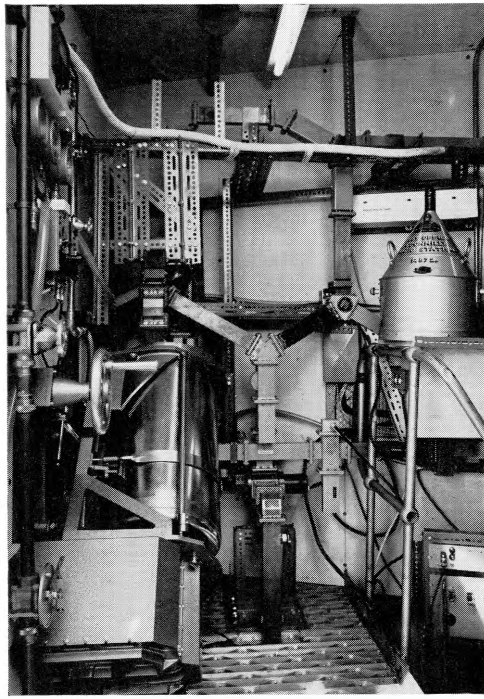
Comparison of the maser and parametric types of amplifier must, of course, take into account the use for which the amplifier is intended. If an amplifier noise temperature of 50°K is acceptable, then the relative

* DAGLISH, H. N., CHILD, M. R., and LEVETT, A. The Helium System of the Maser Installation at Goonhilly Radio Station. *P.O.E.E.J.*, Vol. 56, p. 29, Apr. 1963.



The overall height is about 3 ft 6 in.

FIG. 10—TRAVELLING-WAVE MASER MOUNTED ON INPUT AND OUTPUT COAXIAL LINES FABRICATED FROM THIN-WALLED CUPRO-NICKEL TUBES



The large cylinder is the double dewar holding about 12 litres of liquid helium. The box at the bottom of the maser is a thermally-insulated jacket protecting the permanent magnet.

FIG. 11—COMPLETE MASER INSTALLATION AT GOONHILLY

convenience and low cost of a liquid-nitrogen cooled parametric amplifier will probably be a deciding factor. If lower noise temperatures are required, the cryogenic problems of the maser and the parametric amplifier become more comparable.

The maser is a highly-linear amplifier giving rise to virtually no spurious signals even when partially overloaded. On the other hand, the parametric amplifier will, under certain circumstances, give rise to spurious harmonics and intermodulation frequencies at high signal-levels. In addition to spurious signals due to frequencies within the normal passband, the parametric amplifier is susceptible to cross-modulation by high-level unwanted signals outside the passband. The maser, on the other hand, does not respond appreciably to signals other than those at the resonant frequencies of the ruby. This is particularly advantageous in satellite communication systems, where the maser may have to operate with perhaps 25–50 mW of power leaking into the receive waveguide from the high-power transmitter.

A disadvantage of the maser in some applications is its restricted bandwidth. Bandwidths exceeding about 100 Mc/s seem likely to be impracticable, and 30 Mc/s is a probable limit for operation with a useful gain. Parametric-amplifier bandwidths may exceed 200 Mc/s, although the tuning stability and low-noise performance deteriorate as the passband is widened.

THE TUNNEL-DIODE AMPLIFIER

The tunnel-diode microwave amplifier has properties which make it complementary to the two very-low-noise amplifiers already described. The active element in the amplifier is the Esaki, or tunnel, diode, which uses another quantum phenomenon for its operation. If a semiconductor diode, as described above, is biassed in the reverse direction the potential barrier at the junction prevents current flowing. If the junction zone were made very thin by heavy doping and careful manufacturing techniques the conventional theory would still predict that no current would flow. Quantum theory on the other hand indicates that, when the barrier is very thin, there is a finite probability that electrons will pass through rather than over the potential barrier. The current/voltage characteristic then has the shape shown in Fig. 12.

At a small forward bias this characteristic has a negative-resistance region, so that the diode can be used as an amplifier. There is no tuned element involved in producing the negative resistance, as there is in the parametric amplifier, so the tunnel diode will amplify at any frequency up to its inherent cut-off frequency. A

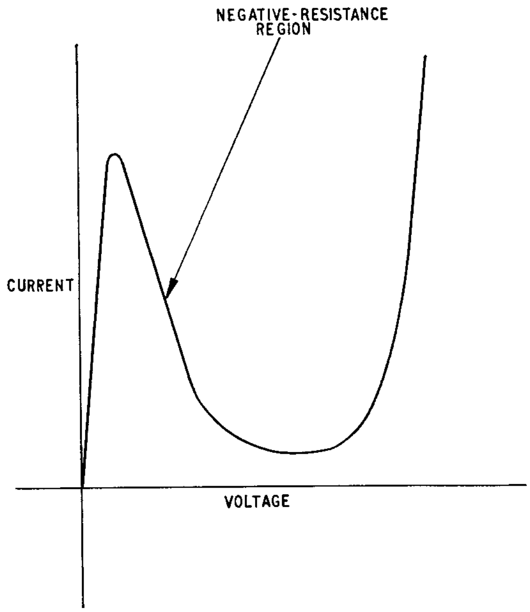


FIG. 12—VOLTAGE/CURRENT CHARACTERISTIC OF A TUNNEL DIODE

problem in designing the amplifier is that of restricting the overall gain to the desired part of the spectrum and maintaining an adequate impedance match at other frequencies. A poor match at any frequency can give rise to unwanted oscillations. With a suitable microwave circuit to ensure stability the tunnel-diode amplifier can provide, for example, a gain of 15 db with a 3 db bandwidth of 200 Mc/s. No high-frequency pump supply is required, the only external source of energy being the d.c. bias, which can conveniently be provided by a small mercury cell. An example of amplifier construction is shown schematically in Fig. 13.

The tunnel-diode amplifier is inherently more noisy than the parametric amplifier, because of the additional "shot" noise due to statistical fluctuations in the current flowing through the barrier. Noise temperatures will be in the region of 300–500°K. Such devices would be suitable for use as the first-stage amplifier in a terrestrial line-of-sight radio-relay link in which the thermal noise from ground and atmosphere is already considerable, or, alternatively, as a second-stage amplifier following a maser or parametric amplifier in lower-noise applications.

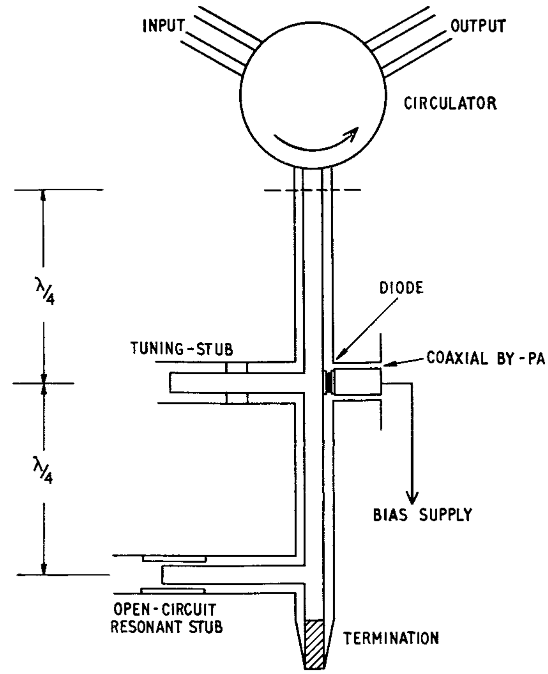


FIG. 13—SCHEMATIC DIAGRAM OF 2 Gc/s TUNNEL-DIODE AMPLIFIER

Because of the curved current/voltage characteristic, the tunnel-diode amplifier is very susceptible to the production of spurious harmonics and intermodulation products if the input signal level is high, and considerable selectivity preceding the amplifier may be required for adequate protection from unwanted signals. The amplifier has therefore a limited dynamic range compared with the other devices that have been discussed. Nevertheless, it is likely that its low cost and simplicity, and, in particular, the absence of any pump supply will ensure many useful applications for this type of amplifier.

ACKNOWLEDGEMENTS

The author wishes to thank Dr. J. C. Walling and Mr. F. W. Smith of the Mullard Research Laboratories for supplying Fig. 9 and 10, and Messrs. E. M. Hickin and B. Easter of the General Electric Company for Fig. 13. Fig. 5 was supplied by Messrs. D. Chakraborty, G. F. D. Millward and D. Geden of the Post Office Research Station.

Book Review

"A Course of Lectures on the Theory of Sound." S. N. Rschevkin. Pergamon Press, Ltd. xv + 464 pp. 101 ill. 84s.

This book is a translation of a course of lectures given to students specializing in acoustics at Moscow University. It begins with the derivation of the wave equation and proceeds to consider the transmission of sound through fluid media, transmission in tubes and radiation from various sources. No attempt is made to provide a complete survey of all aspects of acoustical theory, but the portions considered are well explored. The mathematical analysis, though not original, is well presented. Its usefulness is enhanced by examples of typical values likely to be met in practice, though there is an irritating mistake in these for all pressures quoted in bars are really in microbars.

The text has been well translated into clear English. But the most disappointing feature of the book is the poor quality of the printing, particularly the mathematical symbols. These are often very faint or very blotchy and odd blobs and lines are common. The sizes and sometimes the shapes of these symbols can change from line to line. The spacing and alignment are poor.

Nevertheless, despite its drawbacks, the book is an interesting addition to acoustical literature.

A.N.R.

The Use of Fault-History Records for the Maintenance of Telephone Switching Mechanisms

S. RUDEFORTH, A.M.I.E.E., and F. V. SANDERS†

U.D.C. 621.395.65.004.6

Mechanisms used in telephone switching systems are subject to widely varying amounts of wear and tear. Investigations to determine the practical maintenance requirements of individual items and the best means of meeting them are discussed, and the fault-history card procedure devised as a result of these investigations is described.

INTRODUCTION

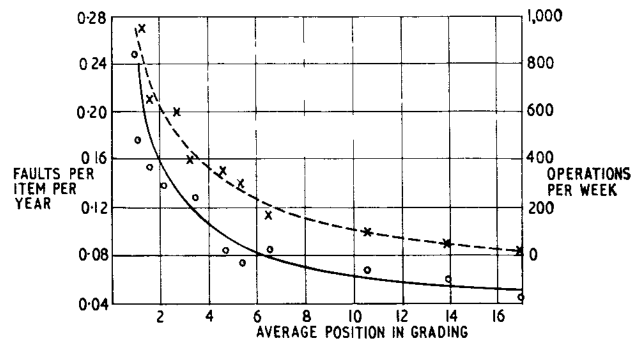
A FUNDAMENTAL requirement of any maintenance method is that it should be readily adaptable to the variety of conditions under which the equipment has to function. In this respect, mechanisms used in telephone switching systems—in particular in the Strowger step-by-step system—are subject to widely differing operational conditions. The maintenance technique adopted has to be capable of ensuring satisfactory maintenance of the most heavily worked mechanical items and yet be flexible enough to cater for the relatively meagre needs of late-choice items.

For many years it was the practice to maintain selector mechanisms and kindred items by inspecting and overhauling them at intervals determined by their average fault-incidence. This incidence of faults is naturally dependent on the number of operations performed by the items in total, and hence on the exchange calling-rate. In main exchanges overhauls were being performed at least yearly and sometimes more frequently, especially on common equipment. The cost of such work was considerable, and it was far from certain that it was justified by the results obtained. An investigation was, therefore, commenced in 1951 by the Post Office Engineering Department to assess the efficacy of the then current fixed-frequency inspection and overhaul method of mechanism maintenance, and to determine if it could be replaced by a more efficient system. Concurrent with the investigation, a number of controlled experiments were commenced in exchanges throughout the country.

EXPERIMENTS, RESULTS AND CONCLUSIONS

One experiment consisted of taking batches of about 200 selectors in various exchanges, overhauling them in accordance with the standard maintenance instruction and putting them back into service. Subsequent maintenance consisted of regular functional testing and lubrication; all other attention found necessary by way of fault clearance, etc., was carefully recorded. From the data obtained, some important factors relating to the performance of mechanisms were established.

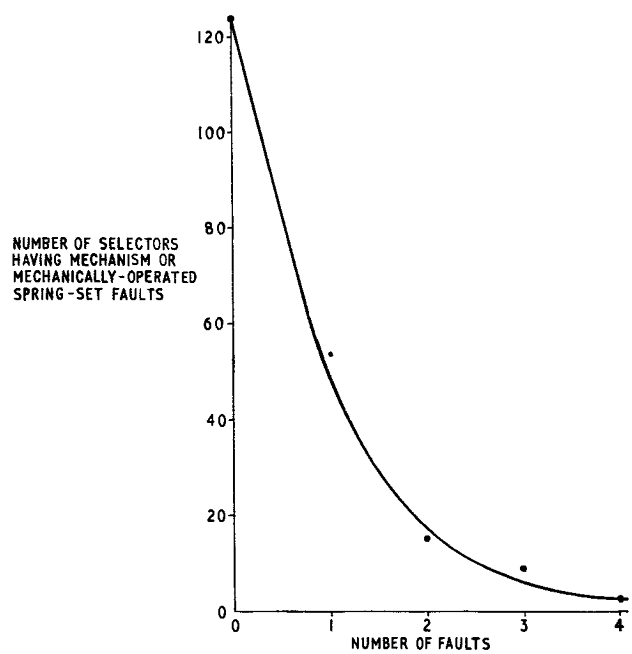
As might be expected, there was, in general, a direct relationship between the number of operations performed by an item—and therefore its position in the grading—and the fault incidence. Fig. 1 illustrates this relationship for one group of selectors in the experiment.



— Average number of faults per item per year
- - - Average number of operations per item per week
FIG. 1—RELATIONSHIP BETWEEN POSITION IN GRADING AND FAULT INCIDENCE FOR MECHANISMS AND MECHANICALLY-OPERATED SPRING-SETS

Some exceptions to the general pattern were found, and this led to the conclusion that although, in general, similar amounts of work produced similar degrees of wear and tear there would always be exceptions and any method of maintenance devised must cater for them.

The distribution of the mechanism and spring-set faults that occurred on the same group of selectors during 69 months following their overhaul is shown in Fig. 2, from which it can be seen that nearly two-thirds



The number of spring-set faults was 31 per cent of the total
FIG. 2—DISTRIBUTION OF FAULTS IN A GROUP OF 203 SELECTORS DURING 69 MONTHS FOLLOWING OVERHAUL OF SELECTORS

†Mr. Rudeforth was formerly in the Telephone Exchange Standards and Maintenance Branch, E.-in-C.'s Office; he is now retired. Mr. Sanders is in the Exchange Accommodation and Equipment Branch, E.-in-C.'s Office, but was also formerly in the Telephone Exchange Standards and Maintenance Branch E.-in-C.'s Office.

of the items suffered no mechanism or spring-set fault and about a quarter had only one fault of this type.

It is readily apparent that readjustment of the moving parts of selectors must disturb the relative positioning of the various mating surfaces concerned. Consequently, a number of operations must be performed before these surfaces bed down once more and assume maximum smoothness. Even the act of disturbing a mechanism merely to perform a perfunctory examination, and perhaps make one or two gauging checks and subsequent readjustments, has a similar disturbing effect, though to a lesser degree. It is not surprising, therefore, that there is a period of time immediately following an overhaul when selectors are more liable to failure. This period is generally followed by a much longer period—often three times as long—of relatively trouble-free functioning, after which there is a regular rise in the failure rate.

The variations in the trend of mechanism and spring-set faults in the years following overhaul is shown in Fig. 3 for the same batch of selectors. From this it is

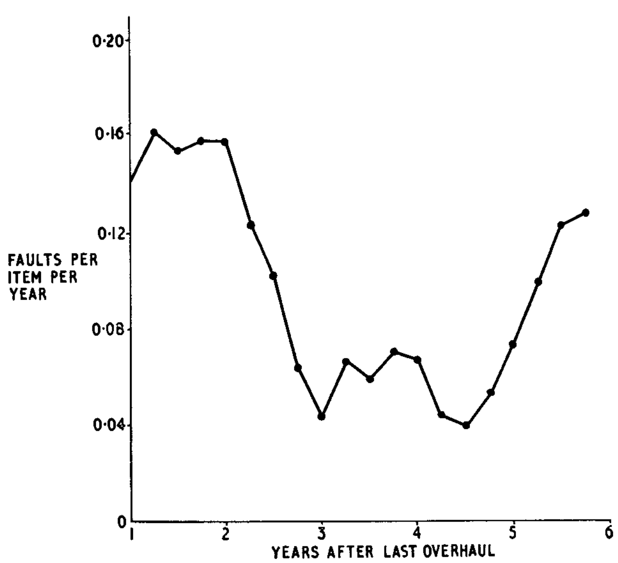


FIG. 3—VARIATIONS IN FAULT RATE OF MECHANISMS AND MECHANICALLY-OPERATED SPRING-SETS IN YEARS FOLLOWING OVERHAUL

clear that a relatively high fault-rate was experienced during the 2 years following the overhaul; this was the settling-down period already referred to for the selectors in question. The fault rate fell sharply during the third year to a very low figure around which it remained fairly steadily until it began to rise during the latter part of the fifth year. Even nearing the end of the sixth year it had barely reached three-quarters of the rate experienced just 15 months after the overhaul. It seemed logical, therefore, that any method of mechanism maintenance must be designed to take full advantage of the very low fault-incidence that follows the settling-down period after an overhaul.

From the results of the investigations it therefore appeared that a method most suited for mechanism maintenance should at least

(*a*) aim at minimum disturbance,

(*b*) meet the requirements of individual mechanisms, and

(*c*) take full advantage of the relatively trouble-free periods that follow settling-down after an overhaul.

During the investigations, when it became clear that mechanisms could operate satisfactorily for 2, 3 or even 4 years between overhauls, the fixed frequency of inspection and overhaul was reduced, as a first step, from yearly to 2-yearly for group selectors and from yearly to 3-yearly for final selectors, respectively. These changes came into effect in 1954.

FAULT-HISTORY-CARD PROCEDURE

The system of mechanism maintenance now usually known as the selector fault-history-card procedure was evolved to take account of the prime objectives mentioned above. Basically, the procedure aims at giving attention to individual items as and when the need arises, e.g. as the result of a subscriber's complaint, or because of the failure of the item to pass a functional test. The method deliberately avoids, as far as possible, regular inspections to check adjustments and wear. However, as with any machine having moving parts, regular lubrication is essential, and this is performed at regular intervals, generally yearly, care being taken to create as little disturbance as possible.

The regular removal of accumulated dust and dirt from a mechanism often creates a disturbance which in itself causes trouble in an otherwise trouble-free item. Careful judgment is required to determine when and just how much, or if any, cleaning is necessary. The decision must be a compromise between the likelihood that the dirt itself will cause trouble and the effect of the disturbance resulting from its removal. The decision whether or not to clean is taken when the mechanism is lubricated.

As yet no practical test has been devised that will check wiper-to-bank contacts satisfactorily, and wipers and their connecting cords are therefore still inspected at intervals most suited to local needs. Apart from wiper inspection a mechanism is given no other regular maintenance until attention is drawn to it as a result of a failure to perform correctly.

Fault Recording, Classification and Remedial Action

A fault-history card (Fig. 4) is prepared and kept for each mechanical item except that one card suffices for a shelf of subscribers' uniselectors. With the possible exception of wiper faults, all faults, however the item is affected, are carefully recorded on its history card. The course of action then followed depends on the type of fault, and the fault has, therefore, to be suitably classified.

Faults are classified as either predictable or chance. Predictable faults are those due to wear and tear, and it is this type of fault that mainly governs the need for overhaul; chance, or unpredictable faults are those that are as likely to occur at any one time as another and cannot therefore be anticipated. Examples of chance faults are: a broken wire or spring, or a dirty contact of an otherwise correctly adjusted spring-set. The incidence of such faults rarely has any bearing on the need for overhaul.

The fault classification is entered on the history card. A predictable fault demands a careful inspection of the mechanism to determine the extent of the wear and tear. The inspecting officer then decides whether or not an overhaul is required of

EQUIPMENT FAULT CARD

Equipment Designation . ... Date of last fault... . .. . Card No. ....

Date	How Found	Symptom	Actual Cause and Clear	Category	Inspected for overhaul		Overhaul not required
					By	Date	

FIG. 4—PART OF FAULT-HISTORY CARD

(*a*) the complete mechanism, or

(*b*) the mechanically operated spring-sets only.

Mechanism overhauls are required to be meticulously performed; all worn parts are changed and adjustments brought up to "readjust" limits. It is important that all the mechanically operated spring-sets should be inspected following a predictable fault on an item. As most spring-sets perform a similar number of operations to the associated mechanism, the degree of wear and tear is likely to be of the same order. Should an overhaul be considered unnecessary, further action is restricted to clearing the fault, care being taken to cause as little disturbance as possible.

The attention given after a chance fault is restricted to the minimum consistent with rectifying the fault and restoring the mechanism to service. It would be foolish to suggest, however, that in no circumstances should any further action be taken. Quite obviously, any defect in an item that must soon affect its satisfactory performance should be rectified. At the same time, if an examination of the history card shows an item to have suffered a relatively high incidence of miscellaneous trouble, especially if the record includes faults not found (F.N.F.s), it may then be considered advisable to overhaul the mechanism to improve its reliability. It is essential, therefore, that in addition to carefully recording the faults, their causes and the subsequent action taken should also be stated.

The relays associated with a mechanism are not normally included in the inspection that follows a predictable fault on the mechanism. The action taken when dealing with a predictable fault on a relay consists of a check of all its adjustments and, if necessary, correcting them. Experience has shown, however, that a simple inspection of all the relays on an item, following a predictable fault on any one relay, is worthwhile and this procedure is being introduced. The extent of this inspection is limited to a general examination and a check that spring-follow is satisfactory.

In conjunction with the procedure described above for mechanism maintenance, functional testing of the items is performed at a frequency controlled by guide figures. Such guide figures are related to a desired quality of service measured by the percentage failure-rate, and are expressed in terms of the ratio of the number of routine operations performed to the number of faulty items found. This principle of "feedback" enables the amount of testing to be related to the service given to the customer. The faults found by functional testing, together with those brought to light by patrolling officers and by reports, direct attention to the items and initiate the application of the fault-history procedure.

Although the procedure normally directs attention to individual items, occasionally, for one reason or another, a general defect in respect of a particular type of part or assembly may become apparent. This may be due to faulty manufacture or a circuit weakness. In these circumstances the normal fault-history procedure is suspended and the defective parts are replaced.

Items Excluded from the Fault-History Procedure

It is emphasized that the procedure outlined above is designed to overcome the difficulties arising from inequalities in the rate of usage, and hence the wear and tear, of mechanisms used in step-by-step switching systems. Certain mechanical items, e.g. time-pulse relay-sets and distribution relay-sets, which have regular use, are excluded from the procedure; for these it is a relatively simple matter to assess the rate of wear and apply overhauls at an appropriate frequency. This principle is also applied to small unit automatic exchanges (U.A.X.s) where the traffic is uniformly spread over the items and wear can be readily assessed.

Results Obtained Nationally

The procedure was introduced nationally in 1960 as standard for all director and non-director exchanges and U.A.X.s No. 7 and 14. At about 8 per cent of these exchanges the scheme had already been in force for experimental field-trial purposes for up to 5 years before national adoption, enabling information relating to costs and performance, and to the overhaul rate of the various items of equipment, to be compiled. From this information it is abundantly clear that the savings in manpower arising from the introduction of the scheme (in total about 25 per cent of the direct-labour costs formerly required for equipment maintenance) are being achieved without any deterioration in the standard of service to the customer; in fact, in many cases the service is significantly better.

A careful examination of the equipment and associated fault-record cards at a number of the exchanges, particularly those relating to common equipment, confirms that the condition of the mechanisms is adequately controlled by the procedure; as would be expected, the amount of attention given to a particular mechanism is closely related to its position in the grading and consequently the number of operations performed.

The rate of overhaul for the various items at exchanges where the new procedure has been in force under limited control conditions for up to 9 years is currently of the order indicated in the table.

Rate of Overhaul Per 1,000 Items Per Year

Item	Pre-2,000 Type	2,000 Type	Uni-selectors
Group selectors and final selectors	5	4	—
A-digit selectors	68	44	—
1st-code selectors	14	8	—
Subscribers' uniselectors	—	—	3
Director uniselectors	—	—	31

CONCLUSIONS

Whilst it is still a little early to form firm conclusions, some pertinent facts are considered below.

The maintenance expenditure in man-hours per automatic-exchange connexion for the 9 years up to March 1963 is shown in Fig. 5. There is as yet no sign of a halt in the downward trend shown. The growth in the number of exchange connexions for the same period is also shown.

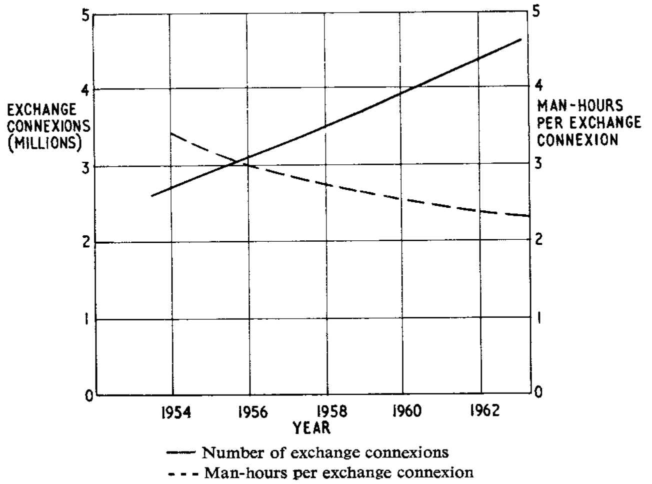


FIG. 5—RELATIONSHIP BETWEEN MAINTENANCE MAN-HOURS PER EXCHANGE CONNEXION AND TOTAL NUMBER OF EXCHANGE CONNEXIONS

In Fig. 6 the quality of service, assessed by local service observations, indicates a steady and continuous decrease in failures due to plant in non-director exchanges, whilst for director exchanges an increase in the fault-rate between 1959 and 1961 is now being contained.

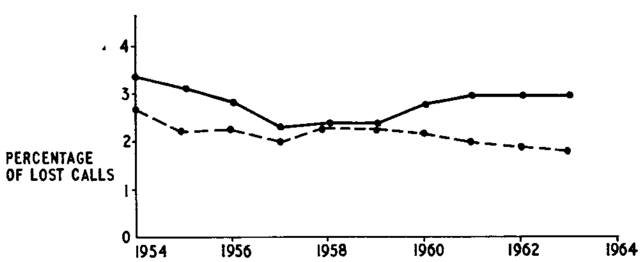


FIG. 6—FAILURES OF SUBSCRIBER-DIALLED CALLS DUE TO PLANT FAULTS IN DIRECTOR AND NON-DIRECTOR EXCHANGES

It is not unreasonable to expect that if the procedure is to have any marked effect, good or bad, on the performance of the plant, it would be most noticeable in director-exchange performance, especially in the London area. The complaint rate arising from exchange-equipment faults in the London director area is shown in Fig. 7 in terms of exchange-equipment faults per exchange connexion, from 1956 to March 1963.

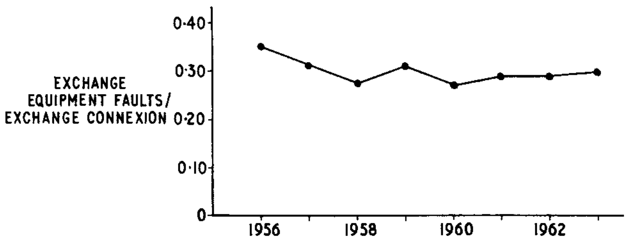


FIG. 7—COMPLAINT RATE DUE TO EXCHANGE-EQUIPMENT FAULTS IN THE LONDON DIRECTOR AREA

As in every instance when new or amended procedures are introduced it is difficult to show beyond doubt their precise effect; other factors and conditions so often exert an influence. Indeed, the upheaval and disturbance caused by the introduction of subscriber trunk dialling, especially in director areas where, for example, large numbers of 1st-code selectors have had to be removed, modified and replaced, has undoubtedly had a marked effect. A continuing insufficiency of suitable staff is a current problem and, associated with levels of traffic quite unprecedented in the annals of British telecommunications, demands the utmost efficiency and economy from procedures both old and new.

It is clear, however, that, in spite of the difficulties, the standard of service and the incidence of exchange-equipment faults are being controlled within acceptable limits at a considerably lower cost than hitherto. It is nevertheless advisable to sound a note of caution. Any procedure, method or scheme can only be as good as those who apply it will allow, and the fault-history procedure is no exception. It calls for a thorough awareness and appreciation, by all the staff concerned, of the principles underlying its conception and adoption, coupled with adherence to the simple basic requirements of carefully compiling the history cards and making an intelligent assessment of the position to decide when to overhaul. Given these basic requirements and a good measure of sound common sense it is believed the procedure will continue to control satisfactorily the maintenance of telephone switching mechanisms and will justify the confidence already being shown in it.

Panel-Mounted Cordless P.M.B.X. Switchboards

F. W. WOOD†

U.D.C. 621.395.65

A new range of private manual branch exchange (P.M.B.X.) switchboards is described. These have been designed to meet the requirements of the Fire Service and similar authorities who have P.M.B.X.s mounted in their control consoles alongside other switching panels. Ancillary working of these P.M.B.X.s is also described.

INTRODUCTION

CERTAIN subscribers, in particular the Fire Service and Electricity Authorities, find it necessary to concentrate their operational controls at a centralized desk or console where their officers can conveniently observe signals, operate switches, etc., and thus discharge their duties with maximum efficiency. It is often necessary for these officers to be provided with ready access to telephone facilities in the form of a private manual branch exchange (P.M.B.X.).

In the past, these requirements have been met by incorporating a standard Post Office type P.M.B.X. as part of the console. More often than not this resulted in an inconvenient, aesthetically displeasing, arrangement, and caused various non-standard type switchboards to be constructed specially for mounting in a console. An example of this type of installation is shown in Fig. 1.

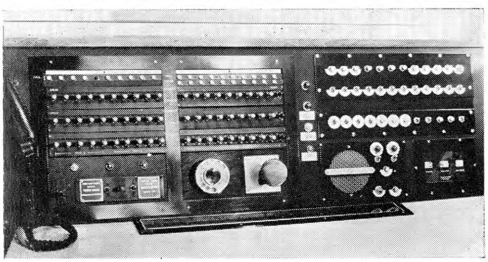


FIG. 1—NON-STANDARD P.M.B.X. PANELS INCORPORATED IN RENTER'S CONSOLE

To meet the growing demand for the type of installation described above, the decision was taken to introduce a standard panel-mounted P.M.B.X. suitable for incorporating in a console. The new P.M.B.X. was to be of modern design and was to compare favourably in appearance with other panels with which it might be associated.

A study of the requirements of a number of proposed installations showed that the needs could best be met by the development of two sizes of board: one, with a capacity of three exchange lines and 12 extensions (3 + 12), has been coded P.M.B.X. No. 3/3B, and the other, with a capacity of five exchange lines and 25 extensions (5 + 25), has been coded P.M.B.X. No. 3/5B.

The decision to produce a 5 + 25 size of cordless switchboard required careful consideration. Such a switchboard would be the largest of this type that the British Post Office had introduced, and it was possible that the large number of keys would introduce operating difficulties. Furthermore, in order to keep the number of keys to a minimum, only seven connecting circuits were to be provided, which is less than the normal provision for a board of this capacity. For these reasons, therefore, the use of the larger board was restricted at first to Fire Service and Central Electricity Generating Board control rooms. It was considered that the lower calling rate at these establishments and the skilled operating staff available would permit the use of the board without difficulty. Recently, however, it has been decided to remove this restriction, and both sizes of P.M.B.X. are now available to any subscriber. For the larger size of switchboard it is, however, stipulated that the traffic rate should be relatively low.

Provision has been made for wall mounting the switchboards if this is required.

PHYSICAL CONSTRUCTION OF P.M.B.X.

Both sizes of P.M.B.X. are of similar physical design and consist of a key panel and an apparatus rack (coded Equipment, P.M.B.X., No. 3/ . . .) having the dimensions and weights shown in the table.

Dimensions and Weights of P.M.B.X.s No. 3/3B and 3/5B

Item	Width (in.)	Height (in.)	Depth (in.)	Weight (lb)
Panel, P.M.B.X., No. 3/3B	16	13	5	15
Equipment, P.M.B.X., No. 3/3B	20	18	8	47
Panel, P.M.B.X., No. 3/5B	24½	18	7	30
Equipment, P.M.B.X., No. 3/5B	24	18	8	60

Fig. 2 shows a front view of the panel portion of the switchboard; it is finished in elephant-grey stoved p.v.c. (Organosol) and contains only that equipment necessary to operate the switchboard, i.e. designation strips, lamps, keys, dial and operator's telephone jack.

The exchange-line designation strips are fitted in a rectangular opening above the exchange-line calling

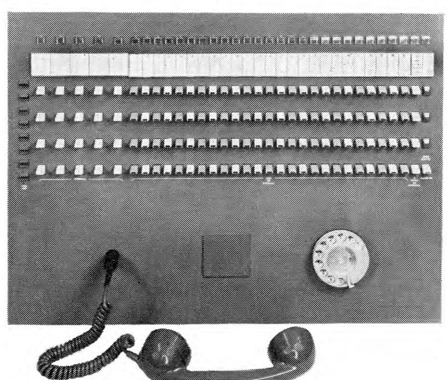


FIG. 2—FRONT VIEW OF KEY PANEL OF P.M.B.X. NO. 3/5B

†Subscribers' Apparatus and Miscellaneous Services Branch, E.-in-C.'s Office.

lamps. If s.t.d. meters are requested, these are fitted in place of the normal designation strip, which is replaced by a smaller type of strip secured by the upper fixing screws of the meters. The extension designation strips are mounted above the extension calling lamps, and are fitted with clips that slide into slots cut in the panel.

The operator's telephone jack provided on the front of the panel can be used to connect either a Handset No. 3 or a Headset No. 1. Tag blocks are provided on the rear of the panel for terminating the cable from the equipment case and to provide a convenient strapping point to enable certain extension terminations to be used either for extensions or private circuits.

The Equipment, P.M.B.X., No. 3/ . . . (Fig. 3), which

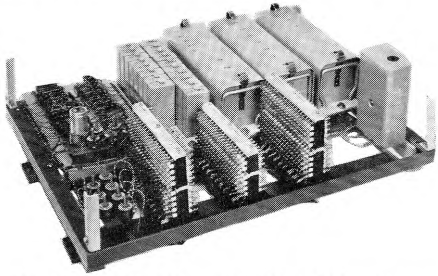


FIG. 3—APPARATUS RACK (EQUIPMENT, P.M.B.X., NO 3/. . .).

may be mounted away from the panel portion, contains the remainder of the switchboard equipment, and consists of a mild-steel framework fitted with relay plates, tag boards for resistors and capacitors, the operator's telephone circuit, and tag blocks for terminating external cables and the interconnecting cable from the panel, all being enclosed by a steel cover finished in elephant grey.

WALL MOUNTING

Although the switchboards were primarily developed for use in consoles and similar positions, the shallow depth of the panel portion, coupled with remote mounting of the bulk of the equipment, makes these P.M.B.X.s very suitable for wall mounting. For this purpose drawings have been prepared of suitable cases that may be constructed by local Post Office staff, or, alternatively, the drawings may be supplied to a customer to make his own arrangement for manufacture.

ANCILLARY WORKING

It is not expected that there will be a big demand for ancillary working, but circuits have been designed that will permit two or more switchboards to be coupled together with a minimum of interference with the permanent wiring of the P.M.B.X.s.

Incoming lines are connected to both switchboards via additional switching equipment associated with each line. Operation of an exchange-line or extension speak key on one position causes the line to be switched to that position, lights the appropriate calling lamp on the other position to indicate a busy condition, and disconnects the control lead from the second speak key to prevent interference with the call should that key be accidentally operated. Simultaneous operation of the appropriate speak keys on both positions will result in the incoming line being switched to only one position.

Fig. 4 shows the basic circuit element of the auxiliary apparatus used to couple a 4-wire internal extension[1] to two P.M.B.X.s No. 3/ . . .. When the extension calls, relay L operates via the telephone loop; contact L2 connects interrupted earth potential to the extension-lamp circuits on both positions, and contacts L3 and L5 operate the buzzers on both positions. Operation of the speak key on position A transfers the calling-lamp circuit on that position only from the incoming B-wire to the C-wire: relay TA operates in series with the lamp circuit, but the calling lamp will not glow in series with the high-resistance windings of relay TA. Contact TA1 disconnects relay TB and operates relay SA. The disconnexion of relay TB prevents interference with the call should the speak key on position B be accidentally operated. Contacts SA1 and SA2 switch the extension line through to the A-wire and B-wire of position A. Contact SA3 connects earth to the calling lamp on

[1]LIDBETTER, E. J. The 4-Wire Extension Principle for Small Cordless P.M.B.X. Switchboards. *P.O.E.E.J.*, Vol. 53, p. 167, Oct. 1960.

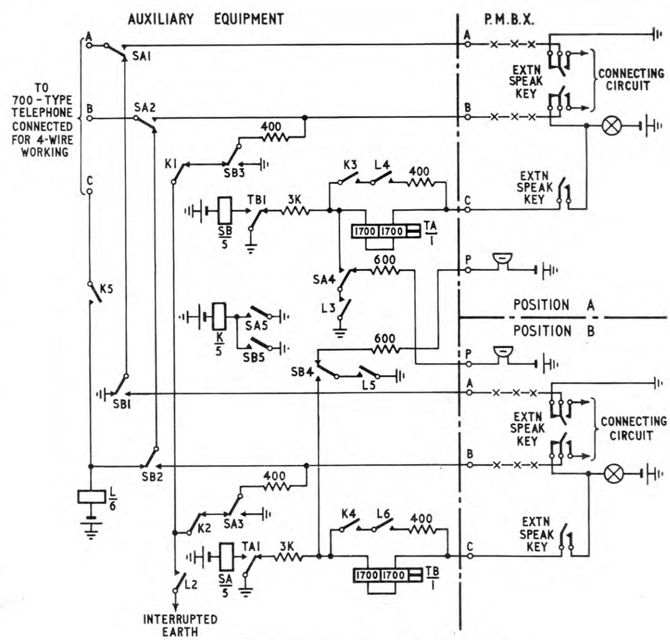


FIG. 4—SIMPLIFIED DIAGRAM OF COUPLING CIRCUIT

position B, causing it to glow and give the busy indication. Relay L releases on the operation of relay SA and disconnects the buzzer circuit on both positions. Contact SA5 operates relay K, which connects relay L to the C-wire of the extension telephone.

If the extension user presses the recall button or replaces the handset earth potential is connected to the telephone C-wire, operating relay L. Contact L3 short-circuits the 3,000-ohm resistor in series with relay TA, and contact L4 connects a 400-ohm resistor across relay TA. This increases the current flowing in the C-wire to position A to a value high enough to cause the lamp to glow without releasing relay TA. Contact L5 connects earth to the buzzer on position A, and contact SA4 prevents the operation of the buzzer on position B. When the speak key is restored, relays TA, SA and K release.

Similar circuits have been developed to provide the coupling facility on 2-wire external extensions, exchange lines and private circuits.

POWER SUPPLIES

Both P.M.B.X.s have been designed to operate from a nominal 50-volt d.c. supply that may be obtained either direct from a power unit connected to the mains or from a battery of float-charged secondary cells if stand-by power is required.

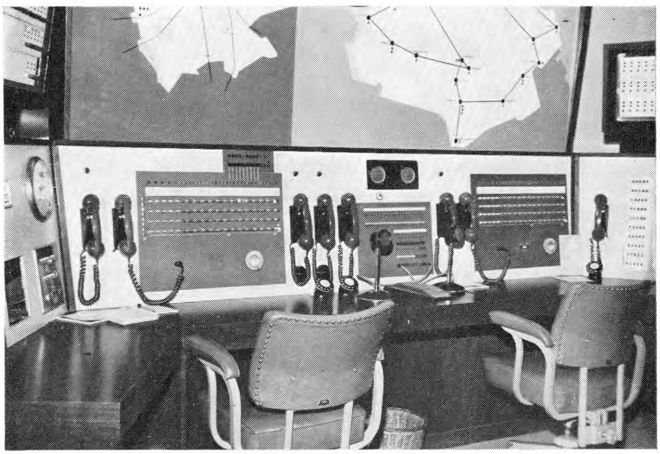
If full operation under mains-failure conditions is not required, ringing supplies are obtained from a rectifier-and-frequency-division unit[2] connected directly to a.c. mains. If the mains fail, established extension-to-exchange calls will be unaffected. Incoming calls on the first exchange-line will ring a magneto bell associated with the operator's telephone circuit; the remaining exchange lines may be extended by the connecting-circuit keys to selected extensions to maintain exchange-line service.

If full operation during mains failure is required, ringing is derived from a transistor-type ringing device energized by the 50-volt battery. Indication of a mains failure is given on a small key-and-lamp unit, which may be mounted on the front of the panel in place of a removable plate.

ADDITIONAL FACILITIES FOR THE FIRE SERVICE

The Fire Service frequently requires the facility of priority signalling,* and provision has been made to cater for this in conjunction with the new switchboards. The appropriate circuits have been designed, and small matching panels of keys and lamps are available which can be mounted adjacent to, and to line up with, the extension lamps on the P.M.B.X.

Matching panels have also been developed to accommodate the keys and lamps, etc., for the miscellany of alarm and firemen's call-out circuits provided by the Post Office for the Fire Service.



The priority-signalling panel is fitted above the left-hand switchboard; the miscellaneous-control panel in the centre.

FIG. 5—TYPICAL INSTALLATION OF TWO 5 + 25 P.M.B.X. PANELS, A PRIORITY-SIGNALLING PANEL AND A MISCELLANEOUS-CONTROL PANEL

Fig. 5 illustrates a typical installation using two 5 + 25 panel-mounted P.M.B.X.s, with a priority-signalling panel above the left-hand switchboard and a miscellaneous control panel, fitted with keys and lamps for call-out purposes, in the centre.

CONCLUSIONS

The panel-mounted switchboards have proved suitable for the operating requirements of the services for which they were designed, and, in practice, have found applications in wider fields than was originally anticipated. P.M.B.X.s of this type have been installed in locations as widely different as solicitors' offices, laundries and radio stations.

*Priority signalling is a facility which enables a P.M.B.X. operator to send an emergency signal (usually to another operator) over an engaged extension circuit.

[2]MOORE, M. B., and GORE, J. S. A New Range of Ringing Convertors for Subscribers' Apparatus. *P.O.E.E.J.*, Vol. 57, p. 187, Oct. 1964.

Path Testing for Microwave Radio-Relay Links

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U.D.C. 621.391.81:621.396.65

The equipment and procedures used for testing propagation paths between microwave radio-relay stations are described, and the methods used in analysing the results obtained are outlined with reference to typical examples.

INTRODUCTION

WHEN planning a point-to-point microwave radio-relay link, sites for radio-relay stations must be located that will enable line-of-sight propagation paths to be established between the transmitting and receiving aerials of each relay section. These propagation paths are required to be sufficiently clear of all natural or artificial features of the intervening terrain so that, for all but the very small percentage of the time when extremes of atmospheric refraction result in abnormal propagation paths being followed, propagation is nearly that obtained in "free space." It is usual to determine the relationship between a propagation path and the terrain over which it passes by drawing a path profile consisting of a plot of the vertical cross-section of the earth's surface along the line connecting the transmitting and receiving aerials. Path profiles are plotted from contoured maps of the area concerned, with additional information not given by maps, such as the heights of trees or buildings, being obtained by a visual survey.

In the United Kingdom, maps prepared by the Ordnance Survey provide a comprehensive and accurate record of the ground heights and topographical features of the country, and, using these maps, path profiles can be drawn from which reliable assessments of proposed propagation paths can be made. However, there are certain paths where, after a map study and a visual survey has been completed, the effect on radio propagation of certain terrain features remains in doubt. Examples of such uncertainties are the existence of unwanted reflected signals due to the presence of an expanse of water or to a bare hill near the propagation path, or the shielding effect of an area of trees or a group of buildings. It is then desirable to determine the suitability of the propagation path by carrying out a radio survey in which an actual radio transmission path is established over the relay section concerned.

RADIO SURVEYS

The radio surveys made by the Inland Radio Planning and Provision Branch of the Post Office Engineering Department take the form of aerial height/gain tests. These tests involve transmitting a microwave-radio carrier signal over the propagation path under test, using an aerial mounted at a fixed height at one terminal of the path whilst at the other terminal the aerial is raised in steps above the ground. As the aerial is raised, measurements are made at regular intervals of the level of the carrier signal received over the test path, and from these measurements the variation of received signal level is plotted against the aerial height. A series of these height/gain characteristics is obtained for various fixed aerial heights at each end of a propagation path, and from these characteristics it is generally possible to

(*a*) check the effective heights of obstacles along the radio propagation path,

(*b*) detect the presence of significant reflections from surfaces near the propagation path and estimate the location of the main reflection points,

(*c*) detect the presence of significant diffraction over natural or artificial features of the propagation path,

(*d*) assess optimum aerial heights, and, in some circumstances,

(*e*) determine the most suitable aerial positions, if the use of space diversity is contemplated.

Testing of paths is usually carried out in meteorological conditions approximating to average atmospheric refraction, i.e. a condition of well-mixed air with k, the ratio of effective earth radius to true earth radius, approximating to 4/3. In order that the results may be readily interpreted it is desirable that these average conditions should exist throughout the testing period. If tests are made in extreme weather conditions, for example when the air is still and stratified or when temperature inversion conditions are likely to exist, then a note should be made of the circumstances, and the tests should be repeated in more normal conditions. Height/gain tests are usually repeated several times to determine whether the results obtained are peculiar to the weather conditions existing at the time of testing. If the conditions are normal, then the height/gain characteristics obtained at different times and on different days should be closely similar.

TEST EQUIPMENT

A block schematic diagram of the portable equipment used by the British Post Office for microwave propagation height/gain tests is shown in Fig. 1. The apparatus is

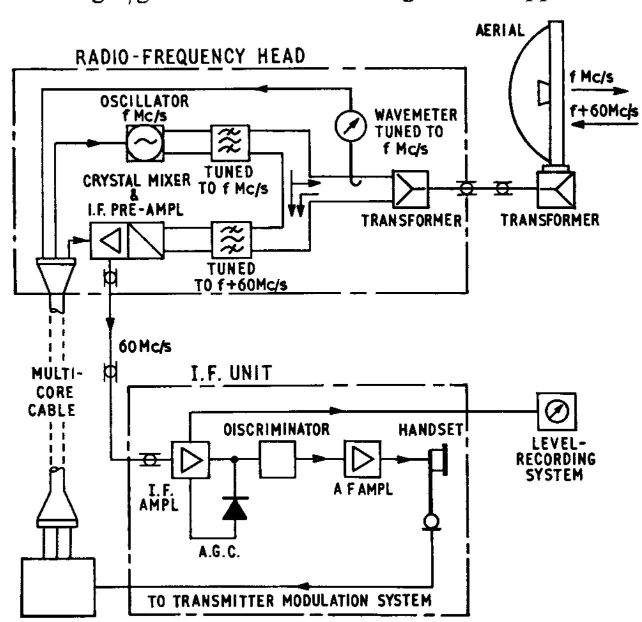


FIG. 1—BLOCK SCHEMATIC DIAGRAM OF PORTABLE MICROWAVE PROPAGATION EQUIPMENT

†Mr. Lelliott is in the Inland Radio Planning and Provision Branch, E.-in-C.'s Office, and Mr. Thurlow, who was also in that Branch, is now in the Ministry of Aviation.

accommodated in three boxes containing, respectively, the r.f. head, the intermediate-frequency (i.f.) amplifier unit and the power unit. Two-way transmission is provided over the test path, using a transmit frequency of 3,970 Mc/s in one direction of transmission and 4,030 Mc/s in the other. The r.f. head contains a coaxial-line oscillator operating in a waveguide cavity; this oscillator provides the transmitted carrier and also acts as the local oscillator used in deriving the 60 Mc/s i.f. from the received signal. An arrangement of waveguide filters enables a common aerial to be used for both transmitting and receiving. The transmitter output power is of the order of 250 mW.

The aerial system at each terminal consists of a 4 ft diameter parabolic aerial with a horn-waveguide feed. The aerial is mounted on a panning head which allows a movement of 120° in azimuth and 5° in elevation. The r.f. head unit is mounted immediately behind the aerial, and the complete assembly is rigidly fixed to a trolley that may be winched up and down a light-alloy mast (see Fig. 2). The aerial mast can be built up to a height of 200 ft using unit sections 8 ft 4 in. long and each weighing 80 lb. The cross-section of the mast is triangular with a 2 ft side.

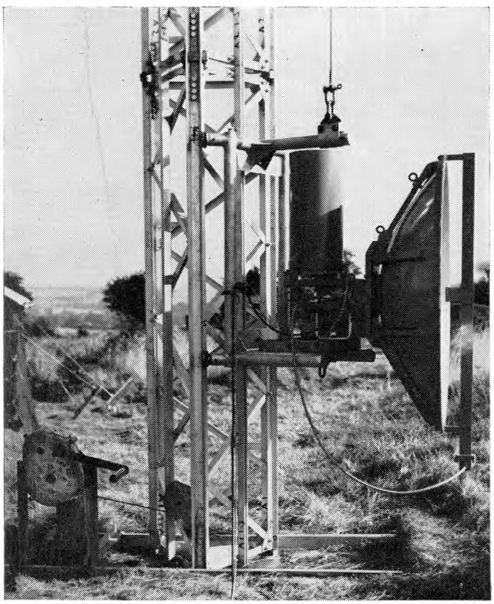


FIG. 2—RADIO-FREQUENCY HEAD AND AERIAL

The i.f. unit and power unit are normally housed in a wooden hut or a test vehicle located near the base of the test mast, and flexible cables are used to interconnect these units and the r.f. head. Fig. 3 shows one of the latest type of test vehicle; it is specially equipped for propagation testing.

FIG. 3—RADIO-PROPAGATION TEST VEHICLE

The equipment operates from a 200–250 volt a.c. supply which is usually obtained from a mobile generator; the total power consumption is about 500 VA per terminal.

Communication between the test terminals can be provided by frequency modulating the transmitted radio-frequency carrier, but it is usually more convenient to use portable v.h.f. radio sets to provide this facility.

TESTING PROCEDURE

Propagation tests frequently have to be carried out at sites located in rough country where vehicular access to the test site is difficult or even impossible. Usually the test equipment must be manhandled from the nearest road or track to the test site, but in extreme conditions a helicopter has been used. The equipment must, therefore, be readily portable and arranged so that both the weight and the bulk of the largest unit are not excessive. The present design of equipment used has been evolved with a 2-man unit load in mind.

Steel-wire guy ropes are used to support the mast, and these are attached in groups of three at 50 ft intervals and anchored at the ground end by a series of stay rods and stay blocks; temporary stays attached during erection are anchored by pickets. In peat and light soils a more substantial form of anchorage may be needed; in these circumstances it is usual to employ a wooden raft, about 6 ft square, placed below ground-level in a direction normal to that of the guy wires and loaded with about 1 ton of hardcore. To erect the mast, the lower two sections are manhandled on to a base formed by wooden sleepers; the upper sections are then lifted and bolted into position using the derrick-pole method of erection (see Fig. 4). Normally a 200 ft mast can be erected by a 5-man team in 3 days.

The trolley carrying the aerial and r.f. head runs up and down the test mast on a pair of guide rails. A set of guide rails is mounted on two of the three faces of the mast and the other face is fitted with a climbing ladder. By using both sets of rails and suitably orientating the mast it is possible, at a site for a proposed radio

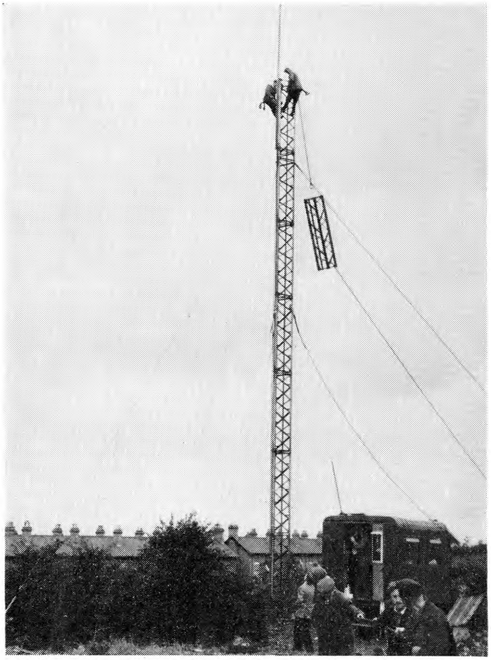


FIG. 4—ERECTING PROPAGATION TEST MAST

repeater station, to test to the two associated distant stations without the need to dismantle and re-erect the mast.

Once the test masts are erected and the equipment set up on site, the test transmitters and receivers are calibrated. The transmission loss over the test path is deduced from a knowledge of the transmitted and received powers. The transmitter output power is determined by measuring on a thermistor bridge a predetermined portion of the output power obtained from a cross-coupler in the output waveguide. The receiver input power is determined by a substitution method, using calibrated attenuators and a s.h.f. oscillator whose output may be measured by a thermistor bridge. The receiver input-power level is indicated on a meter which is effectively controlled by an a.g.c. voltage derived from the rectified output of the main i.f. amplifier. This meter may be calibrated to read directly the input power to the receiver.

The transmission loss over a test path, L, is given by the expression

$L = P_T + G_T - P_R + G_R$ db (between isotropic radiators),

where P_T = measured transmitter output power (dbm),

P_R = measured receiver input power (dbm),

G_T = net gain of the transmit aerial system (db), and

G_R = net gain of the receive aerial system (db).

The net gains of the aerial systems are relative to an isotropic radiator and include the feeder losses to the calibration points.

The gain of the 4 ft diameter aerial used with the test equipment is approximately 31 db at 4,000 Mc/s, and with a transmitter power of 250 mW (+ 25 dbm) a path loss between isotropic radiators of up to 180 db may be measured with an accuracy better than $\pm$ 2 db. Thus, on a 30-mile propagation path, signals 40 db or more below free-space level may be detected.

Having calibrated the test equipment and established a transmission path between the test sites, a program of height/gain tests can then proceed. For convenience, measurements of signal level are made at height increments of either 8 ft 4 in. or 4 ft 2 in., coinciding with the length, or half the length, of the sections from which the test mast is fabricated. At each test height, the aerials must be panned for maximum signal to ensure that any twist or instability of the test mast has not put the aerials off-beam.

INTERPRETATION OF TEST RESULTS

The method used to interpret measured height/gain characteristics is to compare them with simplified theoretical height/gain patterns. Two types of theoretical height/gain pattern are usually considered:

(*i*) those due to a second wave path caused by reflection from a surface, and

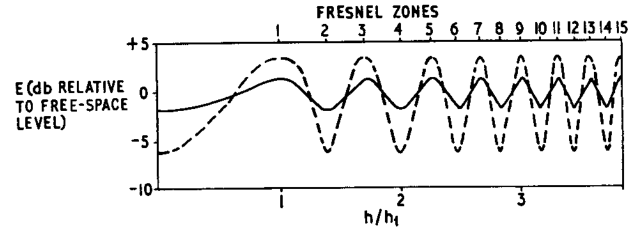
(*ii*) those due to diffraction over a ridge.

Reflection

If the resultant signal received over a propagation path may be considered as the vector sum of a direct component following a line-of-sight path between transmitting and receiving aerials and an indirect component from a reflecting surface along the path, then the amplitude of the resultant will be a function of the phase relationship between the two components. The reflected signal will differ in phase from the direct signal because of the phase change experienced on reflection and because the path travelled by the reflected signal will be longer than that travelled by the direct signal. For small grazing angles, typical of ground reflections on microwave paths, the phase change on reflection is approximately constant and equal to π radians.[1] However, the phase difference due to the difference in the length of the path travelled will change as the relative positions of the reflecting surface and the aerials are changed as, for example, when an aerial is raised in a height/gain test.

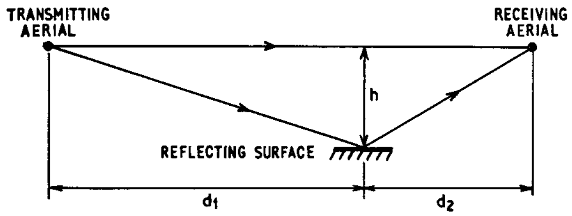
Fig. 5 shows the theoretical pattern of received signal level due to a direct and to a reflected wave normalized in respect of h/h_1, where h and h_1 are, respectively, the actual clearance and the first Fresnel-zone clearance[2] of the direct path over the reflecting surface. The curves have been plotted assuming voltage ratios of direct-to-indirect signal components of 0·2 and 0·5.

If a measured height/gain characteristic exhibits an oscillatory pattern, which may be attributed to specular reflection from a single surface in a fixed position, then the spacing between the maxima and minima of the measured curve will give an indication of the position of the reflecting surface. If the maxima and minima are closely spaced, then the reflecting surface is either several Fresnel zones below the direct path or, more probably, the reflecting surface is near the terminal at which the aerial height is being changed. Fig. 6 illustrates the way in which the position of a reflecting surface along a path affects the spacing between the maxima and minima of a height/gain pattern.



---- $\rho = 0{\cdot}5$ ——— $\rho = 0{\cdot}2$

(a) Received Signal-Level Characteristics



(b) Relationship of h, d_1 and d_2

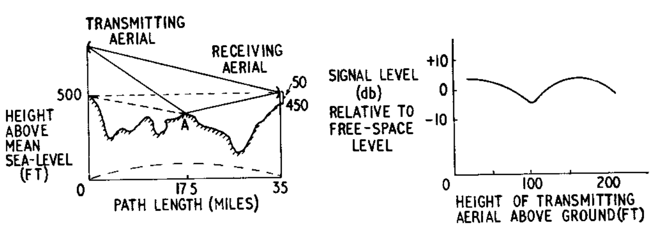
$$E = E_0\left[1 + \rho e^{-j(\phi + \pi)}\right]$$

where E = received signal level,
E_0 = free-space signal level,
ρ = voltage ratio of indirect to direct ray, and
ϕ = phase shift due to difference between direct and indirect path length.

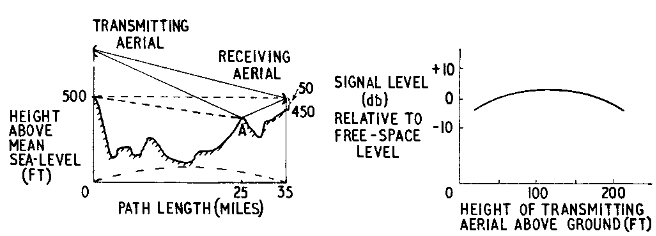
$$h_1 = \sqrt{(\lambda\, d_1\, d_2/d_1 + d_2)}$$

where h_1 = first Fresnel-zone clearance,
λ = wavelength,
d_1 = distance from transmitting aerial to reflection point,
d_2 = distance from receiving aerial to reflection point, and
h = clearance of direct-ray path above reflection point.

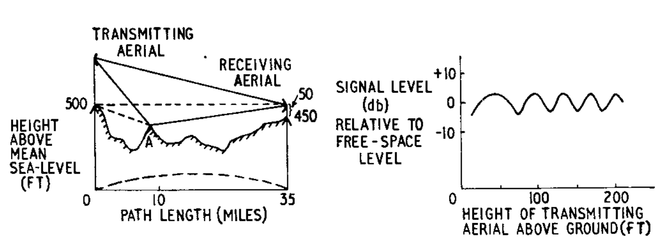
FIG. 5—THEORETICAL VARIATION OF RECEIVED SIGNAL LEVEL DUE TO 2-PATH PROPAGATION



(a) Reflecting Surface at Mid-Path



(b) Reflecting Surface near Receiving Aerial



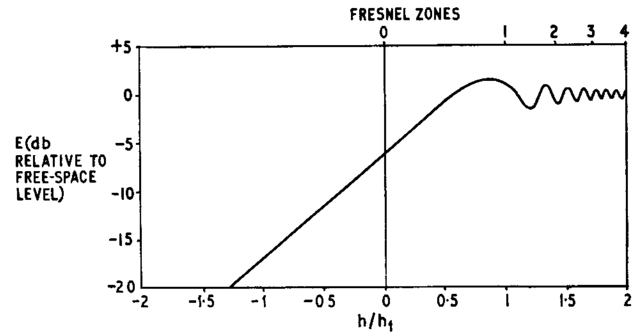
(c) Reflecting Surface near Transmitting Aerial

A—Reflection point
Signal frequency = 4,000 Mc/s
Voltage ratio of indirect to direct ray = 0·5

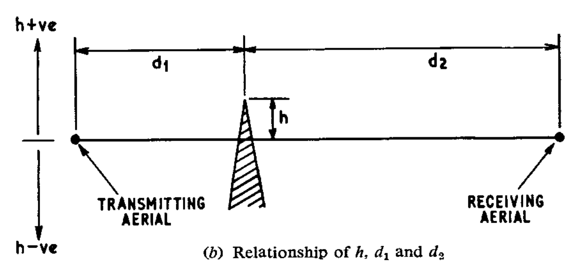
FIG. 6—EXAMPLES OF THEORETICAL HEIGHT/GAIN CHARACTERISTICS

Diffraction

If part of the energy transmitted over a propagation path is shielded from the aerial by an obstacle taking the form of a non-reflecting ridge crossing the path, then the received signal may be determined from the theory of "knife-edge" diffraction.[3] An estimate of the position and height of a diffracting obstacle can be made with the aid of Fig. 7, which shows the pattern of received signal level due to knife-edge diffractions normalized in respect of h/h_1. This theoretical approach is based on a diffracting screen of infinite width, but, in practice, the results will be applicable provided that the width of the screen is large compared with h.



(a) Received Signal-Level Characteristic



(b) Relationship of h, d_1 and d_2

$$E = E_0\left[\frac{e^{j\pi/4}}{\sqrt{2}}\int_{\infty}^{v} e^{-j\pi v^2/2}\,dv\right],$$

where E = received signal level,
E_0 = free-space signal level, and

$$v = h\sqrt{\left[\frac{2}{\lambda}\left(\frac{1}{d_1} + \frac{1}{d_2}\right)\right]}$$

where h = clearance of direct-ray path above diffraction point,
d_1 = distance from transmitting aerial to diffraction point, and
d_2 = distance from receiving aerial to diffraction point.
$h_1 = \sqrt{(\lambda\, d_1,\, d_2\, /\, d_1 + d_2)}$,
where h_1 = first Fresnel-zone clearance, and
λ = wavelength.

FIG. 7—THEORETICAL VARIATION OF RECEIVED SIGNAL LEVEL DUE TO KNIFE-EDGE DIFFRACTION

Measured Height/Gain Characteristics

Radio links are planned to maintain adequate propagation-path clearance over all features of the intervening terrain under conditions of sub-refraction. Height/gain tests are carried out when the conditions of atmospheric refraction are near average, and under such conditions the propagation path is usually several Fresnel zones clear of the terrain. Therefore, in general, diffraction effects will be apparent only at low aerial heights and then only if the diffracting obstacles are near the terminals of the path. Knife-edge diffraction theory leads to the premise that the oscillatory variation of received signal is less than 2 db if the direct-path clearance above the knife-edge is greater than that of the first Fresnel zone. Thus, if an oscillatory variation is obtained greater than 2 db, it follows that knife-edge diffraction is not the prime cause and some other mechanism has a significant effect on the level of signal received.

If the same pronounced oscillations of a height/gain pattern are obtained on repeating a test at different times on different days, the pattern is unlikely to be the result of abnormal atmospheric conditions such as stratification. The oscillations may then be due to a single reflection, and, if so, the position of the reflecting surface may be inferred by a process of comparison between theoretical height/gain characteristics drawn for specific areas indicated by the path profile and map survey.

Frequency Dependence of Height/Gain Characteristics

Variations in the shape of height/gain characteristics due to reflection and diffraction effects are functions of the frequency of transmission over the path. As the test frequencies will not necessarily be the frequencies to be used when the link is operational, due consideration of the frequency dependency of the observed effects must be made when interpreting the results. The test frequencies are normally arranged to be near the centre of the band of frequencies to be used on the link, and on the majority of paths the height/gain characteristics will not change significantly for any frequency within that band. However, for paths on which the direct-path clearance above reflecting surfaces is large, e.g. 20–30 Fresnel zones, there may be considerable variation in the characteristic for a relatively small change of frequency. For such paths, the test characteristics may be used to give information on the position of the reflecting surfaces; theoretical height/gain characteristics can then be deduced for the frequency to be used. Similar theoretical characteristics can be derived for propagation at frequencies not within the band containing the test frequencies.

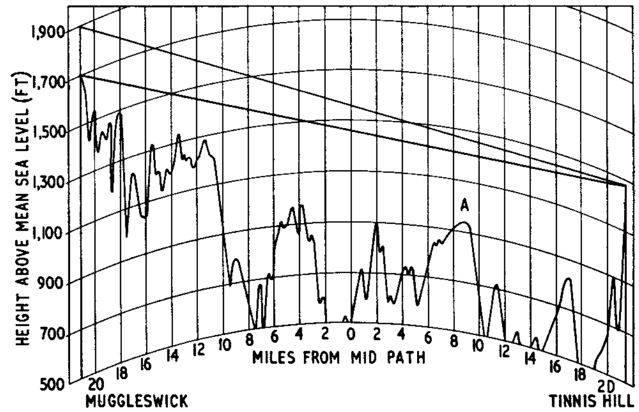
LIMITATIONS OF TESTING PROCEDURE

Whilst the testing procedure described provides useful information on the characteristics of a propagation path, it nevertheless has certain limitations. The tests are carried out over a relatively short period of time and can give no indication of the overall fading characteristics of the path. Also, the signals used for the tests are unmodulated carrier waves, and there exists no means of determining the relative delay of any reflected signals. A long-delayed echo that could cause serious distortion to a television signal could exist on a path, but such an echo might not be detected by the tests. A further limitation is that the test equipment uses horizontally-polarized signals at two discrete frequencies near the centre of the 4,000 Mc/s civil-communications band, and therefore results obtained from the test are strictly valid for only these particular signals. A more rigorous form of testing would use both horizontally-polarized and vertically-polarized signals at several frequencies in each of the frequency bands to be used.

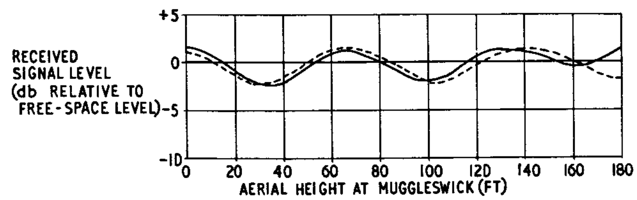
EXAMPLES OF HEIGHT/GAIN MEASUREMENTS

Muggleswick–Tinnis Hill Test Path

Fig. 8 shows a measured height/gain characteristic and the path profile of a propagation path between Muggleswick (near Consett) and Tinnis Hill (near Langholm). The aerial at Tinnis Hill was fixed at a height of 71 ft 8 in. above the ground, and the aerial at



Path length 42·6 miles.
First Fresnel-zone clearance at A = 105 ft. $k = 4/3$
(*a*) Path Profile



——— Measured characteristic
- - - - Theoretical characteristic assuming reflexion at point A (voltage ratio of indirect to direct ray = 0·2)
(*b*) Height/Gain Pattern

FIG. 8—MUGGLESWICK–TINNIS HILL HEIGHT/GAIN TESTS

Muggleswick was raised in 4 ft 2 in. increments from 4 ft 2 in. to 195 ft 10 in. The height/gain pattern shows an overall variation contained within limits of about ±2 db over the test range, and the regular periodic variation of the characteristic suggests the presence of a single pronounced reflection.

The absence of an initial rise in signal level as the aerial is raised above the ground indicates that no significant diffraction is taking place and that first Fresnel zone clearance is being exceeded at all but the lowest aerial heights. This is consistent with the terrain features indicated by the path profile.

A theoretical characteristic was drawn assuming a reflected signal from a point A some 12½ miles from Tinnis Hill. First Fresnel-zone clearance above point A is 105 ft, and raising the aerial at Muggleswick from near ground level to approximately 200 ft increases the clearance from the ninth Fresnel zone to the fourteenth Fresnel zone.

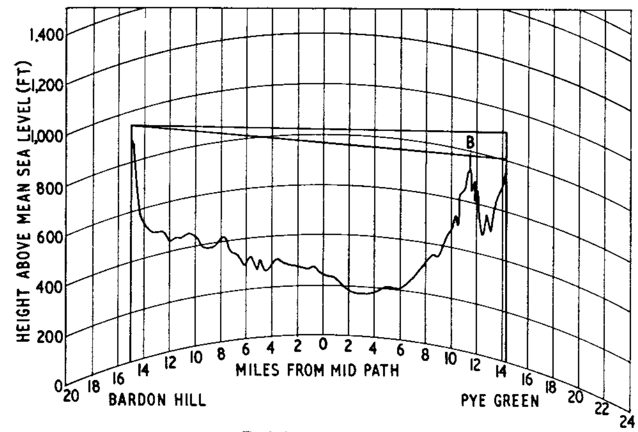
A comparison between the measured and theoretical characteristics suggests that a reflection from A is the predominant factor determining the height/gain pattern, and this assumption was supported by a visual survey which showed the area to be almost flat, covered by peat and heather and without trees, hedges or buildings.

From the results of a series of tests over this path, it was concluded that to minimize the effects of reflections from A, aerials at Muggleswick should be high, e.g. 130 ft, and aerials at Tinnis Hill should be low, e.g. 30 ft.

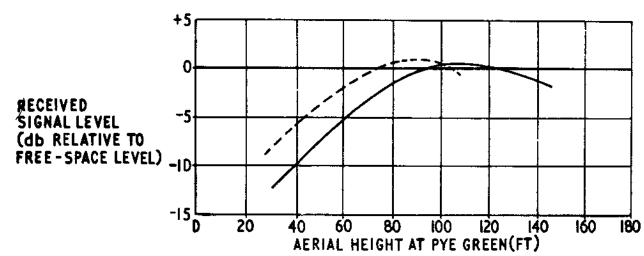
Bardon Hill–Pye Green Test Path

As part of a series of tests, a height/gain test was made over the path Bardon Hill near (Coalville)–Pye

Green (near Cannock), with a fixed aerial at Bardon Hill at a height of 47 ft 6 in. and the aerial at Pye Green raised in 8 ft 4 in. steps from 30 ft 10 in. to 147 ft 6 in. Fig. 9 shows the path profile and measured height/gain pattern obtained.



Path length 29·3 miles
First Fresnel-zone clearance at B = 40 ft $k = 4/3$
(a) Path Profile



——— Measured characteristic
- - - - Theoretical characteristic assuming diffraction at point
(b) Height/Gain Pattern

FIG. 9—PYE GREEN–COALVILLE HEIGHT/GAIN TESTS

The long initial slope of the height/gain pattern indicated an obstruction to the wave path at low aerial heights, introducing a diffraction loss. From the path profile, the obstacle appeared to be at a point B some 3 miles from Pye Green.

A theoretical diffraction curve drawn assuming knife-edge diffraction at B, showed that, for the obstacle height indicated by the profile, a free-space field would be obtained with an aerial height of 75 ft at Pye Green. The measured curve indicated, however, that a free-space field was obtained with an aerial height of 95 ft. Thus, the test suggested that the obstacle height was some 20 ft greater than that indicated by the profile, and this was later confirmed by a visual survey.

CONCLUSIONS

Propagation tests of the height/gain type have been carried out by the Post Office on 30 different propagation paths in various parts of the country. From these tests it has been possible to assess the suitability of the paths concerned and make recommendations as to the heights at which aerials should be mounted. Apart from providing data on specific paths the tests have resulted in the accumulation of a considerable amount of general information on the propagation characteristics of the various types of terrain found in the United Kingdom.

ACKNOWLEDGEMENTS

The portable test equipment used for microwave-propagation tests was designed and manufactured by Standard Telephones and Cables, Ltd. The test aerial mast was produced by British Insulated Callender's Cables, Ltd.

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[3]MEGAW, E. C. S. Some Effects of Obstacles on the Propagation of Very Short Waves. *Journal I.E.E.*, Vol. 95, Part III, No. 34, p. 97, Mar. 1948.

Book Review

"Sampling Systems Theory and its Application." Y. Z. Tsypkin. Pergamon Press, Ltd. Vol. I: xvi + 373 pp., 231 ill. Vol. II: 363 pp., 184 ill. Vol. I and Vol. II: £5.

The author states that the object of this book is "to study the general dynamic properties of pulse systems and the methods of analysing, investigating and constructing such systems." The book is "meant for readers who are acquainted with elements of pulse techniques and the theory of automatic control and who have, consequently, some knowledge of the Laplace transformation."

The book was originally published in Russia in the same year (1958) as Jury's book which covers a roughly comparable field ("Sampled-Data Control Systems." Eliahu I. Jury. John Wiley & Sons (New York), 1958). Both authors devote considerable space to the development of their analytical tools. Tsypkin's ensuing approach to pulse systems is by examination of a selection of practical systems of both open-loop and closed-loop automatic control type. This approach will appeal to readers with an engineering outlook, notwithstanding that the systems are, in fact, treated in great analytical detail—Jury's approach is more generalized and theoretical.

The most noteworthy difference is, however, in methods of analysis. Tsypkin's methods are based on the discrete Laplace transformation and he gives reasons (pp. 166–167) for choosing this in preference to the z-transform favoured by Jury. As a great deal of the work published in English since 1958 on pulse system analysis and synthesis has relied on z-transform techniques Tsypkin's book is not quite so useful as Jury's for readers who wish merely to equip themselves for reading current English-language papers on the subject. Nevertheless, the two techniques are closely related and this fact, together with the somewhat different approaches of the two authors, makes the books a very good complementary pair for a reader wishing to extend his insights.

The book is written with a care worthy of the author's reputation and is well translated. It contains a bibliography which, although now outdated, gives very good coverage of pre-1958 work. There are, however, far too many misprints and typographical errors for a book of this price.

L.W.H.

Replacement of the World's First Traffic-Carrying Submerged Repeater

G. A. AXE, A.M.I.E.E., and E. C. VOGEL†

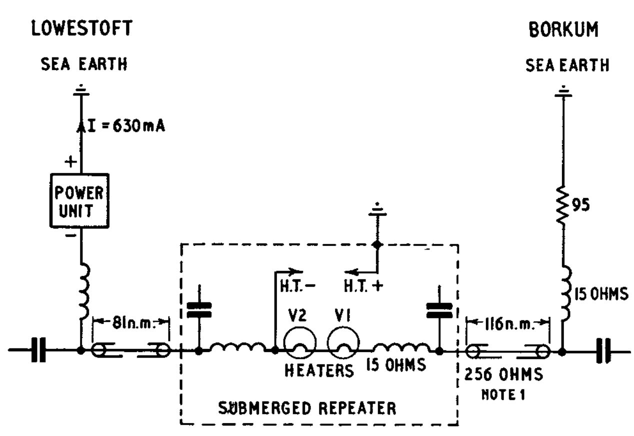
U.D.C. 621.395.64:621.375.2:621.315.28

The first submerged repeater to provide traffic-carrying circuits was inserted in the Lowestoft–Borkum cable in June 1946 and worked entirely satisfactorily until February 1964, when a noise fault developed which led to its replacement by a similar spare repeater on 16 April 1964. Unfortunately, when the repeater fault occurred there was already a fault on the cable, causing similar noise, which had been located approximately but not cleared. The location and clearance of the faults on the cable posed some difficult problems which had novel solutions. These circumstances, and the historic nature of the repeater, make the full story worthy of record, providing good examples of the problems met in the maintenance of the shorter submerged-repeater systems.

INTRODUCTION

THE Lowestoft–Borkum cable is of the 0·62 in. polythene type, and was laid in 1945 to provide circuits to the British forces in Germany. Initially it provided two telephone circuits, but the insertion of the single repeater increased its capacity to five telephone circuits. Multi-channel voice-frequency telegraph systems have always been routed over the cable, and at present the cable is used wholly for these, the five telephone circuits providing a capacity of 120 telegraph circuits.

The system has been described in detail before.[1] It will be sufficient to give here only those facts relevant to the account which follows. The repeater amplifies only the higher-frequency band (24–44 kc/s), having a gain of 73 db at 44 kc/s. The low-frequency band, which is used in the Lowestoft–Borkum direction, passes through a filter and is not amplified in the repeater. The repeater is powered from Lowestoft by a direct current of 630 mA, the arrangement being unusual in that the resistor across which a proportion of the anode voltage for the amplifier is developed is in the terminal equipment at Borkum. These arrangements are shown in Fig. 1.



Notes
1. The resistance value varies with cable temperature.
2. The nominal amplifier high-tension voltage
$= 0·63\ (95 + 15 + 256 + 15) +$ heater voltage.
$= 239 + 11 = 250$ volts.

FIG. 1—POWER-FEEDING AND REPEATER HIGH-TENSION ARRANGEMENT

Until 1963 the system had been relatively fault-free. Although the repeater had been expected to have a life of the order of five years, its performance after 17 years was entirely satisfactory in respect of gain and harmonic production. There had been a few periods in August 1955 when the noise had increased by about 6 db, but these troubles disappeared and caused little interference with service.

All the original joints in the cable and some of the repair joints were hand-made by methods which today would not be considered suitable for any polythene submarine cable, being adaptations of the methods used with gutta-percha and paragutta cable. Nevertheless, up to July 1963 there had been no trouble from these joints, the eight cable faults being due to mechanical damage of various types.

SYSTEM FAILURE

The failure of the submarine cable system occurred in two stages, as described in the following paragraphs.

Stage 1

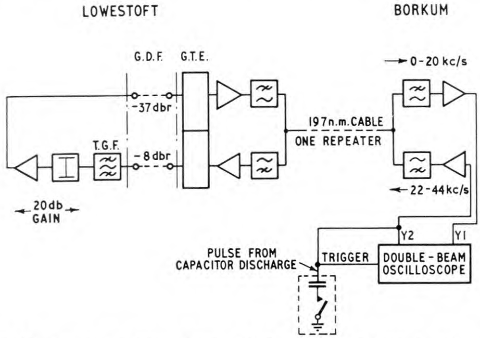
On 24 July 1963 some circuits on the cable were reported faulty, and it was found that there was intermittent crackling noise on all incoming channels at Borkum. The peaks of noise were of the order of 10 db above normal, making the system intermittently unserviceable. Tests showed that the noise was produced only when a reasonably high potential was applied to the cable, either by normal power-feeding or by applying more than 120 volts to the cable from one terminal with the power circuit disconnected at the distant terminal. The noise could be measured in both frequency bands at Borkum, but only in the high-frequency band at Lowestoft when the repeater was energized. The insulation resistance of the cable with repeater varied from about 1 megohm to 100,000 ohms. It was, therefore, concluded that the noise was due to a low-insulation fault between the repeater and Borkum. The potential necessary for production of the noise existed over almost the whole of this section of the cable under normal power-feeding conditions, so no clue could be obtained from this, but the difference in level of the noise at the two terminals indicated that the source was probably towards the centre of the section.

Unsuccessful attempts were made to locate the low-insulation fault by the double-ended overlap test, but the fault resistance was never low enough, neither was it considered worth while taking the necessary systems out of service to provide a good wire via the Netherlands for Varley-loop tests. Attention was then turned to the possibility of location by measuring the difference in time between the reception of noise bursts at one terminal direct from the fault and the arrival of the same noise bursts via a loop at the distant terminal. This method had been used successfully on several occasions for the location of noise in repeaters, but never before, it is believed, for a cable fault. Although the method was tried from Lowestoft, it was obviously more likely to be

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

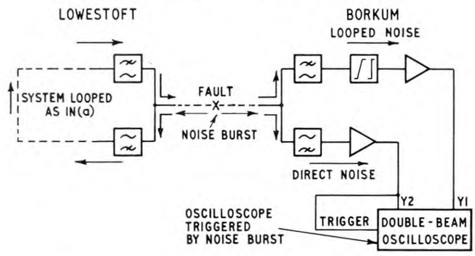
[1] WILLIAMS, H., and HALSEY, R. J. The Anglo-German Cable Scheme. *P.O.E.E.J.*, Vol. 40, p. 49, July 1947.

successful from Borkum. The method was explained to engineers of the German Post Office, and on 11 November 1963, using the arrangements shown in Fig. 2, a location was obtained.

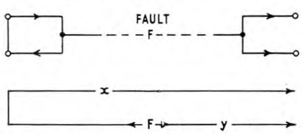


G.D.F.—Group distribution frame. G.T.E.—Group translating equipment. T.G.F.—Through group filter.

(*a*) Arrangement for Measuring System-Loop Transmission Time.



(*b*) Arrangement for Measuring Time Interval of Noise Bursts.



(*c*) Location of Noise Source.

FIG. 2—METHOD OF FAULT LOCATION

From Fig. 2 it will be seen that a noise burst from the fault will travel towards both terminals; in the high-frequency band the noise will reach the receive equipment at Borkum, and later the same noise, having travelled through the repeater to Lowestoft and being translated into the low band and looped back, will reach Borkum in the low-frequency band. Noise will also be received in the low-frequency band at Borkum directly from the fault, but if necessary it can be arranged, by adjustment of levels at the loop at Lowestoft, that the noise received via Lowestoft is at a very much higher level.

By measuring the time between the arrival of the noise bursts and measuring or calculating the total loop transmission time the location of the noise source may be calculated as follows:

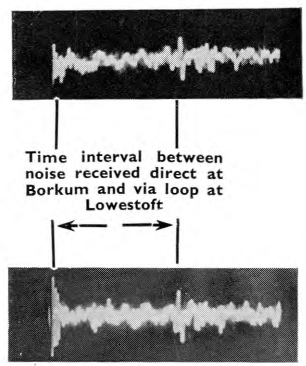
Total loop-transmission time $(x + y) = A$ ms.

Difference in time of direct and looped noise $(x - y) = B$ ms.

Transmission time to fault, $y = (A - B)/2$ ms.

The change in time interval for a change of 1 nautical mile (n.m.) in the position of the fault source is about 0·02 ms. In order to measure time intervals to such accuracy the bandwidth of the transmission path used needs to be about 50 kc/s, but in this system only 20 kc/s is available.

The method used to display the noise bursts on an oscilloscope depends on the nature of the noise. If the noise has no very high peaks, it is necessary to compare the envelope shapes of the two signals displayed on a double-beam oscilloscope to determine the time interval. This is done by taking many photographs using a single-sweep single-shot technique at random intervals. If, however, there are clearly-defined peaks, the noise bursts received direct can be used to trigger the X time-base and the camera, whilst the noise via the distant terminal only is displayed and photographed. The nature of the noise developed by the fault on the Lowestoft–Borkum cable was such that the latter method was used at Borkum. Samples of the photographs obtained are shown in Fig. 3.



The photographs are of the Y1 trace using the arrangement shown in Fig. 2 (*b*).

FIG. 3—PHOTOGRAPHS OF NOISE BURSTS DISPLAYED ON OSCILLOSCOPE

On the Lowestoft–Borkum cable the measured time interval was 3·35 ms, the measured loop-transmission time was 4·42 ms, and the calculated loop-transmission time was 4·05 ms. The measured and calculated loop-transmission times gave locations of 50 and 35 n.m. from Borkum, respectively, allowing for certain terminal-equipment transmission times. As there were reasons to doubt the accuracy of the measured loop-transmission time, a location about 35 n.m. from Borkum was considered most likely.

This was the situation on 12 November 1963. It was considered that the fault was one which a cable ship would have difficulty in finding since the fault disappeared for days and weeks at a time, and it was thought quite likely that there would be no visible damage to the cable. Furthermore, the new Winterton–Leer No. 1 cable,[2] which was due to be completed in December 1963, would provide a good wire for Varley-loop tests. No action was therefore taken to repair the fault, but on 23 November 1963 the sending level on all channels was raised by 6 db

[2]The New Submerged-Repeater Cable System between England and Germany. *P.O.E.E.J.*, Vol. 57, p. 109, July 1964.

at Lowestoft, giving a 6 db improvement in signal-to-noise ratio at Borkum and enabling all circuits to be worked reasonably satisfactorily.

The 6 db level increase was considered justified, as all channels were in use for telegraph purposes. The 120 telegraph channels can be regarded as similar to white noise, the appropriate multi-channel peak factor therefore being 13 db, whereas a higher multi-channel peak factor catering for telephone channels had been used in the original design. The level of the output of the final transmitting amplifier at Lowestoft after the increase was +40 dbr, the overload point of this amplifier being +50 dbm. No significant increase in intermodulation noise was noticed.

On the 15 February 1964 a Varley-loop test was made using the Winterton–Leer No. 1 cable as a good wire. The fault resistance was still high, and an approximate location of 36 n.m. from Borkum was obtained.

Stage 2

Up till this time there had been no indication that any noise was coming from the repeater, but on 20 February 1964 a remarkable coincidence occurred. The Winterton–Leer No. 1 cable, the second direct cable to Germany, had been officially opened on 3 February 1964, when a few special circuits were provided, and the first traffic circuits were put into service on 20 February 1964. On the same day on the Lowestoft–Borkum system a further noise fault occurred that ended the working life of the first submerged repeater in the world to provide traffic-carrying circuits and led to its replacement on 16 April 1964. The characteristics of this fault were in some ways very similar to those of the first fault, which still existed, and yet there were features which made it clear that it really was a second fault.

As before, the noise was produced only when a potential in excess of 120 volts was applied either from one end with the other disconnected, or by normal power-feeding. The noise was a type similar to that previously observed, and bursts of noise seemed to be associated with changes in the insulation resistance, which at times had now dropped to about 30,000 ohms. The difference was that the noise was at a high level in both bands at Lowestoft with the repeater energized, but was at a very low level at Borkum. Furthermore, at Lowestoft the noise in the high-frequency band was apparent only after the repeater power had been on long enough for the repeater valves to warm up. It was, therefore, clear that the noise source was near the Borkum side of the repeater and possibly in the repeater on that side.

The transmission-time-measurement method could not be used, since the level of noise in the high-frequency band at Borkum was not sufficiently high either to measure it there or to loop it back to Lowestoft. D.C. tests were considered valueless as it was possible that there were now two insulation faults. Attempts were made to measure the level of noise in a given band at both ends simultaneously, but the varying nature of the noise made this impracticable. A novel, though possibly unreliable, method was therefore tried. It was considered that if at the source the distribution of the noise power in a given narrow bandwidth was independent of frequency, i.e. white noise, then measurement of the level/frequency characteristic of the noise as received at Lowestoft would give the loss/frequency characteristic of the cable through which it had passed, and, therefore, the location of the fault. This was done on the day the fault occurred, without using any special equipment. Wideband and selective measurements of the noise were observed simultaneously, the noise varying violently over a range of about 20 db. When the meter needles steadied long enough for overshoot to be small, estimations were made both of the wideband and selective readings. Such measurements were made many times, the selective measurements being made at 2 kc/s intervals throughout both transmission bands. For the low-frequency transmission band the measured noise slope over a frequency range of 4–16 kc/s was 18 db. The total cable (197 n.m.) has an attenuation slope of 44·5 db over the same frequency range.

Assuming the noise at the fault source to be white,

$$\text{fault distance} = \frac{18 \times 197}{44{\cdot}5} \text{ n.m.}$$

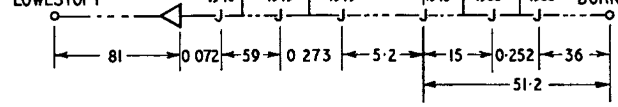
$$\simeq 80 \text{ n.m. from Lowestoft.}$$

This location put the fault at, or very near to, the repeater, while in the high-frequency transmission band the location was a few miles beyond the repeater towards Borkum. Confidence in the validity of the method was increased by the fact that at intermediate frequencies in the ranges measured the noise/frequency characteristic closely matched the shape of the loss/frequency characteristic for 80 n.m. of cable. Therefore, if the location had been based on measurements at frequencies other than 4 and 16 kc/s the same result would have been obtained. Although the variations in noise level in both bands were violent and erratic, the readings were such as to leave no doubt that one source was responsible for the noise measured in both bands.

At about this time it was learnt that the Post Office Engineering Department's Research Branch had a spectrum analyser designed for the study of the energy distribution of speech signals. This analyser, from a few seconds of tape recording, could produce a level/frequency characteristic. Some recordings of the noise received in the low-frequency band at Lowestoft were taken and analysed by this equipment. The results were not available until the repair operations were well under way, but they showed that if the noise were white at source, the source was approximately 70 n.m. from Lowestoft, i.e. about 10 miles short of the repeater.

From the time when the second fault became evident it was always necessary to bear in mind that the results obtained could be due to either or both of the faults.

On 10 March 1964 the action to be taken by the cable ship was decided. It was agreed that H.M.T.S. *Iris*, carrying the spare repeater, should cut the cable at point A (Fig. 4), with the expectation that a low-



The lengths shown are nautical miles.
J—joint.
FIG. 4—DIAGRAM OF CABLE SECTIONS

insulation fault would be found on both sides and that one fault could be cleared by renewal of the two joints made in 1953, at about 36 n.m. from Borkum. It was proposed that the ship should then pick up the cable at point B and, if the fault were towards the repeater, should pick up towards the repeater until the joint of 1946 was recovered. It was considered that in good weather this could be done without disturbing the repeater. If the fault still proved to be towards the repeater then the most likely place was the joint in the repeater jointing chamber. Throughout the discussion it was borne in mind that recovery of the repeater would spoil its unique record, but, at the same time, if the repeater had to be brought on board the ship, which had every facility for replacing it, sentimental reasons could not be allowed to overrule the sound engineering reasons for changing it, one of them being that, if a joint were faulty and allowing the ingress of water to the centre conductor, in this repeater there was no guarantee that water would not travel along the centre conductor into the repeater itself. It was, therefore, agreed that the repeater would not be disturbed if this could possibly be avoided, but if it were raised it would be changed.

It was also thought possible that the noise faults were such that the insulation resistance was dropping momentarily to a very low value and therefore might be discernible on a pulse-type cable-fault locator used from the ship. However, it proved that when the noise faults were active the noise received by the locator always completely swamped the other received signals, so that no information was obtained by this method.

REPAIR OPERATIONS

H.M.T.S. *Iris* sailed on 2 April 1964 and cut the cable at point C (Fig. 4) between the two joints made in the repair of 1953. As it was the intention during the operation to cut out as many as possible of the old joints made before the use of polythene injection-moulding, the whole of this 0·252 n.m. length was replaced. When the recovered joints were tested on board they were found to be good, while the insulation of the remainder of the cable was good towards Borkum and low towards Lowestoft. When the cable had been jointed through it was found that the overall insulation resistance had, fortunately, dropped to 12,000 ohms. A Varley-loop test was therefore made using the Winterton–Leer No. 1 cable again; this put the fault at 51 n.m. from Borkum and agreed with the second of the two possible locations made by the timing method. It was decided that the most suspect section in this vicinity was the repair of 1949. The ship picked this up at point D (Fig. 4) and found the insulation good to Lowestoft and bad to Borkum, with high-level noise on the Borkum side; there was no noise on the section between Lowestoft and the ship. It seemed that the fault near the repeater had disappeared and, to the dismay of those concerned, when the cable was put through the overall insulation resistance had risen to 4 megohms, so that there was no possibility of getting any further information from a Varley-loop test or other method. As the previous Varley-loop test location had been very close to point E (Fig. 4), an original splice, the ship picked up this splice. The timing method of location turned out to be accurate as this splice proved to be the cause of the first fault. The faulty joint had a crack in the polythene, which had been applied in sheets by hand.

The ship now had two good cable ends aboard, and when the final splice was completed power was applied to the cable and the system tested. After some 20 minutes testing the cable ship was advised that the system was satisfactory, but only five minutes afterwards the noise at Lowestoft reappeared. It had the characteristics of the fault which appeared in February 1964, except that no noise at all was received in the low-frequency band. The only possible source consistent with all the facts was the repeater itself, the insulation resistance still being good, and early on the morning of 16 April 1964 the decision to change the repeater was reluctantly made. This work commenced at 07.00 hours on 16 April 1964 and was completed at 23.30 hours the same day.

Overall tests showed that the replacement repeater gave a 4 db reduction in basic wideband noise, was completely free from any high peaks or bursts of noise, and the harmonic performance was improved by 6–8 db compared with its 17-year-old predecessor.

CONDITION OF THE RECOVERED REPEATER

The external condition of the recovered repeater (Fig. 5) was good, considering the length of time it had

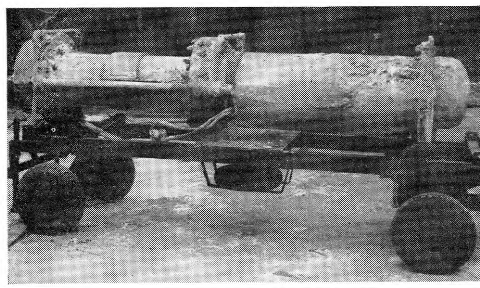


FIG. 5—THE RECOVERED REPEATER

been laid, and it was typical of repeaters that have been laid for five years or so. The parts which had been buried in sand and mud were clean and uncorroded, while those parts that had not been buried were covered with barnacles, sea anemones and similar growths. Around these growths some local corrosion had occurred, but the housing was quite suitable for re-use without re-galvanizing.

Before any dismantling was commenced, electrical tests were carried out, and these fully confirmed the findings during the fault-location period. The table shows the gain/frequency characteristics of the repeater at

Gain/Frequency Characteristics of Repeater before Laying in 1946 and after Recovery in 1964

Frequency (kc/s)	Repeater Gain (db)		
	1946	1964	Change
24·3	60·0	59·7	− 0·3
28	65·4	65·2	− 0·2
30	66·2	66·6	+ 0·4
32	68·6	68·4	− 0·2
36	71·3	71·3	0
40	72·7	72·2	− 0·5
44	73·0	72·6	− 0·4

manufacture in 1946 and after recovery in 1964. These measurements proved that no substantial change in gain had taken place. Fig. 6 shows a sample of a noise-recorder run, and clearly indicates the magnitudes and durations of the noise peaks produced by the repeater, these being typical of the noise received on a channel at

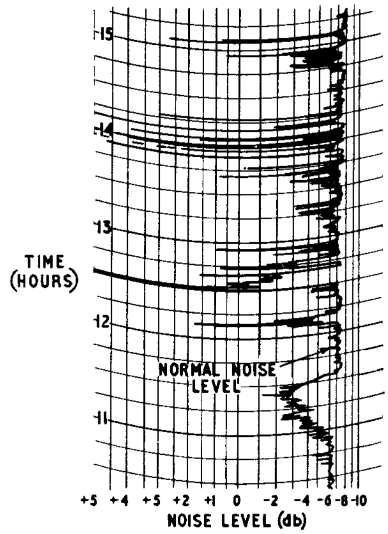


FIG. 6—RECORDER CHART SHOWING SAMPLE OF NOISE BURSTS FROM REPEATER AFTER RECOVERY

Lowestoft before the repeater was recovered. No noise was measured in the unamplified transmission band. Removal of the sealed internal apparatus unit from the main outer repeater housing revealed that some leakage had occurred at the cable-entry glands, as traces of water were apparent. The quantity of water was insignificant and had no relationship to the cause of the fault.

Most significant was a soldered joint where the centre conductor of the B-side cable gland was connected to the internal apparatus unit. There was evidence that this joint was "dry," and it was possible that it could have produced noise. This would account for the low-frequency and high-frequency bands of noise received at Lowestoft and which the tests indicated originated at or near the B-side of the repeater. If this had in fact been causing noise the system had had three noise faults that at times existed simultaneously.

Unfortunately it was necessary and unavoidable to part the joint to continue the investigation of the repeater unit. Further investigation revealed that the first-stage valve in the amplifier unit was responsible for the high-frequency band noise.

CONCLUSIONS

The existence on one cable system of two (possibly three) simultaneous noise faults is probably unique, and it made the trouble one of the more difficult to locate and clear. It brings to the fore the many problems associated with noise faults on repeatered systems and, unfortunately, again proves incorrect the early opinions that repeater noise faults would always be accompanied by some other abnormality that would facilitate a location. The cable fault had no special features (other than that of generating noise), being simply a failure of an early type of joint.

The success of the method of location based on the assumption that noise generated at a fault is "white" may indicate that further investigation of this characteristic of faults may be worth while, with a view to its use in future.

The working life of the repeater, 17¾ years, exceeded all expectations. It is believed that no repeater now working can exceed this life until March 1968 when repeaters in the Key West–Havana cable may reach this age.

ACKNOWLEDGEMENTS

The location and clearance of faults on submarine cable systems, particularly unusual types of fault such as the one described, requires initiative and co-operation from many parties. In this instance the maintenance staff of Lowestoft and Borkum repeater stations, the cable ship H.M.T.S. *Iris*, officers of the German Post Office at Leer (to whom we are indebted for Fig. 3), and the Test and Inspection Branch and the Main Lines Development and Maintenance Branch of the Post Office Engineering Department were concerned.

Book Review

"The Slide Rule." Robert Saffold and Ann Smalley. The English Universities Press, Ltd. 468 pp. 30s.

This is one of a number of books that have been published by English Universities Press, Ltd., in their Tutor Text series. The arrangement of the text employs the principles of programmed self-instruction, whereby after working through a paragraph or two dealing with a particular point of information, the student is asked a question, to which several possible answers are given. Depending on the one chosen, the student is told to turn to a specified page of the book, and if the selected answer is the correct one, it will be briefly reviewed and new information presented. If, however, the student has chosen the wrong answer, he will be told that this is the case and where he went wrong, given additional remedial information and asked to try again.

This treatment is most rewarding for the student who has the necessary patience and industry to work conscientiously through the book, and the repeated question-and-answer technique ensures that he understands each item of information before proceeding. Checks of this sort are much less frequent in the normal text book, with which a student can read through many pages before a test question shows that he has only partially understood the facts presented to him. On the other hand, Tutor Text books are less convenient for normal reference purposes, since, although the chapter divisions are arranged in the correct order, the page numbers bear no relation to the order of presentation of material in each chapter. A brief index at the end of the book is of some help in this respect.

Surprise may be felt at the size of this book compared with the usual few pages devoted to the use of the slide rule. While this is typical of programmed instruction material, because each step is treated so carefully and thoroughly, the coverage is much wider than usual. In addition to the logarithmic foundation and the usual multiplication, division, square and cube-root operations, two chapters are devoted to the use of the sine and tangent scales, and the resulting practical work inevitably gives a good grounding in trigonometry, including the solution of triangles using the sine and cosine laws. In fact, the title of the book is a little misleading since, in learning to use a slide rule, the student is also being taught elementary mathematics—and taught very well!

G.M.K.

General Election Broadcasts, 14–16 October 1964

U.D.C. 621.396.74:621.397.743

Extensive radio and television coverage of the General Election involved a major network operation by the Post Office. The way in which the large numbers of vision and sound circuits were provided is briefly described.

THE very extensive broadcast coverage of the General Election, provided by the British Broadcasting Corporation's (B.B.C.) radio and television services and by Independent Television's (ITV) service, involved the Post Office in a major network operation; large numbers of temporary vision, program and control circuits were provided from the numerous outside-broadcast sites, while the prolonged broadcast transmissions necessitated special staffing arrangements for the switching and maintenance of the Post Office's permanent broadcast networks.

Vision Channels

The Post Office's television outside-broadcast teams, assisted by Engineering Department staff, provided 38 temporary 405-line vision channels: 24 were for the B.B.C. and 14 were for the ITV. Approximately half of these vision channels were from outside-broadcast sites in and around London; the rest were from sites throughout England, Scotland and Wales. The photograph shows a Post Office television outside-broadcast vehicle in Trafalgar Square, between television mobile control rooms of the broadcasting organizations.

Most of the temporary vision channels were provided using video repeaters on spare telephone plant, but three were provided using portable microwave-radio equipments, this being the first major broadcast program in which Post Office television outside-broadcast radio links have been used. The three radio outside-broadcast channels concerned were as follows.

For ITV a channel was set up from Northern Ireland to Carlisle, consisting of two sections operating at 7,000 Mc/s plus two sections at 4,000 Mc/s. This channel included an initial cable link from Belfast to Ballygomartin radio station, using a new transistor-type television outside-broadcast repeater on a spare coaxial pair.

For the B.B.C. two channels were set up: one from Billericay to the Post Office Tower, London, consisting of two sections operating at 7,000 Mc/s, and the other from Orpington to the Post Office Tower, also of two sections and operating at 7,000 Mc/s.

ITV set up a temporary program switching centre in Carlisle repeater station, because it was necessary to "cue" switch three outside-broadcast feeds incoming to Carlisle from Belfast, Scotland and Newcastle, and there were insufficient spare coaxial pairs to extend the three programs to the program-switching centre of Border Television in Carlisle.

OUTSIDE-BROADCAST VEHICLES IN TRAFALGAR SQUARE

Sound Circuits

Throughout the country large numbers of temporary program and control circuits were provided for the television and radio broadcasts. In addition to providing 63 program and 204 control circuits in London, the Post Office provided a number of circuits outside London, use being made of 218 "occasional program" circuits and 239 released traffic-circuits, as well as spare line plant, in the make-up of 43 of these circuits.

The sound circuits provided outside London were switched by the Post Office in accordance with the broadcasting-authorities requirements; this resulted in the B.B.C. having a total of 232 music circuits and 348 control circuits, and Associated Rediffusion, the main co-ordinators for the Election broadcast as far as the Independent Television Companies were concerned, having 61 music circuits and 64 control circuits. Associated Rediffusion were also provided with an omnibus talkback system and a national production-control system linking together 25 remote sites. In all, the length of the temporary program and control circuits provided totalled 34,000 miles.

J.B.S.

New Computing Facilities for the Post Office Engineering Department

H. T. McGRATH, B.Sc.†

U.D.C. 681.142

Additional computing facilities are being provided by the Post Office Engineering Department. The reasons for the choice of computer and peripheral units are discussed, and the programming languages and systems programs of the chosen computer are described in general terms.

INTRODUCTION

An earlier article[1] in this journal described the history and development of computing in the British Post Office Engineering Department, up to the time of installation of the Elliott 803 computer at the Post Office Research Station, Dollis Hill. The broad classifications of Engineering Department computing work were described, and reasons given for the choice of a small machine suitable for scientific, mathematical and engineering-design work.

The Elliott 803 was installed in March 1961, and was subsequently speeded-up by the addition of a floating-point arithmetic unit in November 1962. By late 1963 it was evident that a faster and more powerful machine was needed to meet the increasing demand for computer facilities, and to cater for work which could not be handled by the Elliott 803 for various reasons—usually limitations of storage and excessively long processing times.

A survey to determine the amounts and type of outstanding and potential computer work in the Engineering Department showed that the existing computer facilities needed considerable expansion to provide:

(*a*) more powerful computing capacity for scientific and mathematical work,

(*b*) improved facilities for handling large volumes of engineering data, and

(*c*) a means of simulating switching networks and studying their performance over a range of traffic conditions.

FACTORS AFFECTING CHOICE OF NEW COMPUTER

There are several commercially available machines capable of meeting the current computing and data-handling needs of the Engineering Department. Simulation work, however, makes rather special demands on the "hardware" (circuits, storage medium, etc.) and "software" (programming, monitoring, operating methods, etc.) of such machines. Some of the technical factors considered before finally deciding on the new computer were as follows.

Scientific, Mathematical and Engineering Design and Calculation

Experience with the use of Elliott Autocode on the Elliott 803 computer had confirmed the importance of having a programming language which could be easily learned and used by scientists and engineers in the course of their everyday work. Some 400 people had, in fact, been trained to use autocode, and it was considered essential to provide a new computer having comparable programming facilities, and, if possible, to reduce the amount of re-training, and of reprogramming existing jobs, to a minimum.

It was also important that computing in the Engineering Department should not be too closely tied to any particular computer manufacturer's programming language for new work. In recent years "universal" scientific programming languages have been formulated, and it was specified that one of them should be available with the new computer. The ability to translate programs written in Elliott Autocode to the language of the new computer was also of some importance, particularly for frequently used programs.

Simulation

Early traffic studies of telephone switching systems were made using slow and tedious manual methods; later on, a special-purpose analogue machine was built by the Post Office for the study of step-by-step systems. A different approach was required to deal with new problems presented by the introduction of multi-stage systems with common control. General-purpose digital computers, including the Dollis Hill Elliott 803, have been used for simulation work, but, unless they are extremely fast and have large random-access stores, the time taken to process a call through a simulated switching system is unacceptably long. Processing times can often be reduced by using machine code and optimizing the program, but many man-months are needed to write and test such programs, and it is usually difficult to modify them to accommodate changes in the parameters of the switching network.

Even on a fast machine it is not unusual for simulation problems to require 10 hours or more of computer running time, and the risk of machine breakdown makes it advisable to arrange for all intermediate results and data to be "dumped" at regular intervals throughout the run. Facilities for the semi-permanent storage of data, such as magnetic tape, are therefore required. It is also desirable to print intermediate results, e.g. by means of a line printer, without significantly lengthening the duration of the run.

The main requirements for an efficient simulation system are, therefore,

(*i*) a fast computer, with a large random-access store allowing calls to be processed at rates varying from 10,000 to 3 million calls per hour, depending on the complexity of the switching system being simulated,

(*ii*) a programming language, easy to learn and use, and which enables problems to be prepared for the computer in a matter of days rather than months (the loss of machine efficiency through the use of such a "simulation autocode" should not be excessive),

(*iii*) a system which provides rapid and simple means of changing the parameters of the switching system being studied, and

(*iv*) a means of storing and printing intermediate results and data during a computer processing run.

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[1]Allery, G. D. The Post Office Engineering Department's Computer. *P.O.E.E.J.*, Vol. 55, p. 199, Oct. 1962.

Combinations of hardware and software which meet these requirements should provide a very powerful tool for dealing with all types of simulation work; it should be possible for extensive and detailed studies of new and existing switching systems to be made with economy of effort by traffic engineers, costly expenditure on special-purpose traffic machines of limited capability should be avoided, and, in the field, improved plant utilization should result.

Although great importance was attached to switching simulation, it was recognized that many other problems of an operational-research nature could be dealt with by the same methods. For example, studies could be made of the staffing level required at repair depots to provide a specified quality of service for given fault rates, of the number of spare vans to be held in motor-transport pools, or of spare items in stock.

Engineering-Data Handling

The Dollis Hill Elliott 803 computer, with its paper-tape input and output, is not suitable for processing the large volumes of data which recent developments in the Engineering Department's work are beginning to produce but which can be handled conveniently and efficiently by magnetic-tape machines. A typical case is the use of automatic data loggers to measure transistor parameters during tests: the loggers record the results on punched paper tape, which is read by the computer and then processed very rapidly against the previous results stored in the computer on magnetic tape—a very much faster, and more reliable, process than re-reading the original paper tapes.

General Requirements

Other factors which influenced the final choice were that

(*i*) if possible, the system should have a proven reliability—for both hardware and software,

(*ii*) it should provide efficient facilities for compiling and/or translating, testing and modifying the many "one-off" programs constituting the main scientific and engineering load for the new computer,

(*iii*) an early delivery date was obviously desirable, so that the long delays in getting Engineering Department work processed could be reduced as quickly as possible, and

(*iv*) access to a service-bureau machine was essential for testing the software, for building up a general work load before delivery of the new machine, and for obtaining urgently needed results for current electronic-exchange trunking problems.

THE NEW ENGINEERING DEPARTMENT COMPUTER EQUIPMENT

The configuration decided upon for the new Engineering Department computer consists of a basic Elliott 503 computer, plus magnetic-tape decks, line printer, auxiliary magnetic-core store, and a general-purpose input/output unit.

Basic Computer

The Elliott 503 computer's central processor (c.p.) has the same instruction code as the Elliott 803, but operates about 80 times faster. It is a parallel binary machine, using either fixed-point or floating-point mode. Operation times depend on a number of factors, e.g. digit patterns, but typically they are:

7·2 to 8·7 μs for fixed-point addition or subtraction,
13 to 30 μs for floating-point addition or subtraction,
35 to 47 μs for fixed-point multiplication, and
32 to 42 μs for floating-point multiplication.

The coincident-current core store occupies one of the three cabinets (see Fig. 1) forming the c.p., and consists

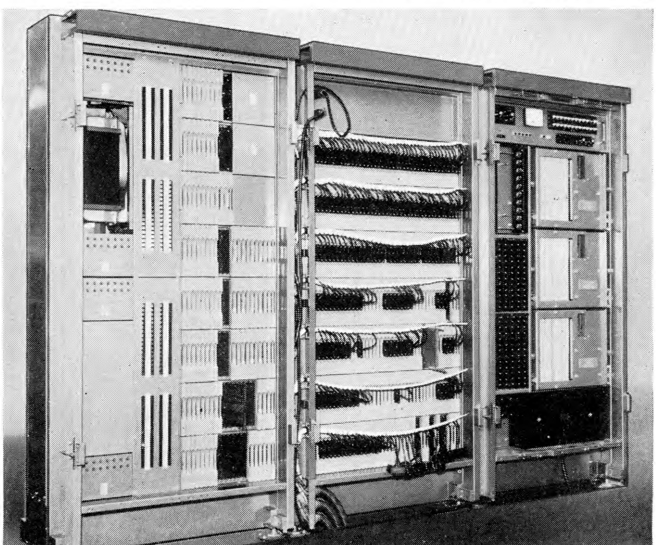


FIG. 1—FRONT VIEW OF THE ELLIOTT 503 CENTRAL-PROCESSOR STORE, ARITHMETIC AND CONTROL, AND POWER CABINETS

of two 4,096-word blocks. Each block has its own control and timing circuits, and is maintained at a temperature of 40 ± 2·5°C. The read/write cycle time is 3·6 μs and the access time is 1·4 μs. Thirty-nine of the 41 bits in each word are information bits available to the programmer and used in exactly the same way as in the Elliott 803. The other two are used as (*i*) a parity bit for checking transfers to and from the store, and (*ii*) a tag bit for monitoring the progress of transfers between the store and peripheral devices.

Power supplies also occupy a complete cabinet, and the remaining one contains the arithmetic unit and control logic.

The principal components are germanium diodes and transistors, metal-oxide-film resistors and polyester-foil capacitors, mounted on 7 in. × 12 in. printed-wiring boards. The main logical elements are AND/OR gates, exclusive OR gates, flip-flops and pulse regenerators, with nominal logic-voltage levels of +2 volts and −2 volts. Typical delays through the elements are 10–15 ns.*

The control and timing of all operations are governed by two control matrices. The matrix components—diodes, transistors and resistors—are mounted on double-sided 21 in. × 12 in. printed-wiring boards with a packing density of approximately 5 components/in^3. The function of the matrices is to reduce each instruction, after decoding in the instruction register, to a sequence of gating and reset waveforms which control each step, or micro-instruction, in the execution of the instruction. Timing pulses occur every 0·3 μs, but are anti-phase to the two matrices, to allow gating and reset waveforms to be obtained separately. The basic speed of the machine is, therefore, 3·3 Mc/s, and precautions taken to reduce stray capacitance and inductance include the provision of an earth plane over the whole of the rear of each cabinet, connected to 1in. wide earth strips covering the perimeter of each printed-wiring board.

In addition to the equipment cabinets the basic Elliott 503 includes a paper-tape station and a manual control console (see Fig. 2); the former is functionally similar to that used with the Elliott 803 computer. It comprises two 1,000-character/second, photo-electric, paper-tape readers, and two 100-character/second paper-tape punches. Normally, an 8-bit parity-checked code is used, but the mode may be manually switched to the Elliott 5-bit code used on the Elliott 803 computer.

*ns—a nanosecond, 1 × 10^{-9} seconds.

Communication between operator and computer takes place via a control typewriter on the console. Typical uses of the typewriter, which is functionally similar to the word-generator on the Elliott 803, are (*i*) by the computer for printing out, in black, error conditions occurring during processing, and (*ii*) by the operator for giving instructions to the computer to change the course of a program as a result of such an error condition. All operator-typed instructions are recorded in red ink.

Peripheral Units

The speed of operation of peripheral devices is very much slower than the speed of the c.p., and the Elliott 503 uses a system of "autonomous data transfers" (A.D.T.) and "normal interrupts" to ensure that block transfers of data between the c.p. store and peripheral devices cause the minimum hold-up to c.p. operations. All peripheral devices involved in block transfer are connected to the c.p. via peripheral controllers. Each class of peripheral device, e.g. magnetic-tape deck, line printer, etc., has its own type of controller, but similar devices may share one controller. The controller's function is (*i*) to provide the correct electrical interface conditions between the device and the c.p., (*ii*) to interpret and pass control signals between the c.p. and the device, and (*iii*) to assemble data into the correct format before transfer takes place, e.g. data received in binary form may be packed into standard 39-bit words.

As an illustration of the operation of A.D.T. and normal interrupt, suppose that only one peripheral device is engaged in a block transfer to the main store. Program instructions will have specified the number of words to be transferred, i.e. the size of block, and the address of the first word in the block of main-store locations to which the data will be transferred. The c.p. operations continue until a first A.D.T. signal is received from the device controller, indicating that a data word is waiting to be transmitted. The c.p. operation is

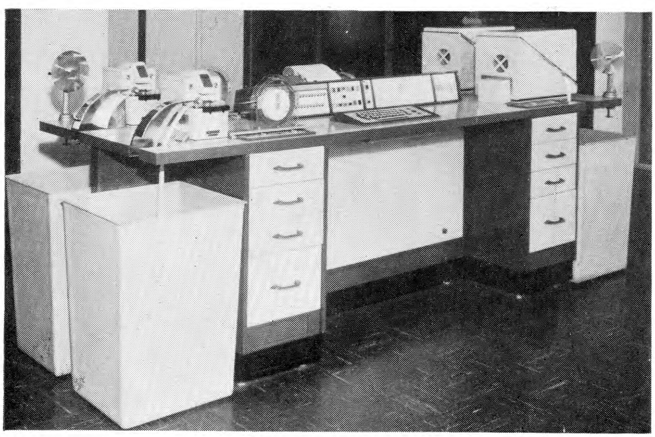


FIG. 2—CONTROL CONSOLE AND PAPER-TAPE STATION

interrupted for approximately 10 μs to allow transfer of the data word direct to the main-store location specified by the starting address. The c.p. operations are then resumed until the next A.D.T. signal, which causes the next data word to be transferred to the next main-store location. This cycle continues until the last word in the block has been transmitted. A normal interrupt signal is then sent from the device to the c.p., and may be used, for example, to initiate c.p. processing of the block just read.

When several peripheral devices are simultaneously engaged in transfers, a fixed priority system operates to prevent loss or corruption of data; for example, magnetic tape cannot be stopped in the middle of a block, and, therefore, has higher priority than the line printer.

Each main-store location used in an A.D.T. is protected by the tag bit, referred to earlier, until transfer to each location is completed. Protection is then removed, and c.p. operations are allowed to make use of the location.

The peripheral units with the Engineering Department's Elliott 503 are as follows.

(*i*) An auxiliary magnetic-core store (backing store) of approximately 64,000 words, made up of four blocks of 16,384 words each and housed in two cabinets, one of which includes the controller. The cycle time is 50 μs and the access time is 20 μs. Single-word transfers may take place between the c.p. accumulator and any location in the backing store, in two steps, via a single-word backing-store register, which is also used during A.D.T.s between the main store and backing store by the processes described earlier.

(*ii*) Four magnetic-tape decks (see Fig. 3), connected to the c.p. via two tape controllers; two controllers are necessary to allow for simultaneous A.D.T.s on two decks, and any deck can be operated via either controller. Any number of non-A.D.T. functions, such as rewinding and erasing, can be executed by the spare decks simultaneously with A.D.T.s. Writing on, or reading from, tape is in variable-length records of any length between 3 and 7,931 computer words, separated by inter-record gaps of 0·75 in. The tape speed of 75 in./second, a bit-packing density of 555 bits/in., and recording on seven parallel tracks across the $\frac{1}{2}$ in. wide tape, gives a character-transfer rate of 42,000 characters/second.

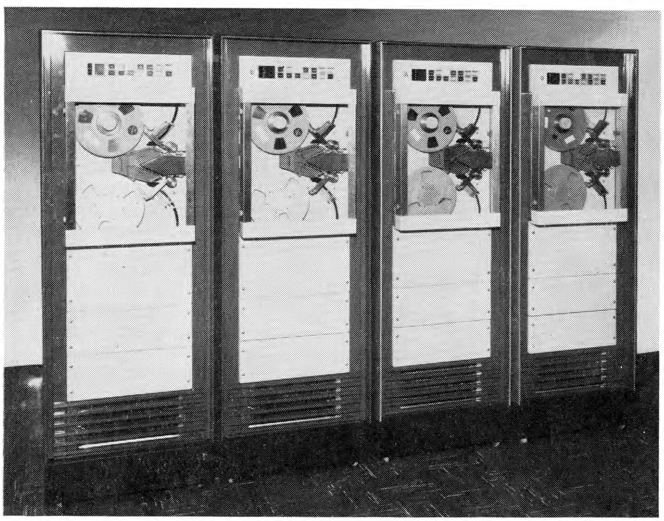


FIG. 3—MAGNETIC-TAPE DECKS

Of the seven tracks, six are used for data; the remaining one is used for parity, which may be either odd or even, and is under the control of the programmer. There are two formats available: all 39 bits of a word may be copied, or only the 36-least significant bits; thus, a word may occupy seven or six characters on tape, depending on the format used. For Engineering Department work, the 39-bit format is recommended, but the alternative may be useful where magnetic tapes need to be exchanged with other types of computer.

Apart from the lateral parity check provided by the parity bit in each tape character, a longitudinal parity character is included at the end of every record to provide an additional safeguard against undetected reading errors. During writing operations all data written on tape is immediately read back, and checked for signal level and parity.

(*iii*) A line printer which will print at 1,000 lines/minute on single or multi-part continuous stationery. There is a repertoire of 64 characters, and printing can occur in 120 character positions across the width of the paper. A continuously rotating type cylinder is embossed with 120 sets of the character repertoire; opposite each set is an electromagnetically operated hammer, and the paper is fed between the rotating cylinder and hammers. Printing is achieved "on-the-fly" by firing the hammers at the cylinder under the control of synchronizing pulses, which indicate the position of the cylinder at any time and, hence, the moment the hammers should be fired to print a particular character.

(*iv*) A general-purpose input/output unit, known as an interface matching unit (I.M.U.), enables special-purpose and non-standard peripheral equipment to be directly connected to the computer. The I.M.U. is, in effect, part of a general-purpose controller, and the user must add special "device logic" to control the peripheral units, e.g. to start or stop a magnetic-tape deck or paper-tape reader. Data, in non-standard format, obtained at source in the field or laboratory, can be fed in to the computer via the I.M.U. for analysis and processing.

Data-Preparation Equipment

Paper tape will be used for the initial input of programs and data to the computer. It will be punched and subsequently verified on Remington-Rand "Invac" equipment in Elliott 8-hole code. The perforator and verifier keyboards are solenoid-assisted, and selection of the character code is photo-electric.

Friden 8-hole code Flexowriters in the computer and data-preparation rooms provide full tape-editing facilities and can be used for volumes of printing too small to justify the use of the line printer.

ACCOMMODATION

The computer will be installed on the ground floor of the Post Office Engineering Department's headquarters at 2–12 Gresham Street, London, E.C.2. A plan of the computer accommodation, known as the City installation, is shown in Fig. 4. The computer room, magnetic-tape store, maintenance room and paper-tape store, are air-conditioned and maintained at a temperature of 29 ± 2°C and a relative humidity of 55 ± 5 per cent. Inter-cabinet cables and power wiring are carried beneath a false floor extending over the whole of the air-conditioned area. Walls and ceilings are accoustically treated to reduce noise, mainly arising from tape decks and the line printer in the computer room, and from the punches and verifiers in the data-preparation room.

PROGRAMMING

The software of the Elliott 503 computer can conveniently be considered under the headings of (*i*) programming languages and (*ii*) systems programs. The former should allow programmers to prepare work for the machine in a simple, general, and straightforward manner without being unduly inefficient in the use of machine storage and processing time. Systems programs are permanently held in the machine and provide the monitoring, storage allocation and program-testing facilities, etc., essential for the efficient operation and utilization of fast, modern computers. Therefore, the programming languages used on the Elliott 503 should be compatible with the systems programs.

PROGRAMMING LANGUAGES

For a general description of programming languages readers are referred to a previous article[2] in this Journal.

Elliott 503 *Autocode*

Elliott 503 Autocode is directly related to the Elliott 803 Autocode, which is familiar to users of the Dollis Hill computer, and, like it, is intended for use by scientists and engineers in the course of their everyday work. Programs are written in a mnemonic code, similar to ordinary mathematical notation, and then punched into 8-hole paper tape which is read into, and translated by, the computer under the control of an autocode-translator program. The translated program can be read out on to punched paper tape for subsequent running or it may be stored in the computer and run immediately translation is complete. The autocode system operates under the control of the reserved-area program (see "Systems Programs" below) and, therefore, a special code—relocatable binary—is used for translated program tapes. Initially, programmers wishing to use the backing store, magnetic tapes or line printer must incorporate machine code blocks in their autocode programs. They must also plan, in detail, the storage and the timing of operations without any assistance from the systems programs. Elliott 503 Autocode is not likely to find favour in its present form, and its use will be discouraged until it is made compatible with the systems programs.

Elliott 803 *Autocode*

Existing programs punched in 5-hole paper tape can be run on the Elliott 503

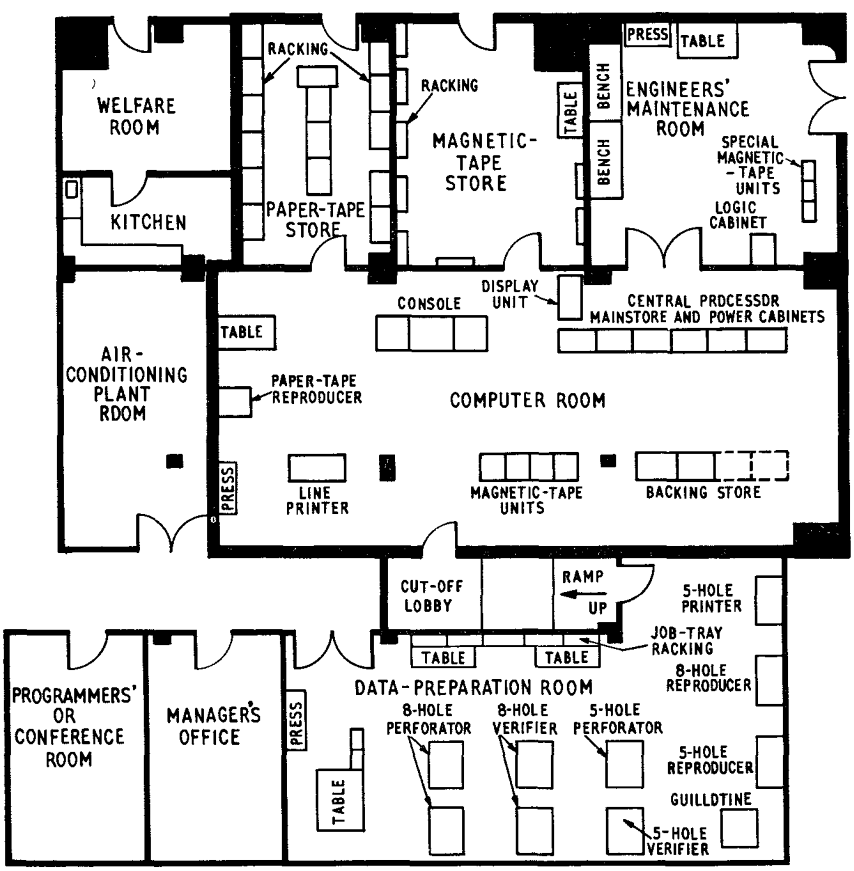


FIG. 4—PLAN OF THE CITY COMPUTER ACCOMMODATION

[2]LAVER, F. J. M. On Programming Computers. *P.O.E.E.J.*, Vol. 55, p. 125, July 1962.

computer under the control of the Elliott 803 "operator program". The computer is then used in the same way as an Elliott 803, with operator control by means of the console word-generator instead of the control typewriter. Alternatively, the programs can be converted to 8-hole code by manual re-punching or, preferably, for greater speed and accuracy, by using the Elliott 503 computer and the "Autocode 5 to 8 program" to read in the 5-hole tape and produce the corresponding 8-hole version.

Elliott 503 ALGOL

ALGOL is a universal programming language designed for mathematical work. Previously it has not been used to any great extent in the Engineering Department mainly because of the limited storage capacity of the Dollis Hill Elliott 803 computer. In future, however, it will be one of the two main programming languages for work on the Elliott 503, and for mathematical and scientific calculations on other computers.

ALGOL is easy to learn and to understand. Consequently, programs written by one programmer can readily be interpreted, modified and used by other programmers. Instructions for evaluating mathematical functions are written with little change of form, whereas, using Elliott Autocode, arithmetic operations are restricted to two operands, and the evaluation process must be broken down into equivalent steps before the corresponding instructions can be written. ALGOL is fully compatible with the systems programs and, therefore, programmers need not concern themselves with details of storage allocation and the timing of peripheral transfers. The task of program testing and "debugging" is also simplified.

Elliott Simulator Package

The Elliott simulator package (E.S.P.) is an extension of ALGOL to include special procedures allowing models of complex switching systems to be specified, and to be subjected to artificial traffic defined in a similar manner by other special procedures. It allows telephone-traffic engineers to study the behaviour of the whole or part of an exchange design and to determine, for example, congestion characteristics under various traffic conditions. Such studies have been possible in the past, but only on a limited scale because of the lack of suitable computer equipment and programming facilities. E.S.P. reduces the programming effort required by a very large factor, and, consequently, results may be obtained quickly and fed back to the design engineers for improvements to be incorporated at an early stage in the exchange design.

Typical procedures generate random numbers for determining call-origination and holding times, or, alternatively, enable these times to be obtained by sampling from histograms derived from data collected in the field or from earlier simulation studies; others collect data from the system under test, e.g. on the distribution of number of engaged circuits, for subsequent computer analysis. Because it is ALGOL-based, E.S.P. can readily be learned by people who are familiar with ALGOL. The advantages of ALGOL are retained in E.S.P., and new procedures can be incorporated to meet changing circumstances. For example, improved component technology may lead to completely different exchange-trunking designs using new methods for routing calls; additional E.S.P. procedures can be written to provide an efficient equivalent method of routing for use in simulated studies of the new system.

Symbolic Assembly Programming

Symbolic assembly programming (SAP), the second of the two main programming languages, is the form of machine code used on the Elliott 503. It is similar to Elliott 803 machine code in that the same functions are common to both, but differs from it in the method of referring to store locations. Using Elliott 803 machine code a program must refer to locations by absolute numerical addresses, and any modification to part of such a program generally leads to many consequential changes throughout the whole program. Using SAP, however, locations are referred to by names or "identifiers" chosen by the programmer. The identifiers must be declared at the beginning of each program so that the input routine can recognize them and decide the actual storage location to be used within the machine. Elliott 803 users will recognize the similarity with the procedures for declaring variables in autocode programs. The use of symbolic addresses offers two great advantages: it is very much easier for the programmer to keep track of the logic of his program during the writing stage, and changes can easily be made to any part without significant effect on the remainder of the program. SAP is fully compatible with, and dependent on, the systems programs, particularly for input and output operations, and will be referred to again in the section dealing with systems programs.

SYSTEMS PROGRAMS

The Elliott 503 systems software is a group of programs composed of several inter-related and interdependent blocks, each specializing in a particular aspect of organizing the work of the computer. The ways in which the program blocks work together are extremely complex and only a brief outline of the main functions of each block are given below.

Reserved-Area Program

The reserved-area program (RAP) provides the input-monitoring and control routines and the link, via the console typewriter, between the basic computer and its human operator. Because it is fundamental to the whole operation of the basic computer, the RAP is held in a protected or "reserved" area of the main core store, and, under normal circumstances, any attempt by another program to write into a location in this area is prevented and causes an error indication to be given to the operator.

Improved utilization of the computer can be achieved by overlapping input/output operations and processing, thereby allowing several programs to be in the main store at the same time. It is generally impossible to forecast the exact "mix" of programs or their size. The RAP input routine must, therefore: (*i*) check that sufficient free store space is available for a new program, (*ii*) know the addresses of free store locations and be able to steer the new program to them, and (*iii*) provide a means of entering the stored program. Thus, all programs on paper tapes which are to be read in by RAP and run under its control on the basic computer are in relocatable binary code so that they may be placed anywhere in the store. Each must have a "header block" giving, amongst other things, the "name" of the program (only the first SIX characters of the name are effective), the total storage space required, and an internal check number formed by summing the binary values of each character on the input tape.

During the input of a program, RAP adds to the header block the address of the previous first and last free locations, and a pointer (i.e. an address) to the last program stored. To enter a program, the operator types the program name on the console typewriter and a search routine scans through the programs in the store, starting at the pointer, until the required program is found. Standard messages to the computer via the typewriter keyboard include "RESET," which erases all programs (except RAP) from the store, "LIST," which causes the typewriter to print the program names of all programs in the store, and "FREE STORE", which prints the number of storage locations available for further programs.

Other standard messages are printed, under the control of RAP, to keep the operator in touch with events within the machine. For example, an error interrupt, due to a store-parity failure, causes the message "ERRINT 3" to be printed. Similarly, "ERRINT 1" indicates that floating-point numbers have exceeded the permissible range, "NO ROOM" that insufficient space is available to accommodate the program being read in, "ERRSUM" that the program to be entered has failed a sum check test and is probably corrupted, "NOPROG" that the program named by the operator is not available, e.g. it has been erased from the store.

Segment Tape Administrative Routines

RAP contains the essential software for a basic Elliott 503 but it does not cater for Elliott 503 systems with magnetic tapes and backing store. The complex requirements of these larger systems are provided by segment tape administrative routines (STAR) and, broadly, the objectives are the same as those for the basic system, i.e. to strike a reasonable balance between the processing efficiency of the computer and the programming effort needed to achieve that efficiency. Maximum processing efficiency implies that all data and program blocks are in the right place, at the right time. The programmer would have to arrange for this ideal state to be maintained throughout the whole program. It must be remembered, however, that there are now three levels of storage to consider—main, auxiliary and magnetic tape. Each has its own basic access time and transfer rate, but mutual interference effects, e.g. those caused by obtaining access to the main store or by the variable speeds of mechanical devices, makes any accurate prediction of block-transfer times virtually impossible and to attempt it would require a great deal of exacting and detailed work.

The productivity of the computer is also reduced by the use of slow paper-tape input and output, and by operator interventions.

STAR, therefore, is designed to reduce operator intervention to a minimum by processing jobs in batches, to reduce paper-tape operations to a minimum by storing programs and data on magnetic tape, and to relieve the programmer of the detailed planning of storage and peripheral operations. The program blocks providing these facilities are as follows.

Storage Planning and Allocation. The Elliott 503 programmer need not be aware that there are three levels of storage; he uses one type of reference for all data and program blocks. For example, a large program of 20,000 words, which exceeds the capacity of the 8,000-word main store, can be written in the same way as a small program of 500 words. Storage planning and allocation (SPAN) allocates program and data blocks to the main-backing or magnetic-tape store in the most economical way and re-allocates the blocks to meet changing conditions during processing.

The programmer makes use of SPAN facilities by incorporating standard SPAN macro-instructions (macros) in SAP or ALGOL programs. For example, the macros

consider (VOLTAGES)
banish (OUTPUT)

will cause the block named VOLTAGES to be copied on to magnetic tape by the tape handler whose address is given by the contents of location OUTPUT.

The dynamic re-allocation of SPAN blocks may slow down a program, e.g. it may be held up waiting for data to be brought from the backing store to the main store. There are, however, standard macros for specifying where SPAN blocks are stored, and they can be used to improve processing times.

Peripheral Control Program. The peripheral control program (P.C.P.) provides the peripheral software, and works in conjunction with the peripheral hardware facilities—A.D.T.s and normal interrupts—to permit efficient use of all the peripheral devices, including paper-tape input and output.

The standard set of P.C.P. macros is as general as possible. The macros specify, amongst other things, the type of peripheral device to be used and its number, the size and position of the buffer area in the main store, and the type of operations to be executed by the device. The macros are included in SAP or ALGOL programs, in the same way as SPAN macros. The P.C.P. takes over the organization of all peripheral operations: it forms a queue of the requests for the use of a particular device and deals with them in order, it will arrange for concurrent peripheral and c.p. operations, it will check that peripheral devices are working correctly, and it will initiate re-read or an error routine, as appropriate.

Device Selection Program. It is convenient to allow programmers to refer in general terms to peripheral devices during the program-writing stage, and for the actual devices to be selected from those available for use at the time the program is run. In the program, devices are referred to as source x or destination y, for input and output, respectively. At run time, a list of the devices to be used is prepared and read in to the computer. The device selection program (D.S.P.) processes the list and, making use of P.C.P., selects the appropriate device.

Information Manipulation Program. The information manipulation program (IMP) provides facilities for handling data in the form of characters as well as complete words or blocks. It is useful for packing and unpacking buffers, and provides the essential link between ALGOL programs and P.C.P.

Editall. Modifications to programs are made by preparing an "edit tape" specifying the changes required —deletions, insertions or replacements—to the original or "input tape" and processing the two tapes under the control of EDITALL. A similar process is used for editing programs held on magnetic tape.

BATCH PROCESSING OF PROGRAMS

For the testing and modification of programs during their development phase, and for actual production running, programs are batched and held on a reel of magnetic tape for processing, one after the other, with a minimum of operator intervention.

A batch is made up of a number of segments, normally one per programmer, and each segment may contain a number of files, e.g. different programs written by the same programmer, or different versions of the same program, or blocks of data to be processed by a program in the same segment. It must also contain all the library files needed to process and run the programs in it. Programs may be stored in source language, e.g. SAP or ALGOL, or in compiled form. There are, therefore, two types of file: (*i*) binary files, for compiled programmes, and (*ii*) 7-bit character files, for source-language program, and data. Each file is stored in SPAN block form.

Files are distinguished by an identifier (of up to six alphanumeric characters) plus a version, or issue, number. A directory of all the files in a segment is held at the beginning of each segment.

At the beginning of each batch reel, there are program blocks of STARSTRAP (a small program to set up the STAR system), STAR, SPAN and P.C.P., followed by a batch directory and segments containing files of the standard compilers and library routines.

The batch run will, in addition to running and testing programs, produce an updated batch reel containing new programs, modified programs, and unchanged versions of old programs, but omitting programs no longer required.

Each batch run is controlled by a STAR "command tape" which must specify the programs to be run and all the additions, modifications, and deletions affecting the batch. The run is started by the operator using standard RAP operating methods to transfer the control, via a small link program in the store, to STARSTRAP. The latter sets up the full STAR, SPAN and P.C.P. system in the store, and, when the setting-up is completed, the command tape is read in and the commands obeyed one by one. The operator is kept informed of the progress by printouts, on the control typewriter, of the commands obeyed.

CHANGE TO THE DOLLIS HILL COMPUTER

Limited compatibility will exist between the Dollis Hill Elliott 803 computer in its present form and the Elliott 503 being installed in the City. However, to gain full advantage of the designed compatibility features of the two machines, the Elliott 803 will be converted to 5-hole and 8-hole working, and its store extended from 4,096 to 8,192 words. These modifications will allow ALGOL to be used on the Elliott 803 and programs to be interchanged more freely between the two installations.

COMPUTER ORGANIZATION

The Organization and Efficiency—Maintenance and Computers—Branch (OMC Branch) has a general responsibility for all Engineering Department computing, including the operation of the Dollis Hill and City installations. The computers will be staffed by Executive and Machine Operator (M.O.) grades. A Computer Manager will be responsible for the day-to-day running, the overall efficiency of the installations, allocating jobs to the two installations and deciding their priorities. OMC Branch engineering staff will provide support on technical, programming, systems, and operating matters. They will also have an overall responsibility for all computer documentation and literature.

Initially, programming training will be provided by Elliotts, but eventually it will be the responsibility of the Engineering Department's Training Branch.

Both computers will be operated on a "closed-shop" basis by Senior M.O.s, but, at the City installation, an M.O. will load the magnetic-tape decks and line printers, and provide general assistance in the computer room. The Dollis Hill installation will have limited facilities for preparing 8-hole paper tapes, and the bulk of the data-preparation work will be done in the City by the M.O.s, supervised by a Senior M.O.

It is expected that the Elliott 503 load will grow rapidly and will soon justify two-shift operation of the computer, but not of the data-preparation equipment. The main day-time shift will deal with general engineering work and program testing, leaving the evening shift free for simulation and other long production runs.

ACKNOWLEDGEMENT

The author wishes to thank Elliott Brothers, Ltd., for supplying the photographs.

Book Review

"Elementary Particles." A. A. Sokolov (translated by W. E. Jones). Pergamon Press, Ltd. 75 pp. 13 ill. 10s.

The atom has long since lost its "indivisibility"; after its division into nucleus and cloud of electrons, the nucleus in turn became recognized as made of lesser parts, protons and neutrons. The positive electron was discovered as a fourth primary particle, and a fifth, the neutrino, was evoked to explain away a failure of conservation of energy in some natural radioactivity. The neutrino had near-zero rest mass and no charge, and was predicted to be well-nigh impossible to detect. Photons, i.e. quanta of electromagnetic radiation, gave little cause for concern to seekers after primary particles; indeed, having zero rest mass, no charge and unity spin, they were admitted to the particle club only as associates. The scene is much changed today. Yukawa paved the way in 1935 by suggesting that nuclear field quanta existed. These new particles, with very considerable rest mass, are interchanged between protons and neutrons to secure the powerful binding which experiments had failed to break on any scale until the coming of the powerful particle accelerators. Unfortunately for the simplicity of the scene, when the experiments did triumph they revealed not one or two new particles, but many; new conservation laws had to be proposed to explain why some particles could interact but not others. Energy, momentum, charge and spin are not the only quantities to be watched.

This little book tries to condense a very complicated story into a small space; it succeeds in fair measure. Some of its statements may puzzle readers, perhaps because of occasional difficulties in translation, and may break up the argument; but the fascination of the story is never lost. Evidently the nuclear physicist has as many problems to solve as ever.

J.R.T.

Dry-Reed Relays—Post Office Relays Type 14 and Type 15

B. H. E. ROGERS and W. L. RIDGWAY†

U.D C. 621.318.56

Dry-reed contact units are being introduced into exchange equipment now under development for the British Post Office. Two types, available either as board-mounted relays or for use with 3,000-type mountings, have been standardized for a limited range of applications. These relays are the forerunners of others that will have a wider use in telephone exchanges. The construction, characteristics and performance of the relays are discussed.

INTRODUCTION

THE fundamental requirement of any telephone relay is that its system of contacts should operate reliably to particular signals, and, in non-polarized and non-latching designs, the contact system should return to its former state when the motivating signal is removed. The final design of a relay depends entirely on the functions it is required to perform in service and on the costs involved.

For many years, telephone relays have been based upon the principle of an energized solenoid moving a magnetic armature mechanically linked to a contact system by means of metal pins or insulated comb-plates. A typical example of this type of device is the Post Office 3,000-type relay. However, the contacts of relays in this general class are open to local atmospheric contamination, with the result that their switching reliability suffers.

In 1936, following experiments directed towards a more reliable contact mechanism, the Bell Telephone Laboratories introduced the magnetic-reed switch,[1] which made use of magnetic alloys of high relative permeability then becoming available. Subsequent development has produced a variety of reed devices of two basic categories: dry reeds, and mercury-wetted reeds.

Dry-reed contact units are available in a number of sizes, with the glass envelopes ranging in length from about 2·1 in. for the large type down to 0·5 in. for the miniature types. Each contact unit contains a single contact action, and in most types this can be a make, break or change-over. Basic sensitivity and load-switching capacity vary widely with the different sizes and even between nominally similar devices made by different manufacturers.

A range of relays having small contact-units for use in electronic telephone exchanges is now being developed, but this article is concerned mainly with the characteristics of the larger dry-type make-action contact unit specified by the British Post Office for use in a board-mounted relay (Relay Type 14) and in a relay suitable for use with the 3,000-type mounting (Relay Type 15). Here, the term "contact unit" has been adopted to describe the reed element; these elements are also known as capsules, switches and inserts. A typical make-action contact unit is shown in Fig. 1.

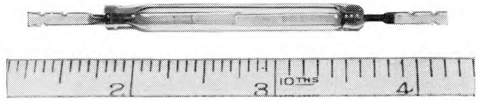


FIG. 1—MAKE-ACTION CONTACT UNIT

OPERATION OF REED CONTACT UNIT

The operating mechanism of a contact unit is shown in Fig. 2. The make-action contact unit shown consists of two accurately positioned magnetic-alloy reeds, or blades, sealed into a glass tube. The inner ends of the reeds overlap, and they are separated by a gap ("contact opening") of about 5 or 10 mils, depending on the operating sensitivity required. The overlapping area carries the contact material in the form of a suitable metal plating or of wafers of the chosen material welded to the ends of the reeds.

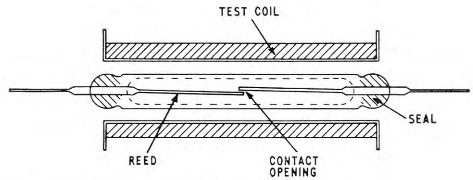


FIG. 2—OPERATING MECHANISM OF MAKE-ACTION CONTACT UNIT

As well as providing a rigid support for the reeds, the glass tube acts as an effective gas-tight seal that allows the tube to be filled with a suitable gas; it also gives a high degree of electrical insulation between the reeds.

When a magnetic field is applied along the major axis of a contact unit, opposite polarity will be induced in the overlapping free ends of the reeds; they will be mutually attracted, making electrical contact together via their contact surfaces. On reducing the magnetic field, a point will be reached when the mechanical energy stored in the reeds due to their flexure is greater than the magnetic force between them, and they will separate.

All currently produced reed-type contact units are electromagnetic devices working basically as described above. They may sometimes use the repulsive force between like poles, or embody permanent magnets for correct functioning, improved sensitivity, or to provide a polarized contact-action.

The principles of operation of these devices and the forces involved in their operation have been described in greater detail elsewhere,[1, 2, 3] and a further description will not be given here.

MATERIALS AND ASSEMBLY OF REED CONTACT UNITS

Reed Materials

The relative permeability of the reeds must be high to ensure operation at reasonably low coil-currents and to provide adequate contact force. Remanence must be low, or releasing difficulties will occur. The inherent reed resistance must be small and yet must minimize the eddy currents due to movement of the reeds in the controlling field. The physical dimensions of the reed are determined from the modulus of elasticity of the

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

material, the contact opening, the minimum contact force, and the need for mechanical stability. An alloy of nickel-iron (50:50) has been found to give very satisfactory results and is now commonly used for this class of contact unit.

Contact Material

The selection of a suitable contact material is an extensive subject; however, in essence, the choice will be determined by the type of contact mechanism, the contact loads to be switched, and the service life required.

The contact units fitted in Type 14 and Type 15 relays are in the light-current range, capable of switching inductive loads of up to 0·1 amp at 50 volts. At present, gold is the most usual contact material for this load range; its use was recommended by the Bell Telephone Laboratories at an early stage, and its performance has been confirmed by British Post Office tests. The gold is plated over the contact ends of the reeds to a thickness of between 0·1 and 0·2 mils.

The type of gold and its treatment subsequent to plating have to be selected with care, as this material has a tendency to cold weld, or stick, in conditions of extreme cleanliness, as in a reed-type contact unit. The degree of sticking can vary from a fleeting weld, almost immediately broken by the restoring force of the reeds and resulting in a small increase in release time, to a firm weld that can only be broken by mechanical jarring of the contact unit.

In the Type 14 and Type 15 relays the gold deposited is sensibly pure, and it is afterwards diffused into the surface of the reed by a stoving process. This has been found to reduce the tendency to stick and to give a contact life better than 10^7 operations when switching inductive loads (e.g. quenched relays) of up to 0·1 amp at 50 volts. Diffusion results in a small increase in contact resistance, which may vary from one operation of the relay to the next; however, the resistance is stable during any one operation, and thus does not generate noise.

In some types of reed contact unit an acid-hard gold-plate is used; it is claimed to be free from sticking as well as giving a very low contact-resistance, but these claims have still to be substantiated. Other contact materials used commercially are tungsten, molybdenum, silver, rhodium, palladium and platinum-cobalt.

Capsule Material and Gas Filling

The type of gas filling within the glass tube depends to a large extent on the contact material and manufacturing processes involved. For gold contacts, hydrogen is considered the most suitable gas filling, but, where this constitutes a hazard during manufacture or subsequent use, nitrogen with a few per cent hydrogen is used. Gas pressures within the contact unit usually range between 15 and 20 lb/in^2 for hydrogen and about 10 lb/in^2 for a nitrogen-hydrogen mixture. In certain specialized types of contact unit, pressures of up to 260 lb/in^2 are employed, while in some types the glass is evacuated for high-voltage working.

Contact-Unit Assembly

Contact units of early design were made by welding flat magnetic reeds to nickel-iron tubes, two of which were then sealed into the glass envelope. The envelope was evacuated via one of the tubes prior to being filled with the appropriate gas. Subsequent simplification of manufacturing techniques resulted in a one-piece forged reed sealed into the glass envelope in the presence of the gas filling.

Various production techniques are used today, some completely automatic and requiring very costly machinery. The following outline, however, is typical.

Each reed is forged or pressed from circular-section nickel-iron wire, leaving circular the part around which the glass seal will be formed. After various trimming, cleaning and annealing treatments, the mating, or contact end, of each reed is plated, and, when required, the plating is diffused into the base metal.

Two reeds are jig-mounted in a length of glass tube, and the gas filling is flushed through the tube. The reeds are positioned mechanically and electromagnetically, and one reed is sealed into the glass. The second reed is then re-aligned magnetically for correct mating of the contact surfaces and is clamped in this position. The gas flow is adjusted and the magnetic field is removed, after which the second reed is backed off to give the required contact opening and sealed in this position.

Sealing is accomplished by softening the ends of the glass tube, by means of a heating coil, until the glass forms around the reeds, which have previously been oxidized in the sealing area to ensure satisfactory adhesion. The outer ends of the reed blades are tinned to facilitate soldering. Finally, the contact units are pulsed for a time without a contact load in order to "run in" or improve their mating, which may have been disturbed during cooling of the glass.

Contact units are manufactured under "clean-room" conditions, early experience showing this to be a major factor in the production of a reliable device having a predictable performance.

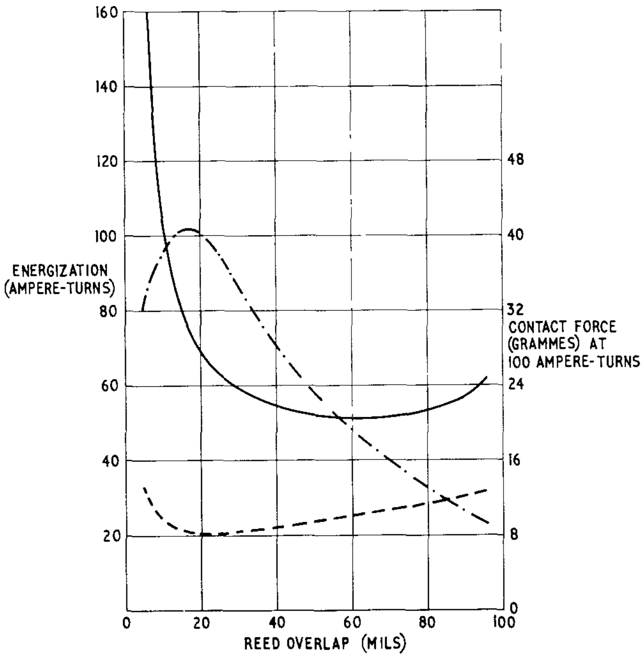
CHARACTERISTICS AND PERFORMANCE OF CONTACT UNITS

The performance of a contact unit is governed mainly by the magnetic and mechanical properties of the reeds, and their physical dimensions and positions relative to each other, i.e. gap and overlap. Other factors are the geometry of the operating coil, location of the contact unit within it, and the total reluctance of the magnetic circuit embracing the contact unit. Consequently, in order to ensure consistent test conditions, a standard test coil is used for all contact units. The coil consists of 10,000 turns of 43 s.w.g. enamelled-copper wire wound on a cylindrical coil former of $\frac{7}{16}$ in. outer-core diameter and $1\frac{7}{8}$ in. winding length. Before testing is started, the coil is arranged to be free from the influence of adjacent magnetic materials or fields and the axis of the contact unit is orientated east to west, as it has been found that the Earth's field can make a difference of up to 2 per cent in the magnetic performance of a contact unit.

OPERATE, RELEASE AND CONTACT-FORCE CHARACTERISTICS

Neglecting the effects of coil design and mode of operation, the operate, release and contact-force characteristics depend primarily on the magnetic and elastic properties of the reeds, the degree of overlap and the contact opening, as well as on the contact-material thickness.

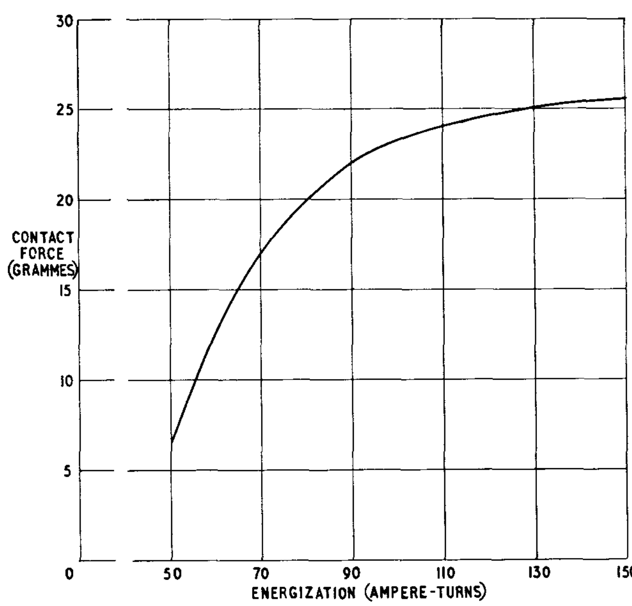
Fig. 3 illustrates the effect of overlap on the operate and release sensitivities and the contact force for a contact unit with a released-contact opening of 10 mils.



—·—·— Contact force
———— Operate
— — — Release
Contact opening: 10 mils

FIG. 3—EFFECT OF OVERLAP ON OPERATE AND RELEASE SENSITIVITIES AND ON CONTACT FORCE

It is clear that the final design must be a compromise between operate sensitivity, operate-to-release ratio, and an acceptable value of contact force, and, in practice, a nominal overlap of 50 mils is usually provided. Fig. 4



Contact opening: 10 mils
Contact overlap: 50 mils
Contact gold-plating: 0·2 mil thick

FIG. 4—RELATIONSHIP BETWEEN CONTACT FORCE AND ENERGIZATION FOR TYPICAL REED CONTACT UNIT

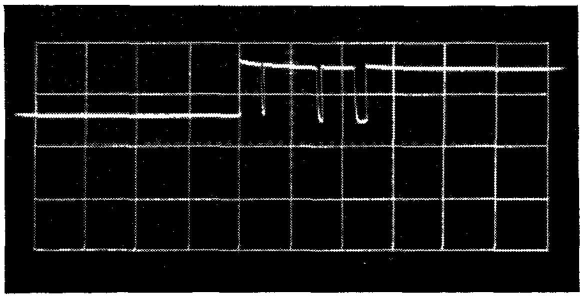
shows the relationship between contact force and energization for a basic contact-unit of the type used in these relays, the variables being as shown.

During operation of a contact unit, the reeds move together with a snap, or toggle, action. This is because the force tending to restore the reeds to their normal position is proportional to their deflexion, while the magnetic force of attraction between them increases much more rapidly, being inversely proportional to the square of the distance between them. The contact opening at which the two forces balance is known as the "trigger point."

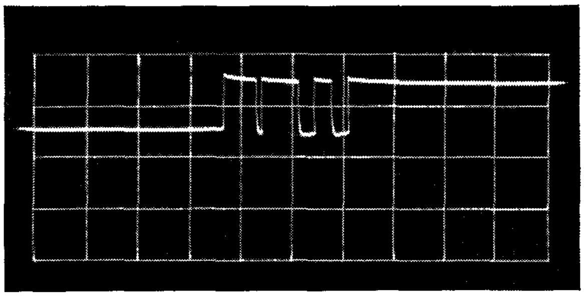
Timing Performance and Operating Frequency

The operate time of a reed relay, i.e. the time interval between the application of the operating voltage and the first make or closure of the contacts, is mainly dependent on the rate of current rise in the operating circuit, as, once the trigger point has been reached, the mechanical movement of the reeds is completed in less than 0·5 ms.

During operation, the momentum of the reeds and the lack of mechanical damping at the contact surfaces, together with side electromagnetic effects, result in contact bounce. With the contact units used in the Post Office Type 14 and Type 15 relays this takes the form of three interruptions within the first millisecond, each of up to 0·1 millisecond, the pattern being typical of this class and size of contact unit. Contact bounce varies with energization and is least at the just-operate value, but this is not a practical condition for circuit use. The best compromise between operating speed and minimum contact bounce occurs at energizations of the order of twice the just-operate value. Fig. 5 (*a*) and



(*a*) Five-mil Contact Opening



(*b*) Ten-mil Contact Opening
Each division of the graticule corresponds to 0·1 ms
Each relay was energized at twice the just-operate value

FIG. 5—CONTACT-BOUNCE PATTERNS

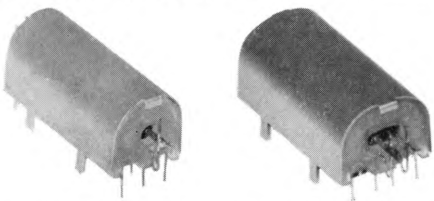
(*b*) show typical contact-bounce patterns for contact units with 5-mil and 10-mil contact openings, respectively, energized at twice the just-operate value.

Factors controlling contact-unit release times are the coil constants, reed elasticity, contact opening and contact-material thickness. Typically, the Post Office contact unit with a 10-mil contact opening, when released by a disconnexion of the operating current, has a release time of about 0·3 ms. Where the contact unit has a contact opening of 5 mils, release to the same conditions gives a slightly longer time—about 0·4 ms.

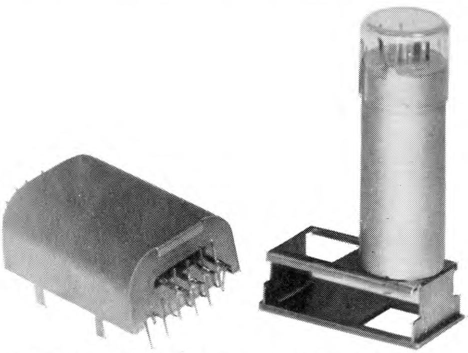
The natural vibration frequency of the large reeds is about 900 c/s, although this will vary for contact units from different manufacturers; this characteristic, together with the low mass of the reeds, allows them to be pulsed at up to 400 pulses/second, a considerably higher rate than is possible with conventional relays.

RELAY DESIGNS

There are many commercial types of dry-reed relay, some with the contacts inside the coil, others with them on the outside. The designs so far standardized by the British Post Office are shown in Fig. 6. Of these, the



(*a*) Type 14 Relay—Single Contact Unit (*b*) Type 14 Relay—Two Contact Units



(*c*) Type 14 Relay—Four Contact Units (*d*) Type 15 Relay

FIG. 6—DRY-REED RELAYS STANDARDIZED BY THE BRITISH POST OFFICE

cylindrical relay is the Type 15, two of which can be mounted in the space required for a 3,000-type relay; the others are Type 14 relays and are designed for board mounting. Two windings can be provided on either type of relay, and the coils are magnetically screened by a soft-iron shield. A side effect of the screen is that by reducing the external reluctance, the effective magneto-motive force is increased by about 30 amp-turns.

Both relays have been designed around the large type of contact unit, and will accommodate from one to four such units. In the board-mounted version three sizes of coil former are used: for one, for two or three, and for three or four contact units. The Type 15 relay has a flexible membrane at each end of the coil former; the membranes serve to locate the contact units and also allow easy removal if necessary. There is also a moulded cover to guard the projecting contact-unit ends.

Break and change-over actions have not yet been introduced for Post Office use, although either type can be fitted into the coil formers of the two relays standardized. Break actions are usually achieved by using make actions pre-operated by a permanent magnet or a separate winding; the contacts break when the operating flux is neutralized. The present Post Office make-contact unit can be used in this way, although difficulties may arise if the full complement of four units in a coil is required to function as break contacts.

Change-over-contact units usually embody one non-magnetic and two magnetic reeds, or all three may be of magnetic material; their physical construction varies considerably. In all types so far tested by the Post Office, contact bounce on release is excessive, and until this can be reduced there seems little hope that they will approach the reliability of the large make-contact unit.

So far, only passing reference has been made to contact units other than the large type of Fig. 1. The size of contact units and hence, relays, can be substantially reduced: several commercial units are now becoming available with a glass length of little over a 0·5 in. and an outside diameter of less than 0·1 in. Compared with the large type, small contact-units are, in general, more sensitive, they require less copper in the operating coil, and they allow considerable savings from reduced power consumption, space and weight.

CONCLUSIONS

Relays employing dry-reed contact units can be fast, reliable and robust; they provide the circuit engineer with a new and useful device for light-current switching. The use of relatively few parts of simple design should contribute to a cheap device requiring little maintenance.

ACKNOWLEDGEMENTS

The Type 14 and Type 15 relays were developed by the Automatic Telephone and Electric Co., Ltd., on behalf of the British Telephone Technical Development Committee.

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Retirement of Sir Albert H. Mumford,

K.B.E., B.Sc.(Eng.), M.I.E.E., F.Q.M.C.

SIR ALBERT MUMFORD retired on 19 March 1965 after 41 years' service in the Post Office, having been Engineer-in-Chief since February 1960. His has been a career of great distinction, and he has for long enjoyed a high reputation both nationally and internationally, notably in the radio field.

Sir Albert joined the Engineering Department in 1924, and soon demonstrated at Dollis Hill Research Station his abilities as a research and development engineer. He made important contributions both in the radio and coaxial cable fields, and achieved several promotions before returning to the City in 1938 as Staff Engineer of the Radio Branch, whose activities he was to guide during the heavy program of work carried out during the war years. He was awarded an O.B.E. in the New Year Honours, 1946.

It was during the next five years that he achieved considerable international experience, initially as a senior member, and later as the leader, of United Kingdom delegations to various international radio conferences, at places as far apart as Moscow, Paris, Atlantic City and Geneva. He also, in 1948, spent a year on a course at the Imperial Defence College.

Promotion to Assistant Engineer-in-Chief in 1951 faced him with very different problems. Instead of discussions about such matters as international frequency allocation, he plunged with his usual energy and enthusiasm into engineering organization and staff work. This work included the chairmanship of the Boards dealing with promotion to Area Engineer/Senior Executive Engineer and above, and to Motor Transport major grades, negotiations with Staff Associations, membership of the Engineering, Factories and Supplies Departmental Whitley Council, as well as of the Engineering Department (Engineering) Whitley Committee, and Chairmanship of the Standing Joint Committee on grading questions affecting Post Office Engineering Union grades. His acute mind, and his analytical and debating ability, enabled him to carry out these new duties with great success, and he continued with the greater part of them after his promotion to Deputy Engineer-in-Chief in 1954, as well as assuming wider responsibilities generally.

In addition to all these heavy official loads, Sir Albert found time to render conspicuous service to The Institution of Electrical Engineers. He was a member of the Radio Section for many years, and its Chairman in 1945–46. Later, he was elected to the Council of the Institution, and became a Vice-President in 1958. During that time, and subsequently, he also rendered yeoman service to the Institution of Post Office Electrical Engineers, originally as Chairman of the London Centre, and a member of the Board of Editors of its Journal, and later, when Engineer-in-Chief, as President of the Council.

As his career approached its zenith, more and more appointments and honours were accorded to him: Engineer-in-Chief in February 1960; Fellowship of Queen Mary College, University of London, December 1962; Knight Commander of the Order of the British Empire, Queen's Birthday Honours List, 1963; and President of The Institution of Electrical Engineers, 1963–64.

In the latter capacity, Sir Albert and the Secretary of the Institution, together with their ladies, carried out in 1964 an arduous, but enjoyable, tour extending over some six weeks, to joint overseas branches of the Institutions of Civil, Mechanical and Electrical Engineers. The tour, which covered Toronto, New York, the Bahamas, Jamaica, Barbados, Trinidad, British Guiana, Rio de Janeiro and Buenos Aires, included an enforced stop at Miami on account of the activities of Hurricane Cleo. Luckily, however, all emerged safely.

The outstanding and most lasting impression of those who know Sir Albert will perhaps be not so much his technical accomplishments, which speak for themselves, but his extraordinary vitality and enthusiasm. His thick dark hair, his apparently boundless energy, the amount of time he always seemed able to spare to discuss problems with his colleagues, have to be known to be appreciated. Little information is yet available as to what the future holds for this dynamic personality—but it is already known that he will be continuing with his work for The Institution of Electrical Engineers, and that he has accepted for the next two years the post of President of the Association of Supervising Electrical Engineers.

Their many friends at home and abroad most sincerely wish Sir Albert and Lady Mumford many more years of health and happiness.

D.A.B.

Appointment of Mr. D. A. Barron, C.B.E., M.Sc., M.I.E.E., as Engineer-in-Chief

THE appointment of Mr. D. A. Barron to be Engineer-in-Chief in succession to Sir Albert Mumford is an event which we signal with sincere personal congratulations, having confident expectation of his ability to maintain and extend the traditions and responsibilities of this high office.

The career of the new Engineer-in-Chief has embraced the wide range of experience that service in Areas, Regions and the Engineering Department has accorded. Mr. Barron's service in the Post Office commenced in 1927, when, after graduating (in engineering) with Honours, at Bristol, he entered the then Technical Section of the old South Western Engineering District at Bristol. This was followed by a period at Plymouth and, after promotion to Area Engineer, at Liverpool. In retrospect, therefore, not only has he seen and resolved at first hand the problems that confront staff in the field, he has had also a first-hand experience of the formation of Area and Regional organization, as now known, and of the problems of that organization.

He was called to the Engineering Department in 1940, joining the Telephone Branch, and was soon promoted to Assistant Staff Engineer in charge of circuit and apparatus designs, and of the Circuit Laboratory. During the 1939–45 war he remained with the Post Office, being responsible for, among many other things, telecommunication facilities for the radar chain, which included one of the earliest applications of automatic aircraft-location computers.

Immediately after the war, in 1945, Mr. Barron's experience was extended overseas. He was selected for special appointment as chief consultant to the Indian Posts and Telegraphs Department to plan the conversion of the Calcutta area to automatic working, one of the major steps in the post-war re-engineering of the Indian telecommunications network. Two years later, in 1947, he led a working party in a world-wide survey of automatic switching methods and plant. This was the main part of a forward-looking survey of the possibilities of further mechanization of the telephone network of the United Kingdom. The work done by the team, so ably led by Mr. Barron during this time in their two-year task, laid the essential foundations of the nation-wide program for the introduction of S.T.D.

It was fitting that on promotion to Staff Engineer, Telephone Branch, in 1949, Mr. Barron should assume executive control of the heavy and continuing program of S.T.D. works that were needed to convert the forecasts of his study team into the hard facts of a commercially viable and technically satisfying system. The opening of the first installation in Bristol in 1958 and the subsequent spread of S.T.D. over the country stand as evidence of his wise judgment and unremitting endeavour.

Paralleling Mr. Barron's work on S.T.D. has been his close concern with the development of the fully electronic telephone exchange. He was the Chairman of the important Technical Sub-Committee of the Joint Electronics Research Committee, and in this capacity directed the research activities in this field of the Post Office and of the five co-operating industrial organizations. More recently he has been appointed Chairman of the Project Executive Board, set up by the Director General in January 1964 to establish overall plans for electronic systems for both major and small exchanges.

In 1954 Mr. Barron was promoted to Assistant, and in 1960 to Deputy Engineer-in-Chief. At each promotion he has enlarged his interests with evident ease and understanding. On assuming the post of Assistant Engineer-in-Chief he was quick to concern himself with matters affecting cost and quality of service. His promotion to Deputy Engineer-in-Chief absorbed him in a wide range of organizational and staff matters, and during this period he was awarded the C.B.E.

The Deputy Engineer-in-Chief traditionally shoulders the main burden of negotiations with the Engineering Staff Side, and Mr. Barron has been able to give ample expression of his natural talent for guiding men with conflicting interests towards a sensible conclusion. As Chairman of the Standing Joint Committee on Post Office Engineering Union questions he has helped to resolve many important and difficult issues. Recently, for example, there has been the notable re-organization of jointing and installation work, and the introduction of the Senior Technician grade with all the implicit possibilities of increased productivity that these measures afford.

Mr. Barron's interests outside those of the bounds of immediate office range through the international and the professional. He has been active in the work of the C.C.I.T.T. as a member and Chairman of Study Groups; he was leader of the United Kingdom Delegation to the Plenary Conferences in New Delhi, in 1960, and in Geneva, in 1964—with all their political intricacies. He has served for three years as a member of Council of the Institution of Electrical Engineers, and in 1963 gave a memorable performance as Faraday Lecturer. He has been a strenuous worker over a decade or more in the service of this Institution.

To the problems and responsibilities of the office of Engineer-in-Chief, therefore, Mr. Barron brings experience that is wide ranging, and a career that is marked by success and achievement. But to this must be added qualities of kindliness, firmness, carefulness and good humour that, over the years, have evoked the response from his staffs and his colleagues that, in turn, has enabled so many important objectives to be achieved. We look with confidence to his years in office, and, assuring him of our support, wish him well for the future.

J.H.H.M.

Reed Relays in the Small Electronic Exchange Systems at Leamington and Peterborough

U.D.C. 621.318.56:621.395.345

The main features of the reed relays to be used in the field trial of the two small electronic exchanges at Leamington and Peterborough are described, with reference to size, cost and reliability.

INTRODUCTION

A DESCRIPTION is contained elsewhere in this Journal[1] of the two small electronic-exchange systems that are to be given field trials. The general features and characteristics of dry-reed relays, with particular reference to the Post Office Type 14 and Type 15 relays, are also discussed elsewhere.[2]

The reed relays to be used in the Leamington and Peterborough trial exchanges differ from each other and from the Post Office Type 14 and Type 15 relays. Both of the types described here, however, have four make-contact units and are arranged so that they can be readily mounted in coordinate arrays to form crosspoint switches—their major use. The relays are also used in the control and supervisory circuits of the exchanges.

THE GENERAL ELECTRIC CO. RELAY

Fig. 1 shows the general arrangement of the General Electric Co. (G.E.C.) relay and a view of one reed contact-unit. Overall dimensions of the relay are approximately 3·7 in. × $\frac{7}{8}$ in. × $\frac{7}{8}$ in., while the reed contact-unit has a length over the tags of 3·19 in. The relay is arranged to operate with 180 ampere-turns. When assembled to form a crosspoint switch, multiple wiring is taken directly between the tags, the wiring at opposite ends of the relay being mutually at right angles.

Although the type of relay described above is used in the Leamington equipment, a production form of the relay would be reduced in overall length, using a smaller reed contact-unit now becoming available. This would allow the space-saving potential of the small electronic exchange to be fully exploited.

FIG. 1—G.E.C. REED RELAY

ERICSSON TELEPHONES RELAY

The Ericsson Telephones (E.T.) relay, used in the Peterborough equipment, also makes use of the smaller reed contact-unit referred to above, which has an overall length of 1·8 in. Overall dimensions of the complete relay are approximately 2 in. × 1 in. × 1 in., and Fig. 2 illustrates the relay and one contact-unit. Connexion tags are mounted on the end cheeks of the coil former, and for crosspoint use the sets of tags at opposite ends of the relay can be positioned at right angles to each

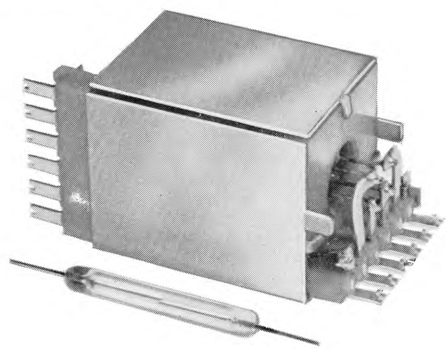


FIG. 2—E.T. REED RELAY

[1] HILLEN, C. F. J., LONG, R. C., and PORRITT, W. R. A. The Field Trial of Two Small Electronic Exchanges at Leamington and Peterborough. (In this issue of the *P.O.E.E.J.*)

[2] ROGERS, B. H. E. and RIDGWAY, W. L. Dry-Reed Relays—Post Office Relays Type 14 and Type 15. (In this issue of the *P.O.E.E.J.*)

other. If coordinate wiring is not required, one end cheek can be turned through 90° before assembly, so that both sets of tags lie in the same plane.

The basic characteristics of the relay are:

Operate ampere-turns	100
Release ampere-turns	12·5
Hold ampere-turns	70
Non-operate ampere-turns	35

NUMBER OF OPERATIONS

In small electronic-exchange systems the number of operations that a reed relay will perform, over the full life of an exchange, will vary widely according to its function. Crosspoint usage should not exceed 500,000 operations per relay, but some control relays may have to perform more than 100 times this number of operations in the life of the exchange.

RELIABILITY

As the reed relay is the majority component in the small electronic exchange systems that are the subject of the field trial, the success, or otherwise, of the systems will be strongly influenced by the reliability and cost of these components. Reed contacts, by their nature (gold plated and sealed in an inert atmosphere) should be potentially reliable. But the field trials, while they will be invaluable for system proving and assessment of maintenance problems, cannot be expected to give any assurance of the long-term reliability of reed relays. This assurance must come from accelerated life-tests and an understanding of the failure mechanisms. Tests have already shown that a proportion of reed contact-units will operate, without failure, 100 million times. If a high level of reliability is to be achieved consistently in quantity production, close control of the manufacturing, testing and inspection processes will be required. The extent of control found to be necessary will clearly influence the ultimate cost of the reed relay.

ACKNOWLEDGEMENTS

Acknowledgement is made to Ericsson Telephones, Ltd., and to the General Electric Co., Ltd., for information contained in this article and for permission to reproduce the photographs.

A.C.E.

Book Reviews

"Fernwahlsysteme in der Welt." (Long-Distance Dialling Telephone Systems in the World) Dr. Ing. G. Seelmann-Eggebert. R. Oldenbourg, Munich. 132 pp. 40 ill. 26 DM.

This is a small book giving general digest information of the arrangements adopted by the various European countries and U.S.A. to introduce national subscriber trunk dialling. The information covers for each country: the various manufacturing and operating organizations, type of switching equipment, national numbering scheme, routing plan, transmission plan, general trunking of the switching, and method of charging (ticket accounting or periodic pulse metering).

The book enables immediate comparison to be made between the main features of the various arrangements. Some countries have a national numbering scheme with a variable number of digits, others a fixed number. All the routing plans are significantly similar, being based on high-usage direct-circuit groups overflowing to a low traffic-loss 4-wire switched transit network in a hierarchical transit switched order (e.g. Group–District–Main switching centres in U.K.). The transmission plans are also all basically similar in that 4-wire working extends down to the lowest order transit switching centre with direct 2-wire circuit groups connecting these centres to the local exchanges. In almost all cases the highest order transit switching centres are directly interconnected.

The book concludes with brief details of the C.C.I.T.T. approach to world subscriber dialling, giving information on the recommended world numbering plan, with one, two, or three digit country codes to achieve an international subscriber number of preferably 11 digits, but exceptionally 12.

While the book is brief and limited to the general, it is a most useful reference in this field, and is an introduction to the detailed field as it includes a list of relevant publications for each country from which detailed information may be obtained. For these reasons, together with the presentation, as the author, of the German Post Office Engineering Department, Darmstadt, is an expert in his field, the book is recommended to both engineers and students.

The book is excellently produced, but, being printed in German, will unfortunately have limited readership in the U.K.

S.W.

"The Atlantic Cable." Bern Dibner. Blaisdell Publishing Co. 188 pp. 42 ill. $1.95.

This story is concerned only with the events leading up to the successful completion of the first transatlantic telegraph cables in 1866. After glancing at the very comprehensive bibliography of 60 references, mostly contemporary, one wonders at first what justification there is now, a century later, for a further presentation. Admittedly this scientific achievement of the nineteenth century will never fail to thrill. No doubt the recent transatlantic telephone cables have revived interest.

The book makes easy and enjoyable reading. The style, layout and printing is excellent for a paperback and the text is enhanced with over 50 illustrations, eight of which are from Russell's magnificent lithographs. The author has carefully studied the material available and produced a well-balanced factual account which, however, in no way diminishes the drama of the five expeditions. No factual or printing errors were apparent, though Merrett's (1958) "Three Miles Deep" is an obvious omission from the bibliography.

Personalities, many famous, are well portrayed. Cyrus Field deservedly receives the highest eulogies, and it is refreshing to note that British scientists, engineers, captains and cable makers receive their due tributes.

The story of the final expeditions would not be complete without some description of Brunel's leviathan *The Great Eastern*. The author does not dwell on this but observes, so rightly, that this ship has her own saga. The book reminds of how less than a century ago it took weeks to communicate between the two continents, of how patience was rewarded after 13 years, and of how the bleak little wooden hut at Valentia was manned day and night for over a year awaiting a response by a spot of light! Its illustrations will never be dated, and at the price equivalent of 14s. it is a very good purchase. It would be equally at home on the technical, adventure, drama or thriller shelves.

R.A.B.

Providing Post Office Plant on Bridges and Viaducts

S. L. F. FAGG and F. G. MEAD†

U.D.C. 621.315.232:624.21

The problems met in providing Post Office ducts on bridges of modern design are discussed, and the methods used to overcome these problems and to satisfy essential Post Office requirements are described.

INTRODUCTION

OVER the past few years, with the introduction of motorways and with large-scale expenditure on new and improved trunk roads, much thought and time has been devoted to the designing of bridge structures. The opportunity has been taken to implement new and more economical designs now possible with modern stressing techniques. Compared with older bridges the physical dimensions of present-day bridges are drastically reduced, lightness with strength being the order of the day.

For the Post Office this "new look" brought in its wake practical difficulties not previously encountered. In the past it was comparatively easy to lay Post Office ducts and to provide jointing chambers in a bridge while it was being constructed, as the depth of the relatively large structure enabled Post Office requirements to be incorporated with little difficulty.

Economics naturally play a large part in bridge design today, and any additional weight, such as that of public-utilities' plant, cannot always be accommodated without some additional strengthening of the bridge. As a consequence, a fair and reasonable proportion of the costs for the additional strengthening of a bridge sometimes has to be borne by service undertakers using the bridge.

On motorways the Post Office are the only service undertakers who lay plant, and this normally consists only of a single duct along one side of the road, and then only in positions where it would be impossible to lay ducts later, e.g. in bridges, viaducts, slip-roads, etc. In such circumstances no additional strengthening of bridges is necessary, the additional weight being very small.

Although the duct requirements of the Post Office are made known to the designer in the early stages of the design of large bridges, detailed discussions on the actual location and methods of providing plant take place some time after the bridge design has been accepted by the Fine Arts Commission. After approval of the design, detailed drawings are prepared and the placing of Post Office plant on the bridge is then the subject of close consultation between the bridge consultants and the Post Office engineers. During these consultations many aspects of the work are considered, e.g. the type of duct, the expansion of the bridge, and access to plant; all of these matters are discussed in the following paragraphs.

POST OFFICE DUCTS ON MOTORWAYS

When the first section of the M1 motorway was planned, some 180 bridges were to be constructed over its 72-mile length, and the Post Office had to decide whether or not to use motorways for their future trunk network. Before making any decisions, estimates were prepared to compare the costs of various formations of duct laid under the hard shoulder of the motorway during its construction. The estimates showed that the costs would be very great, and it was thought, after careful consideration, that in the foreseeable future it did not seem probable that the Post Office would require a large number of ducts on motorways, due to the fact that the motorways would keep clear of towns and because of the added difficulty of providing repeater stations along the road. It was decided, however, that some ducts should be laid through such places as bridges and viaducts, and through any other place where it would be impossible to provide ducts later after the structures had been constructed. This early decision resulted in 9-way ducts being laid in bridges, viaducts and under slip-roads on the M1 motorway.

Later, with the introduction of other motorways, the Post Office, having decided that they could be considered as possible routes for future waveguide systems, decided to provide along each motorway a 6 in. bore steel duct, in lieu of the multi-way ducts, to carry a possible waveguide on one side of the road in bridges, viaducts and under slip-roads; the major provision of duct between these various points was deferred for the time being. In the meantime the duct would carry the accident-reporting cable through those positions, the cable being buried under the grass verge on the same side of the motorway as that on which the duct had been provided.

The requirements for laying a 6 in. bore steel duct for possible use with waveguides were rather stringent. The minimum permissible radius of any bend in the duct was 1,320 ft, and this introduces difficulties where ducts leave a bridge with little or no cover or where drainage structures immediately follow a bridge, obstructing the line of the duct route. Recently, however, the Post Office have decided to provide the 6 in. duct only on certain motorways, and, in future, the minimum bending radius of this duct when laid will be 100 ft. This will ease the problems involved in laying the ducts in bridges.

On other motorways, where a waveguide duct is not required, a Post Office standard 4 in. steel duct is provided. Although this particular type of duct is comparatively simple to lay under normal circumstances, great care is necessary when planning the laying of the duct route in any bridge.

POST OFFICE DUCTS IN MOTORWAY BRIDGES

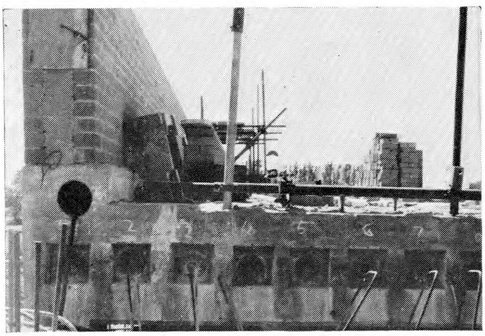
Position and Depth of Duct

A position for the 6 in. duct in motorway bridges has to be agreed so that it can be laid as straight as possible. The ducts have to be laid in the bridge, ideally in line with the grass verge of the motorway, and left in such a position that any future extension will not be impeded by drainage gullies or catch-pits, etc. The ducts should also have sufficient depth of cover when leaving the bridge; this should normally be 3 ft, but on occasions this

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

depth can be difficult to obtain. Where drainage catch-pits, gullies, etc., immediately follow the bridge, the ducts are extended beyond these drainage structures or incorporated in them during the construction of the motorway, thus ensuring the future line of route. Where no drainage structures follow the bridge, only 9 in. of duct are left protruding from the ends of the bridge: it has been found that to leave longer lengths results in damage to the duct during later construction stages.

In certain circumstances, e.g. due to the design of a particular bridge, it is impossible to lay the duct in line with the grass verge, and the duct has to be placed under the hard-shoulder position on the bridge and then continue off the bridge on a gradual curve until the duct terminates under the grass verge clear of any drainage, so that, if necessary, it can be extended in the future. When a number of bridges closely follow one another, the duct was sometimes laid continuously under the hard shoulder linking the bridges, jointing chambers being provided as necessary between bridges. Fig. 1 shows how the position of the Post Office duct is often dictated by the position of the bridge-stressing cables. The 6 in. steel duct was cast straight in this bridge and was then continued into the wing wall of the bridge on a gradual curve, thus ensuring that the duct had cover when leaving the bridge.



The circular duct is visible on the left-hand side of the bridge
FIG. 1—POST OFFICE STEEL DUCT CAST INTO BRIDGE STRUCTURE

Method of Laying Ducts

The three main methods of placing ducts in motorway bridges are as follows.

(*i*) The first and most common method is to cast the duct in the concrete of the bridge. To meet all the Post Office requirements regarding depth and position, it is often found that the one position suitable for the 6 in. duct is not favoured by the bridge designers; this often leads to difficult negotiations as it sometimes necessitates repositioning steel reinforcements in the bridge, something the designers are naturally reluctant to do having completed all the design calculations and drawings. The joints of ducts laid in concrete have to be wrapped with tape to prevent the entry of cement mortar, while the ducts themselves also have to be secured to reinforcing bars, as it has been found that, despite their weight, the ducts tend to rise when the concrete is being vibrated during the placing process.

(*ii*) The second method is to suspend the duct under the bridge, passing it through the diaphragms and crossbeams, between the main supporting beams. The diaphragms, and, if necessary, intermediate steel brackets. support the ducts.

With some bridges the contractors leave oversize asbestos-cement sleeves through the diaphragms. This method is favoured by contractors who use steel shuttering, as no holes need be made in the shuttering, but very careful alignment of the sleeves is necessary. Very careful planning of the placing of the duct is also called for. The contractors do not always complete bays between piers consecutively, and the duct has to be placed in position before scaffolding is moved to a new bay. As the standard length of the Post Office 6 in. duct is often longer than the distance between diaphragms, to leave the ducts until last would result in rough handling of the ducts when passing them through the asbestos-cement sleeves from the ends of the bridge, and would probably call for the re-erection of scaffolding.

In some instances, due to changes in the original plan by the contractor, threading of the ducts from the ends has been necessary: to have cut the 6 in. duct into smaller lengths would have resulted in a greater number of joints and consequent difficulties in alignment.

(*iii*) The third method is to lay the duct in an already provided sand-filled pipe bay. On some motorways shallow bays were nearly always constructed on top of the bridge deck, and, therefore, any duct laid in these bays had the disadvantage of leaving both ends of the bridge with practically no cover—in fact, often above the level of the motorway.

For this reason the method was not favoured by the Post Office for the 6 in. duct and was avoided where possible. Where such bays were used, however, because there was no alternative, the bridge builders were asked to taper off the ends of the bridges or to build up the verge, thus enabling the Post Office duct to have cover until, on a 1,320 ft radius curve, the duct passed into the ground.

Checking the Bending Radius of the Duct

The 6 in. steel ducts are of the spigot-and-socket type, and any curves occurring in the route are obtained by putting slight sets in the spigot-and-socket joints. The horizontal and vertical bending radius of a length of duct are checked with a simple theodolite.

POST OFFICE DUCTS IN OTHER LARGE BRIDGES

As with motorway bridges, the number of ducts required to be provided for the Post Office in other large bridges is decided after careful planning and co-ordination between the Post Office Engineering Department and the various Regional Offices concerned. The ducts provided should be sufficient to last a considerable number of years. With the old deep type of bridge it is possible in many instances to lay additional ducts at a future date, but today, with the type of design now in vogue, the ultimate number of ducts required must be placed initially. Many of the ducts are cast in concrete during the bridge construction work, making it impossible to add any more at a future date.

The following table gives some guide to the number and types of duct provided for the Post Office on some of the larger bridges and viaducts.

Post Office Ducts Provided on Bridges and Viaducts

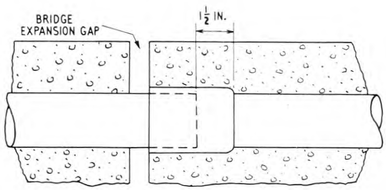
Name of Bridge or Viaduct	Approximate Length of Duct Route	Type of Duct	Number of Ducts
Tay Bridge, Perth	7,485 ft	4 in. steel (Duct No. 70)	8
Mossband Railway Bridge, Glasgow	846 ft	4 in. steel (Duct No. 70)	7
Tamar Bridge	1,850 ft	4 in. (provision deferred)	6
Runcorn–Widnes Bridge	4,082 ft	4 in. steel (Duct No. 70)	9
Winthorpe Bridge, Newark	550 ft	6 in. steel (Duct No. 71)	1
*Medway Bridge Approach Viaducts Central Spans	 2,150 ft 1,125 ft	 4 in. steel (Duct No. 70) 6 in. steel (Duct No. 71)	 6 1
Usk Bridge, Newport	2,000 ft	4 in. steel (Duct No. 70)	12
Wye Bridge, Hereford	1,060 ft	4 in. steel (Duct No. 70)	9
*Queenhill Bridge	612 ft	4 in. steel (Duct No. 70)	2
*Severn Bridge	9,920 ft (Including viaducts and Wye Bridge)	4 in. steel provided by contractor	6
Forth Road Bridge	8,260 ft	4 in. steel provided by contractor	6
*Cresswell Viaduct	Three separate bridges of 656, 1,030 and 848 ft	6 in. steel (Duct No. 71)	1
*Gathurst Viaduct	860 ft	$3\frac{1}{2}$ in. asbestos-cement duct	1

*In connexion with motorways

EXPANSION PROBLEMS ON BRIDGES

For each bridge, expansion and movement are allowed for in the design. The expansion movements are approximately $\frac{1}{2}$ in. per 100 ft of bridge and, when planning to lay Post Office ducts across a bridge, special steps have to be taken to allow for these movements so that damage to the cables will be avoided. Several methods have been used, and a few of them are described below.

(*a*) The most common method employed for taking up small movements (up to $1\frac{1}{2}$ in.) in a duct route is to lay the ducts in such a manner that the spigot of one duct is not pushed fully home into the socket of the next duct, as shown in Fig. 2.



To allow for expansion the spigot of the steel duct is not forced fully home into the socket

FIG. 2—METHOD OF TAKING UP SMALL MOVEMENTS IN DUCT TRACK

(*b*) For larger expansions the ducts are sometimes passed through oversize sleeves and terminated in a jointing chamber, as shown in Fig. 3, thus allowing movement of the duct. Loops of cable are left in the jointing chamber, often on a timber platform. However, for the Forth Road Bridge, the maximum anticipated expansion movement, located near the main towers, has

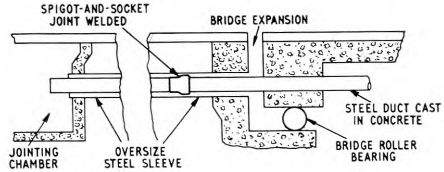


FIG. 3—METHOD OF ALLOWING FOR LARGER EXPANSIONS, USING OVERSIZE SLEEVES AND A JOINTING CHAMBER

been calculated to be approximately ± 3 ft. Fig. 4 shows the method adopted to allow for this movement of the bridge structure, which also necessitates the laying of

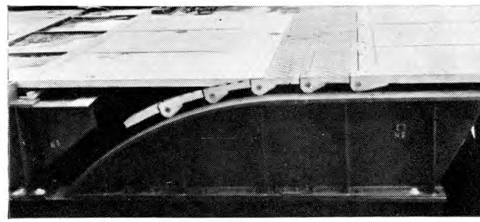


FIG. 4—EXPANSION ARRANGEMENT USED AT MAIN TOWERS OF FORTH ROAD BRIDGE

large loops of Post Office cable around the main towers in specially designed guide boxes.

The Forth Road Bridge deck is constructed in 30 ft sections, and small movements are expected between these deck sections. Fig. 5 shows the method used for

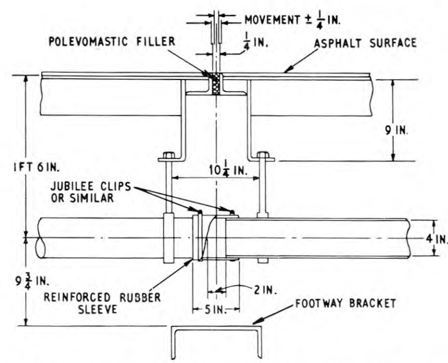


FIG. 5—EXPANSION JOINT FOR DUCTS TO ACCOMMODATE MOVEMENT BETWEEN DECK SECTIONS OF FORTH ROAD BRIDGE

joining the Post Office ducts together. The ducts were fitted to the underside of the deck at ground level before the deck sections were raised into position. The ducts had to be very carefully aligned to preclude damage during subsequent cabling operations; fully adjustable brackets were therefore necessary to ensure duct alignment when the deck sections were levelled.

(*c*) Where the expansion is designed to occur near the centre of a bridge and the ducts are cast-in, expansion chambers are sometimes located on both sides of the bridge expansion gap, as shown in Fig. 6.

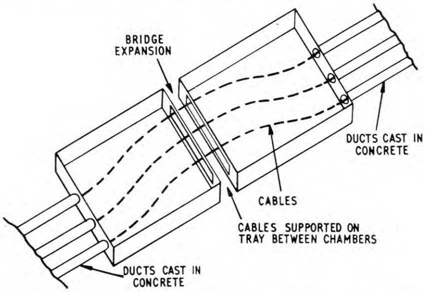


FIG. 6—USE OF EXPANSION CHAMBERS ON BOTH SIDES OF THE BRIDGE EXPANSION GAP

(*d*) Where fibre ducts are used, accommodating the bridge expansion is always difficult. Fig. 7 illustrates one method used to overcome the problem; for this

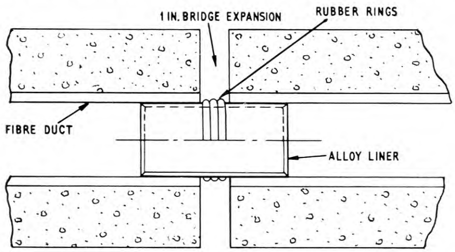


FIG. 7—METHOD OF PROVIDING AN EXPANSION JOINT WHERE FIBRE DUCTS ARE USED

bridge the outside diameter of the Post Office fibre ducts could not be exceeded and the expansion device had to be accommodated within the diameter of the duct.

(*e*) Where the ducts are suspended under a bridge and the expansion occurs near the bridge centre, suspended steel chambers are designed to accommodate the expansion. Fig. 8 shows such a chamber viewed from

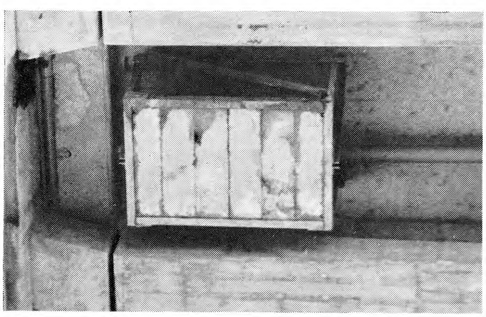


FIG. 8—STEEL EXPANSION CHAMBER SUSPENDED BENEATH BRIDGE STRUCTURE

beneath the bridge structure. As these suspended-type expansion chambers can be subject to pulling stresses during cabling operations, it is necessary that they be sturdily built. In addition, thought must be given to the safety of working personnel, and each of the chambers should be encased with a strong wire meshing. The entrance to a chamber is through the bridge deck and a short steel ladder is provided.

JOINTING CHAMBERS

Where, because of the duct position, difficulties are encountered in endeavouring to terminate the duct under the grass verge of the motorway on leaving the bridge, longer lengths of duct route have to be laid than is normally considered desirable. Lengths of up to 250 yd have been laid without jointing chambers, but these exceptionally long lengths are considered the maximum from a cabling point of view, and where longer lengths are planned jointing chambers have to be installed. Under the hard shoulder of the motorway these are normally standard Post Office jointing chambers (type JRC12 or R4), but because of drainage obstructions non-standard manholes often have to be designed. Where jointing positions are required under bridges, special jointing platforms are provided. Fig. 9 shows a

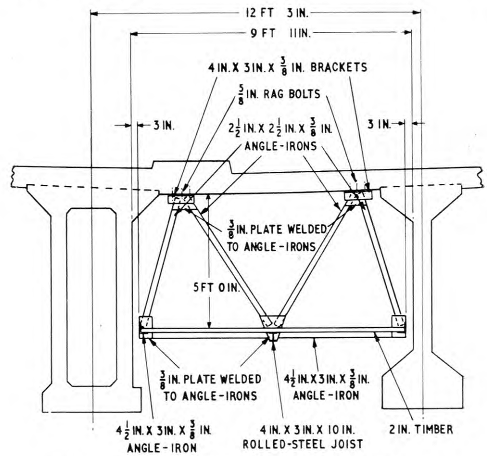


FIG. 9—TYPICAL SUSPENDED JOINTING PLATFORM

typical jointing platform suspended from a bridge; the ends of the platform would be covered with suitable mesh.

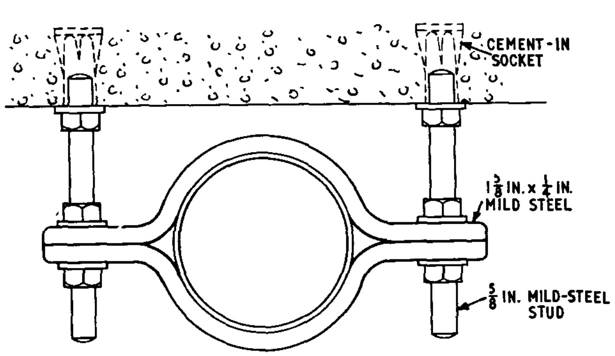
DUCT SUPPORTS AND FITTINGS

Various types of brackets and fittings have been designed to support ducts. It is important that a duct should be supported in such a manner that the bracket cannot become loose, e.g. due to traffic vibration, as there may be extreme difficulty in getting access to the bracket position at a later date.

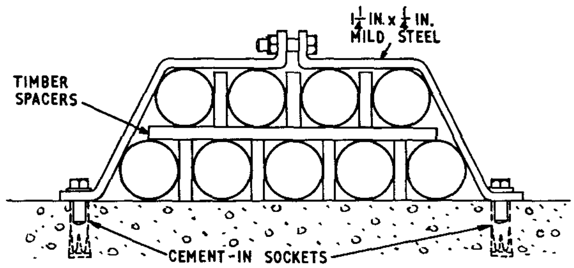
Some of the methods that have been employed to support ducts are shown in Fig. 10.

SERVICE TRENCHES

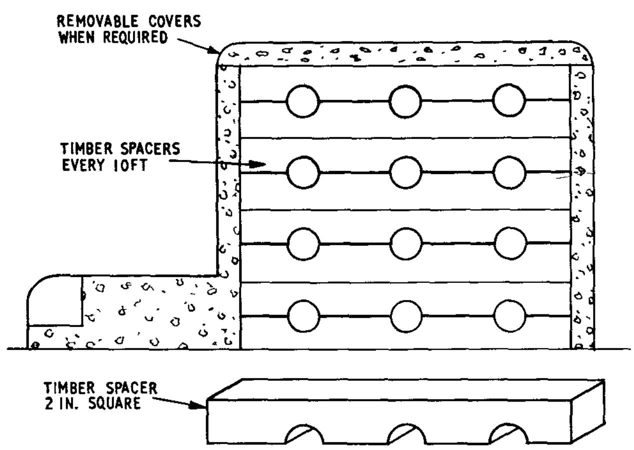
Many bridges are designed to carry public-utilities' plant along the bridge in a concrete trench provided especially for the purpose. If more than one of the four



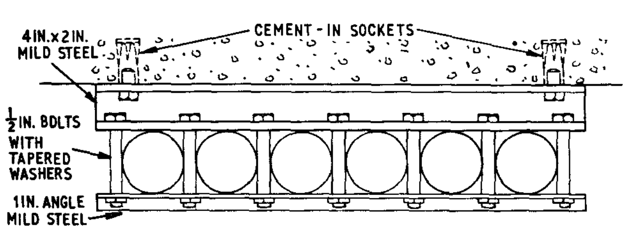
The brackets are normally spaced 10 ft apart
(a) Adjustable Bracket used to Support 6 in. Steel Duct Suspended from Bridge



(b) Support for Nine Steel Ducts Laid in Sand-Filled Pipe Bay



(c) Formation of 12 Steel Ducts Laid on Top of Bridge Deck



The brackets are normally spaced 10 ft apart
(d) Bracket for Suspending Six 4 in. Steel Pipes Under Bridge

FIG. 10—METHODS OF SUPPORTING DUCTS ON BRIDGES

main services, gas, water, electricity and telecommunications, are provided, clearance space between one service and another, and space for various types of associated plant, is required. The need for access to the respective plants and for movement within the trench make it necessary for the Post Office to lay a strong type of duct in the service trench; this is generally a 4 in. bore steel duct.

The provision of a service trench can, however, involve the Post Office in additional expenditure since, if the duct requirement is small, it might otherwise be preferable to cast the ducts within the concrete of the bridge.

Service trenches designed for the centre reservation of the bridge are not favoured by the Post Office because of the restricted accommodation usually available and the safety problems involved when installing and maintaining plant. Service trenches also introduce difficulties where the ducts are led off at the ends of a bridge.

Sometimes a specially designed chase or chute at the bridge abutments is used to carry cables to a road below the bridge. This arrangement, however, requires special consideration to be given to the method of supporting the weight of the cables as they pass down the chute when the cables are laid at a later date.

The weight of cables has been a problem in the past when cables passed from some height down to ground level, but the matter has been made easier by the introduction of polythene-sheathed cables, which are now used on all bridges; these cables, which replace the older types of lead-covered cables, give greater flexibility and are much more suitable for bridge work.

TAPING STEEL DUCTS UNDER BRIDGES

Where steel ducts are suspended under a bridge which crosses another road, e.g. a motorway bridge crossing a trunk road, it would be unsightly to see, some time later, the hessian covering of the duct working loose and hanging down. To clean off the compound-and-hessian wrapping initially, in order to paint the duct prior to its suspension under the bridge, would be very expensive. A very effective method of dealing with this problem is to cover each length of duct with a wrapping of 3 in. wide grey p.v.c. adhesive tape. The wrapping is done by hand prior to the raising of the ducts into their position under the bridge.

CONCLUSION

Because the provision of Post Office plant on bridges can be extremely costly, very careful planning and close consultation with the bridge engineers is essential when such an installation is necessary. For each major bridge detailed study is needed, and individual design of the duct supports and fittings may be required, especially where relatively large expansion movements have to be accommodated.

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:

Birmingham Telephone Area	E. Snape	Leading Technical Officer	British Empire Medal
Engineering Department	W. J. E. Tobin	Staff Engineer	Officer of the Most Excellent Order of the British Empire
Factories Department	A. E. Kittle	Assistant Factory Manager	Member of the Most Excellent Order of the British Empire
Home Counties Region	E. N. Clark	Executive Engineer	Member of the Most Excellent Order of the British Empire
Liverpool Telephone Area	H. G. Crook	Area Engineer	Member of the Most Excellent Order of the British Empire
South West Telephone Area, London Telecommunications Region	R. C. Weller	Technical Officer	British Empire Medal

J. H. H. Merriman, O.B.E., M.Sc., A.Inst.P., M.I.E.E.

The appointment of Mr. J. H. H. Merriman as Deputy Engineer-in-Chief will be welcomed by his very many friends and colleagues, not only in the Post Office and other Government Departments but also within the fields of industry and international telecommunications.

Mr. Merriman graduated at King's College, London, and followed this by post-graduate work first under Appleton and later under Blackett before entering the Post Office on 1 July 1936 as an Assistant Engineer (old style). Appointed to the Research Station, Dollis

Hill, he became a member of the team engaged in the design of the steerable aerial (M.U.S.A.) to be built at Cooling Radio Station for the improved reception of transatlantic h.f. communications. In 1939 he was placed in charge of radio laboratories at Castleton, near Cardiff. In the following 10 years he and his team designed and developed a number of radio equipments, including, in 1942, the first commercially used multi-channel v.h.f. equipment employing frequency modulation. This equipment, built in an emergency to combat severe power-line interference at a v.h.f. site, became the highly successful forerunner of many similar equipments later installed on radio-telephone links to the Scottish Isles and to other remote parts of the country. Following the war he turned his attention to the design of wide-band radio-relay equipment which was subsequently used to carry the first television signals to Wales.

Two years after his promotion, in 1949, to Executive Engineer (old style) he was moved back to London to undertake the planning and provision of inland radio links—a task for which his earlier design experience well fitted him. In 1953, he was promoted within the Radio Branch to Assistant Staff Engineer and was responsible for the early development of the national network of microwave radio-relay links as well as the expansion of overseas h.f. radio services.

Mr. Merriman was selected in 1954 for a year of training at the Imperial Defence College, and in the following year returned to this Department to take charge of the Organization and Methods Section of the Engineering Organization and Efficiency Branch. This was followed in 1956 by his appointment as Assistant Secretary to assist H.M. Treasury in the formulation of policies and programs for the utilization of computers in Government Departments. His work there included a major and influential report on the place of automatic data processing in Government Service. The value of his contribution in this field was recognized by the award of the O.B.E. in 1960.

In August 1960 Mr. Merriman returned to the Post Office as a Staff Engineer, first in the Overseas Radio Planning and Provision Branch and then in the Inland Radio Planning and Provision Branch. By this time the development of microwave radio-relay links to carry both multi-channel telephony and television was advancing rapidly, and he was able to play a full part both in the expansion of the national network and in the establishment of international standards for such links. His ability and reputation in this field led to his appointment as International Vice-Chairman of the C.C.I.R. Study Group IX, which is concerned with microwave radio-relay systems.

On 1 April 1963 Mr. Merriman was appointed Assistant Engineer-in-Chief of the Post Office, in charge of radio and allied matters. In addition to the direction and control of the more conventional radio work of the Department, this brought him into the rapidly developing field of space communications. Much of his time and effort during the past two years has been spent in the formulation of technical policy and in directing the Department's efforts both at the Goonhilly Downs earth station and in the space sector aspects of satellite communications. In this period he has attended numerous international meetings in Europe and in North America, and he shared in the negotiations leading to the United Kingdom's decision to join the international Interim Communications Satellite Committee when it was established in Washington in August 1964.

All who have worked with Mr. Merriman recognize those qualities of leadership which have prepared him for this appointment. To his new responsibilities he brings a breadth of interest and a characteristic alertness of mind which have never failed to stimulate his colleagues in the past. In offering their sincere congratulations, they would assure him of their continuing good wishes as he enters the wider spheres of activity ahead.

J.K.S.J.

J. R. Tillman, D.Sc., A.R.C.S., A.M.I.E.E.

Dr. J. R. Tillman has been appointed a Deputy Director in the Research Branch, where he is taking control of the work on materials and devices—roughly, but not exactly, that carried out by Scientific rather than Engineering staff.

He is a physicist by training, having taken his first degree (B.Sc. with 1st Class Honours) at Imperial College, London, and followed it with four years of research on electron diffraction and on slow neutrons,

which earned him his Ph.D. In 1936 he entered the Post Office in the grade now known as Executive Engineer, and successfully turned his hand to the engineering of audio and carrier systems. During the early years of the war he tackled a wide variety of the odd problems in optics and in electromagnetism that found their way into the Post Office Research Station; later he was seconded to R.R.E., Malvern (then known as T.R.E.) for two years.

Soon after his return to the Post Office, the Scientific grades were introduced, and he became a Principal Scientific Officer. He organized work on electronics, taking an interest both in devices and in the circuits in which they were used, and in 1952 he was again promoted, still working in the same field. This was the period in which the transistor appeared as a possibly usable device, and Dr. Tillman watched carefully over its first cautious introductions into Post Office apparatus. In 1955 the University of London recognized the high standard of his numerous published papers by the award of a D.Sc. degree.

As transistors became established, he extended his range to other and more speculative work on semiconductors, and will no doubt retain these interests in spite of the administrative responsibilities which he now takes on.

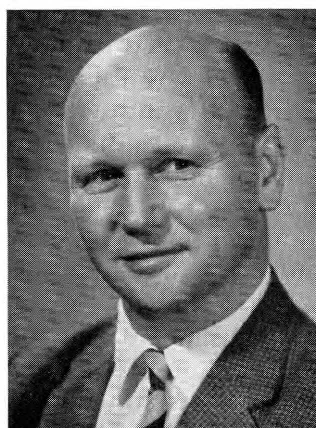
He has maintained his contacts with the academic world, and in the past few years has led the team which has had some success in recruiting Scientific Officers and Executive Engineers from the universities.

Vigorous physically as well as intellectually, he is a golfer and mountain walker when opportunity arises. His colleagues know that he will bring to his new task both enterprise and an insistence on scientific soundness, and will wish him also the element of good fortune without which success in research is elusive.

A.C.L.

E. W. Ayers, B.Sc.(Eng.), A.M.I.E.E.

Eric Ayers, recently appointed Senior Principal Scientific Officer in Research Branch, joined the Engineering Department in 1936 as an Inspector and, after initial training, was posted to the Subscribers Apparatus and Miscellaneous Services (S) Branch, where he was concerned with special subscribers' equipment. After taking first place in the 1939 Open Competition for Assistant Engineers (old style), he went to the Radio Branch laboratories at Dollis Hill to help



in the design of terminal equipment for the early coaxial systems and multi-channel v.h.f. radio links.

Promoted in 1948, he set up a group in Research

Branch responsible, in collaboration with the Medical Research Council, for the design of the National Health Service hearing aid. Three years later he was appointed to a new Principal Scientific Officer post to study the fundamentals of speech and hearing from a telephony standpoint. Analysis-synthesis telephony systems designed to save transmission bandwidth were his main interest for the next seven years, and his experimental equipment, reciting "Mary had a little lamb" in a robot voice, was a popular item at exhibitions. He maintained his interest in hearing defects, assisting in clinical studies for the Medical Research Council and serving on their Electro-Acoustics Committee. During this period he became a recognized authority on speech and hearing; he contributed to several international conferences and published a number of scientific and popular articles. He served on the Committee of the Physical Acoustics Group.

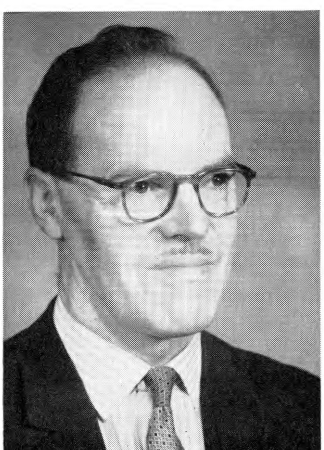
After a period on defence work he started, in 1962, to study lasers and their applications, which work he has had to leave on his new appointment. He helped to organize the 1964 Institution of Electrical Engineers Conference on Lasers.

Thus, Mr. Ayers brings a wide range of experience to his new duties in the Telephone Switching and Signalling Division of the Research Branch, where he is concerned with advanced developments in subscribers' equipment, recalling his S Branch experience at the start of his Post Office career, and with electronic switching, recalling the private automatic exchange—alas electromechanical—that he built as a schoolboy. He also brings a lively mind and a fund of energy, which he replenishes from time to time by trips, in search of sun and photogenic surroundings, to such places as Greece and Morocco. We wish him well.

H.B.L.

R. W. White, O.B.E., B.Sc., F.Inst.P., M.I.E.E.

The well-deserved promotion of Mr. R. W. White to Staff Engineer, Radio Transmission and Long-Life Transistors Division of Research Branch, is welcomed by his many friends, both inside and outside the Post Office. To his new job he brings a wealth of experience in the radio field, and a critical and perceptive mind that quickly gets to the root of technical problems.



He graduated with Honours in Natural Philosophy at Glasgow University and, after two years in the Research Laboratories of the General Electric Company, Wembley, entered the Post Office Engineering Department by Open Competition in 1939. After a brief period at the Research Station, Dollis Hill, he moved to the Post Office Radio Laboratory at Castleton, South Wales, in 1940, and became Engineer-in-Charge at Castleton in 1948. He was promoted to Assistant Staff Engineer in 1957, with responsibility for both the Castleton and Backwell Radio Laboratories.

His work in the radio field has covered a wide range, from v.h.f. single-channel radio links, to microwave radio-relay systems for multi-channel telephony and television and long-distance trunk waveguide systems; in recent years, he has been concerned with research and development for satellite communication systems. He and his team were responsible for much of the transmitting and receiving equipment used at Goonhilly for the TELSTAR and RELAY communication satellite experiments. He was also the "Controller of Experiments" at Goonhilly during the opening phase of the experiments with the TELSTAR and RELAY satellites.

In the historic first transmission of live television from Goonhilly to the United States on 11 July 1962, the then Deputy Engineer-in-Chief, Capt. C. F. Booth, with a twinkle in his eye introduced Robert White to the viewing millions as "that dour Scot." His friends and colleagues know that in fact Robert White is far from dour, as witnessed for example by those lively and hilarious annual dinners held by the Castleton staff when both junior and senior members of the staff were subject to much good-natured but often critical "leg-pulling." It is, in fact, this combination of a very human approach to staff matters and excellent technical ability that has made Robert White a very successful team leader. His colleagues were more than pleased that his qualities were recognized, in 1964, by the award of an O.B.E.

His other interests include colour photography, motor cars and—surprisingly—brick-laying! He has, in fact, a City & Guilds Certificate for Brick-Work, and has designed and supervised the building of his own house.

He has now returned to the Research Branch at Dollis Hill, where, without doubt, he will continue to inspire and persuade his staff towards even greater efforts and achievements. His friends and colleagues wish him well and continued success in the future.

W.J.B.

Mr. D. A. Barron, C.B.E., M.Sc., M.I.E.E., Chairman of the Board of Editors

The members of the Board of Editors have noted with pleasure that their Chairman, Mr. D. A. Barron, has been appointed Engineer-in-Chief of the Post Office Engineering Department. Details of Mr. Barron's Post Office career are given on page 51 of this Journal.

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. 57, Part 1, Apr. 1964	28,900
Vol. 57, Part 2, July 1964	29,100
Vol. 57, Part 3, Oct. 1964	29,100
Vol. 57, Part 4, Jan. 1964	29,300

Approximately 10 per cent of the Journals are sold to overseas readers in more than 50 countries.

Board of Editors

At the invitation of the Board of Editors, Mr. E. W. Ayers has joined the Board, replacing Mr. T. H. Flowers who recently left the Post Office Engineering Department to take up an appointment in the telecommunications industry.

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 of 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 of the Supplement to the Journal.

Institution of Post Office Electrical Engineers

Library Catalogue—1965 Supplement

A Supplement listing books added to the Library since the publication of the 1962 Library Catalogue has been printed. Copies may be obtained from Honorary Local Secretaries or from the Librarian, I.P.O.E.E., G.P.O., 2–12 Gresham Street, London, E.C.2.

Additions to the Library

Library requisition forms are available from Honorary Local Secretaries, from Associate Section Centre Secretaries and representatives, and from the Librarian, I.P.O.E.E. G.P.O., 2–12 Gresham Street, London, E.C.2.

2770 *Insulation Handbook.* (Brit. 1963).
A reference book: includes sources of materials and firms operating in the field of thermal, acoustic and vibration insulation.

2771 *An Introduction to Automatic Computers.* N. Chaplin (Amer. 1963).
Explains the way these machines are used and the way they function.

2772 *Diodes and Transistors.* G. Fontaine (French. 1963).
Aims at illustrating the fundamentals, either by physical explanations or by the frequent use of graphs, to the extent required for the application of semiconductors in the most favourable conditions.

2773 *Loudspeakers.* E. J. Jordan (Brit. 1963).
Directed to all interested in loudspeakers: the enthusiast, the student, and engineers.

2774 *Tape Recording and Reproduction.* A. A. McWilliams (Brit. 1964).
Provides the hi-fi enthusiast with the requisite technical and practical information to enable him to use his equipment to the best advantage.

2775 *Technology: Man Remakes His World.* J. Bronowski (Editor) (Brit. 1963).
A comprehensive survey.

2776 *Probability and Statistics for Everyman.* I. Adler (Brit. 1963).
Requires no special mathematics knowledge beyond high-school algebra.

2777 *Elements of Mathematical Statistics.* J. F. Ratcliffe (Brit. 1962).
A systematic treatment of the fundamentals of mathematical statistics for technical and university students, and for practising engineers and scientists.

2778 *Electrical and Electronic Engineering Fundamentals* A. E. Fitzgerald and D. E. Higginbotham (Amer. 1964).
Intended primarily as a text for electrical technology courses in technical institutes and colleges.

2779 *Disc Recording and Reproduction.* P. J. Guy (Brit. 1964).
Written to enable the reader to get the best possible reproduction from both monaural and stereophonic records, but also describes how recordings are made and records processed.

2780 *Management and Mathematics.* A. Fletcher and G. Clarke (Brit. 1964).
Describes the mathematical techniques available to assist management in decision-taking.

2781 *Discovering the Universe.* B. and J. Lovell (Brit. 1963).
Explains in simple language why the telescope was built and what it is doing.

2782 *Thermodynamics and Heat Engines.* W. D. Brown (Brit. 1964).
Presents the subject as completely and in as rigorous a manner as possible. and at the same time encourages the student, by a simple style of writing, to read and digest every page thoroughly. The level is O.N.C.

2783 *Radio Reception.* H. Henderson (Brit. 1963).
Concerned with the high-fidelity reception of radio signals and their final conversion into audio frequency electrical signals.

2784 *Telecommunication Satellites.* K. W. Gatland (Editor) (Brit. 1964).
A series of articles by specialists who explain, in great detail, the projects on which they are engaged and the lines of development which they consider will be important in the future.

2785 *Transistor Amplifiers for Audio Frequencies.* T. Roddam (Brit. 1964).
A practical book on the design of a.f. amplifiers; primarily intended for those new to the subject.

2786 *Stereophony.* N. V. Franssen (Dutch. 1964).
Aims at promoting an understanding of the mechanism of auditory perspective, which is inseparable from stereophony and acoustics.

2787 *The Two Cultures: and A Second Look.* C. P. Snow (Brit. 1964).
A reprint of Sir Charles' earlier lecture on the gulf that exists between the scientist and the non-scientist and how fatal the lack of communication between these two groups could have become, followed by his further thoughts on the subject.

2788 *Examples in Engineering Science for General Course Students—2nd Year G.2.* D. R. L. Smith (Brit. 1964).
A useful addition to lecture notes for students entering the second year of the General Engineering (G) Course, and also for those who cover the G Course in one year.

2789 *Car Body Refinishing.* J. H. Ousbey (Brit. 1963).
A guide to the methods and materials used in motor-car finishing.

2790 *Transistor Circuit Design.* Edited by J. A. Walston and J. R. Miller (Amer. 1963).
Compiled for the practising circuit design engineer by Texas Instruments Inc. A very comprehensive textbook.

2791 *Rounding Errors in Algebraic Processes.* J. H. Wilkinson (Brit. 1963).
A study of the cumulative effect of rounding errors in the arithmetic operations of digital computers. Requires no previous knowledge of the subject.

2792 *Automotive Electrical Equipment.* W. H. Crouse (Amer. 1963).
Includes information on the construction, operation and maintenance of a.c. generators and alternators, transistorized regulators, new configurations of cranking motors, piezoelectric and magneto-pulse ignition systems, and transistorized coils as well as the traditional methods.

2793 *Information Transmission.* E. Edwards (Brit. 1964).
An introductory guide to the application of the theory of information to the human sciences.

2794 *The Tape Recorder.* C. G. Nijsen (Dutch 1963).
A complete handbook on magnetic recording.

2795 *Audio Quality.* G. Slot (Dutch 1964).
Discusses the subject in simple terms and leads to the requirements of a hi-fi system.

2796 *Your Guide to Plastics.* J. G. Cook (Brit. 1964).
Written for the layman.

2797 *Matrix Algebra for Electrical Engineers.* R. Braae (Brit. 1963).
Enables the electrical engineer to work in easy stages from first principles to a standard where they will be able to read and understand articles employing matrix techniques.

2798 *Analogue & Digital Computer Methods.* D. J. Harris (Brit. 1964).
Sets down the characteristics of three types of computer to enable the reader to compare their characteristics and techniques.

2799 *Experimental Radio Engineering.* E. T. A. Rapson (Brit. 1964).
Sets out a number of experiments and methods of measurement suitable for a three-year or four-year course in radio engineering.

2800 *Colour Television Explained.* W. A. Holm (Dutch 1963).
Describes in detail the theoretical bases of colour television, and attempts to make the problems arising out of its practical realization more familiar and intelligible to a larger public.

2801 *Functions, Limits and Continuity.* P. Ribenboim (Amer. 1964).
Provides a well-grounded basis for the study of mathematical analysis.

2802 *Engineering Reliability & Long Life.* R. P. Haviland (Amer. 1964).
Provides the concepts and techniques essential to the attainment of engineering solutions and reliability problems.

2803 *Colour Television Fundamentals.* M. S. Kiver (Amer. 1955).
Gives a full working knowledge of colour television; should present no difficulty to anyone familiar with radio and black-and-white television.

W. D. FLORENCE,
Librarian.

Book Reviews

"Boolean Algebra and its Applications." H. G. Flegg, M.A., D.C.Ae., A.F.R.Ae.S., F.R.Met.S. Blackie and Son, Ltd. xv + 261 pp. 162 ill. 50s.

This book starts with three mathematical chapters which cover binary numbers and Boolean algebra. The remainder of the book describes the applications of these subjects to the design of switching circuits. The better known methods of simplifying switching functions are described, and the last two chapters are devoted to various kinds of Boolean matrices. Other books are available which cover all this material except Boolean matrices, and many of them are better. However, the interest of the last two chapters in part outweighs the disadvantages of the rest of the book. The presentation of the algebra amounts to little more than a list of theorems with only superficial explanations, and at times the notation is confusing. The chapters on the propositional calculus and symmetrical functions are particularly bad in this respect. At this level it is quite unnecessary to introduce a separate sign for each of the 10 non-trivial Boolean functions of two variables. Also, by trying to write in an easy and informal manner the author has occasionally been less precise and less clear than his subject matter requires. The author is to be congratulated on the excellent bibliography and on the examples with answers.

D.J.B.

"Digital Magnetic Recording." A. S. Hoagland, Ph.D. John Wiley and Sons. x + 154 pp. 66 ill. 60s.

Literature on magnetic recording has usually concentrated on analogue applications capable of analysis by steady-state methods. This book, however, treats digital recording as a subject in its own right. The theory of recording step functions is developed from general magnetic theory using a series of mathematical models. Emphasis throughout is on the basic principles involved rather than the technology.

The first two chapters explain the uses of magnetic tape, and so-called random-access devices, disks and drums, for mass storage of digital data. Then follow chapters on magnetic principles and their application to digital recording. This leads naturally to consideration of magnetic heads and storage media, followed by a description of recording techniques. Included here is an interesting section on obtaining improved resolution by electrical equalization. The advantages of phase modulation for high-density recording are clearly stated.

The book is intended for professional engineers and designers interested in the basic problems of data storage. The material is presented logically, and adequate references are included. The author has intentionally omitted details of particular systems, but the work would have been more helpful to newcomers to this field if more practical considerations had been included.

E.L.

Regional Notes

North Eastern Region

LEEDS INNER RING-ROAD

The Leeds Corporation has a comprehensive scheme for the construction of urban motorways and motorway feeders. As part of this scheme, stage I construction of the Leeds inner ring-road started in 1964, and when completed will serve to relieve the considerable traffic congestion in the city centre area.

The attendant diversions of statutory undertaker's services will cost in the region of £360,000 of which the Post Office share will be about £85,000 spread over two years.

Perhaps the most complex of all the diversions was at Clarendon Road and involved Post Office underground plant. Diversions using single permanent changes had been designed with the co-operation of the City Engineer's Department, but these were subsequently seen to be unworkable in the light of the schedule of works adopted by the road-works contractor; temporary diversions were made necessary and the completion of the original permanent changes was programmed for a later date. The temporary work considerably increased the cost of the scheme but its timing has enabled the work to be carried out in two successive financial years, thereby avoiding straining labour resources to the limit, with the consequent exclusion of more profitable work.

In view of the six to seven months required for obtaining large-size cables it was thought that there would be difficulty in completing the temporary work by the programmed dates. However, suitable cables, which had already been obtained for the permanent scheme, were available for use on the temporary scheme.

The local-cable diversions were the most complex, but main trunk and junction cable diversions required most labour. Considerable use was made of temporary footbridges for diverting services over the carriageway. These were constructed of I-section steel beams, having an 85 ft span and supported on columns built up from spun concrete pipes filled with reinforced concrete. The bridge decks were constructed with railway sleepers supporting a wooden walkway under which rectangular-section cable ducts were formed. The cables were supported by box ramps where they were led up to the bridge deck from ground level. The photograph shows the general construction of the bridge at Clarendon Road.

The re-routing of trunk and junction cables over the Clarendon Road footbridge involved the construction of two temporary manholes almost in the position of those to be built for the permanent scheme. These manholes, which have timber walls and roof, were built by the road contractor to an approved specification. This was a cheap and speedy expedient and perfectly safe since no traffic was to pass over the top of the manholes. The larger of the two was used to accommodate loading coils, and its construction involved the breaking away of a 28-way octagonal duct: this was carried out without damage to any of the 18 cables in the duct.

With a project of this nature, a large fleet of earth-moving equipment was always on the site and any attempts to mark above ground the position of Post Office underground plant proved futile. Continuous supervision of the road works was essential, therefore, until all the temporary diversions had been completed.

The temporary diversions were completed in advance of the programmed dates and did not in any way hold up the progress of the road works.

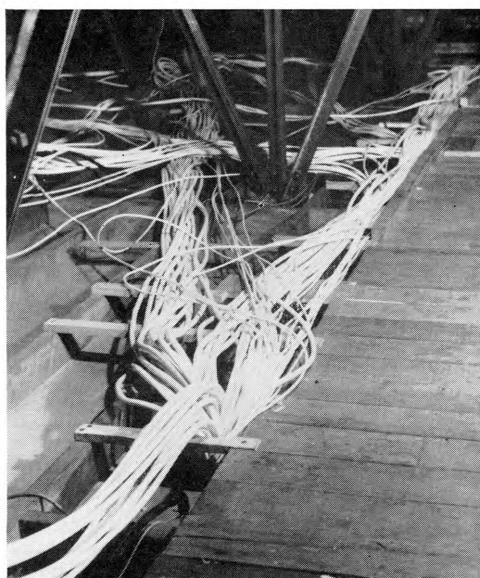
A.A.G.

GENERAL CONSTRUCTION OF THE BRIDGE AT CLARENDON ROAD

OVER-CEILING CABLING AT A U.A.X. 14 IN THE PETERBOROUGH AREA

St. Ives, Huntingdonshire, a desirable residential town a few miles from Cambridge and easily accessible from London, has a rapidly expanding population of the class which incorporates a high percentage of telephone users. During 1963 it became evident that the U.A.X. serving it must be extended quickly if a long waiting list was to be avoided. The exchange already had 1,200 lines and a 400-line multiple addition was needed.

Apparatus for the extension became available in early 1964 from another exchange within the Midland Region, and, as completion was required urgently and a staff shortage existed, the local planning group investigated methods of speeding up the work. Over-ceiling cabling was one of the methods considered in order to save labour.



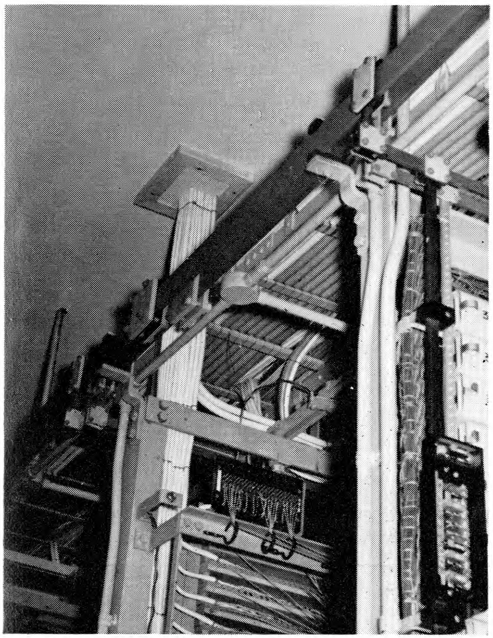
OVER-CEILING CABLING AT ST. IVES EXCHANGE

The exchange roof was close boarded, dry and ideal for housing the cables, and the catwalk did not need modifying. Only some kind of light support for the cables between joists was necessary.

It was an easy matter to cut holes in the ceiling above the apparatus racks for the p.v.c. cables to enter the roof space. The cables were run by three men, each cable being placed in position along the joists in the loft to follow the shortest route between the terminal points. No tying or tidying was attempted. Wooden support slats were placed between the joists where necessary. The cables were laced below ceiling level to make the vertical cable-runs neat. The operation did not interfere with the existing conventional racks and cables.

On completion the ceiling holes were sealed by asbestos sealing glands obtained from a telephone equipment manufacturer. The plates were cut to fit the cables and surrounded by a wooden fillet. The appearance of the final result can be seen in the photographs.

The estimated saving in materials was: 50 yd of 125-wire cable, 300 yd of 41-wire cable, and 26 yd of cable racking; a total value of about £60.



COMPARISON OF CABLING BY OVER-CEILING AND TRADITIONAL METHODS

The saving in labour was approximately 350 manhours making a total saving on the work of nearly £200.

The experiment shows that conventional racking and cabling can be mixed with over-ceiling cabling, and overall assessments of the use of these techniques, both at St. Ives and at other exchanges where trials have been conducted, are being completed by the Exchange Accommodation and Equipment Branch, Engineering Department.

V.P.L.

THE P.A.B.X. No. 4 AT HARWELL

At the southern tip of the Oxford Telephone Area lies the Atomic Energy Research Establishment (A.E.R.E.), Harwell, the largest establishment of the A.E.R.E. group, which is responsible for research into non-military uses of atomic energy.

For a short period after taking over this old Royal Air Force airfield site, service was provided by the existing 10 + 50 switchboards, but in 1948, to meet rapid expansion, a complete P.A.B.X. installation recovered from a Royal Ordnance Factory was installed. This comprised a three-position manual board with full extension multiple and a 600-line non-standard pre-2,000 type automatic exchange. The installation was eventually extended to seven positions with 1,740 lines.

For some years it had been evident that the restricted facilities of this old equipment and the urgent need of a multiple extension necessitated a complete review of requirements to meet the present and the future and to take full advantage of modern techniques. Due to the congested state of the multiple, actual telephone growth had for some time to be met mainly by additional plan-number stations. The old automatic equipment merely provided for extension–extension calls, all outside calls having to be made via the manual board. In order to relieve the operators as much as possible and to conform to modern practice a new system was planned to give as wide an out-going service as possible from all extensions, both to other A.E.R.E. establishments and via the public network.

In order to reduce the total length of line plant involved (and hence reduce rental) two satellite exchanges were planned in addition to the 1,300-line main exchange which was to be situated close by the old exchange in the administrative office block. The satellites, of 900 line and 300 line, were to be situated at the western end of the main site and at the more remote reactor area, respectively.

This P.A.B.X. No. 4 installation was designed and installed by Standard Telephones and Cables, Ltd., to meet detailed requirements laid down by the A.E.R.E. Installation commenced in February 1964 and transfer from the old equipment took place at 8.30 a.m. on 30 November, 1964. An inaugural call was made at noon that day by Harwell's Director, Dr. R. Spence, to Mr. R. B. Gray, managing director of S.T. & C., Ltd. The new manual board comprises four cordless console-type operating positions primarily required to answer incoming calls to the establishment and to provide assistance for the extensions. A supervisor's control console and an inquiry console are also features of the switchroom.

Exchange-line groups are provided to Abingdon, Oxford, Didcot and London—some 60 lines in all with subscriber trunk dialling (S.T.D.) access from unbarred extensions via the Oxford group. There is also code-dialled access to 10 others of the authority establishments via some 50 inter-switchboard lines; five of these routes, being to other P.A.B.X.s, provide for direct extension–extension calls.

Over 3,000 existing 300-type telephones had to be changed to 700-type to provide for standard operator recall and transfer facilities, neither being previously available. The whole of this operation, together with extensive rewiring and external development work, was carried out by Post Office staff, the majority of whom were staff loaned from Northern Ireland, a peak of 50 men being reached at one time. Some 800 telephones in "active" areas were changed by A.E.R.E.'s own electrical staff.

The entire P.A.B.X. installation comprises some 70 selector racks accommodating 500 linefinders, 965 group selectors and 465 final selectors. There are also some 300 relay-sets on 25 racks. The design of the P.A.B.X. No. 4 provides the standard separate path for incoming calls from exchange lines through to final selectors, at present only accessible with operator assistance, but ultimately available for "direct dialling in" calls. Unlike most other P.A.B.X. No. 4 operators' consoles designed by S.T. & C., Ltd., the operator answers incoming calls by means of selective-answering keys instead of the more usual common answer bar. These eight keys are situated to the left-hand side of the keyshelf, the calling lamp glowing through the key top appropriate to the route associated with the calling line. Some measure of priority may be provided by these keys on the various types of calls—exchange lines, private circuits, assistance, inquiry and recall. Each position is provided with a route indicator to show which routes are busy and to identify the route to which the operator is connected. Calls attempted by extensions to busy private-circuit routes automatically call on the private-circuit call lamp on the manual-position selective-answer keys.

The supervisor's position provides full monitoring facilities on all exchange lines and private circuits by rotary-switch access, and she may, if necessary, interrupt. Any extension call may be monitored by dialling from the supervisor's control turret; the howler may be connected from this turret if monitoring reveals that the receiver is off. The supervisor's position also provides a complete "State of Exchange Line" indicator and exchange-line busying facility under the control of the supervisor in order to keep certain lines open for incoming service when necessary.

Discriminatory ringing is provided to enable any extension to distinguish between an outside call, using standard ringing periods, and an inside call, using equal on-off periods. Another interesting feature is the conference facility whereby selected extensions are advised to dial the conference number and a number of extensions may be so connected together. The operator may then enter the circuit and will be advised to operate the conference busy key to prevent any further intrusion.

Power Plants No. 210 are provided at the main exchange and the larger satellite, with batteries of 400 + 400 Ah and 250 + 250 Ah, respectively. The smaller satellite is provided with a Rectifier 61 (Special) floating one 250 Ah battery.

This is by far the largest and most complex P.A.B.X. installation in the Oxford Area and the largest P.A.B.X. No. 4 so far installed by S.T. & C., Ltd., in this country. After minor teething troubles all has now settled down well and the installation is providing the much-improved service expected for the 2,500 extension lines, together with greatly-improved operating efficiency.

E.T.

Associate Section Notes

Sheffield Centre

The 1964–65 program continued with a day visit to Ericsson Telephones, Ltd., Nottingham, on Wednesday, 21 October. Members were shown all phases of assembly of many items of telephone equipment. There were magneto telephones in polished mahogany boxes still being made for Australia, and nearby the latest British Post Office 700-type telephones with printed circuits and brightly coloured cases. Members saw equipment being manufactured for many parts of the world.

On Thursday, 19 November, the Centre held a film show. The films were from the Mullard film library and illustrated transistors, radio telephony and other aspects of modern communications.

In December the Centre was addressed by Mr. J. T. Smith, Assistant Area Mechanization Officer, East Midlands Division, National Coal Board. The lecture was illustrated with slides and a film of a remotely-operated coal-cutting machine. Mr. Smith showed how coal-cutting methods had advanced through the years, from pick and basket to complete mechanical and electronic machines that only need to be started and stopped. A lively discussion followed and we are now hopeful that a visit to a coal mine can be arranged in the near future.

The annual Christmas social was held on Saturday, 16 January.

B.A.S.

Bath Centre

The following visits and lectures have taken place during the last few months of 1964.

In August there was a visit to the Bath and Portland stone mines at Corsham.

The first lecture of the Winter Session was given by Mr. B. J. Woollett and Mr. B. Body, who, in a combined lecture entitled "Swedish Exchange Visit," gave an account of their experiences during an exchange visit to Sweden. They gave a first-hand account of the way in which Sweden runs its telephone service. Mr. Body also showed an 8 mm colour film of some of the highlights of his visit.

The visit in September was to Southampton. During the morning the party went on a conducted coach tour of Southampton Docks. After lunch a visit was made to the Pirelli cable works, where members were shown the many processes involved in the manufacture of cable.

A talk in October given by Mr. J. A. Cawsey, Regional Engineer, S.W. Region, on "Some Aspects of Regional Organization" was extremely interesting. It gave an insight into the problems of management, and the cost of providing and maintaining a telephone service within the Region and its attendant problems. It did much to widen the horizons of those present and communicate a greater knowledge of the work of the Regional staff. In November the Centre held its first dinner-dance for members, their wives and friends. It proved very successful and we hope it will become an annual event. Also during this month there was a well patronized visit to the Austin motor-car factory at Longbridge. Prior to Christmas a party of members from Bath and Bristol Centres visited No. 12 Group Headquarters of the Royal Observer Corps. There, they were given a talk and shown a film by the Deputy Commandant, Mr. Stewart, on the function of the R.O.C. It was interesting to see how the communication network provided by the Post Office was used.

R.R.D.

Inverness Centre

The Inverness Centre continued its 1964–65 program with a film show on 21 October. The films shown were "Powered Flight," "Rig No. 20," "Mirror in the Sky," and "To Dream of Yachts."

On 25 November, Mr. J. J. Loughlin, Area Engineer, gave a talk on "The Radio Control of Models." His talk was illustrated by slides, and demonstration models with all the associated ancillary equipment were on view. These models aroused a great deal of interest and Mr. Loughlin was kept busy answering queries after his talk had ended.

Mr. Loughlin was then followed by Mr. J. W. Innes, whose talk was entitled "Some Aspects of Television and the Post Office." This illustrated the large part played by the Post Office in bringing television to the viewer. This meeting was greatly appreciated by a record turn-out of 42 members and guests.

W.C.

Glasgow Centre

The first meeting of 1965, at which Dr. A. W. M. Coombs gave a lecture on "Character Recognition," was held on 22 January. The subject, one of the many steps contemplated in postal mechanization, is basically that of designing a machine which will recognize characters on an addressed envelope. The complexity of the task undertaken by Dr. Coombs, of the Post Office Research Station, was appreciated as he described the many and varied problems involved with such a project. The members present were delighted and fascinated by Dr. Coombs' talk, and it will be remembered as one of the most outstanding meetings.

The speaker at the February meeting was Mr. M. B. Cantley, a member of the local planning group and Secretary of the Senior Section of I.P.O.E.E. in Glasgow. His subject was "S.T.D. in the Glasgow Telephone Area." This proved to be a most interesting talk on a subject of particular interest to many of our members in the area. A complete description of the method of providing S.T.D. in the Glasgow Area was given, amply illustrated by the use of diagrams and slides. A complementary visit was made in March to the S.T.D. switching centre in Telephone House, Glasgow, and members were able to see the apparatus used to provide the S.T.D. service.

At the April meeting, Mr. David Johnstone, producer of documentary programs with Scottish Television, spoke on "Television Production," giving an insight into the problems behind the scenes of television work.

The annual general meeting of the Centre was held at the end of April. The session finished with a visit during May to Chapelcross atomic power station at Annan. The day's outing was most enjoyable and we are indebted to the Atomic Energy Commission for the marvellous facilities made available to us. The technical advisers presented the operational details with great clarity, and members came away from the visit very much impressed by the size of the station and the intricate machinery involved in the production of electricity from atomic power.

The secretary, Mr. R. M. Fraser, in a recent report to members, remarked on the continued growth of the Centre's membership, which is now over 400, and it is hoped this trend will continue in the future.

R.M.F.

Edinburgh Centre

Meetings and visits in the first half of the 1964–65 session were as follows:

15 September: One of our members, Mr. A. A. Simpson, read his essay "Transmission by Waveguide." Aided by illustrations, Mr. Simpson's talk gave some idea of the problems and the various ways of overcoming them in this method of transmission.

1 October: A party of 28 members of the Centre visited the Ravenscraig steel strip mill of Colvilles, Ltd., at Motherwell. This was a most interesting and well-conducted tour of the mills, the distance covered being quite considerable. Fortunately this was one occasion when we had a coach available.

12 November: A visit was made to the National Coal Board Colliery at Woolmet near Dalkeith. Despite typical November weather we had a full turn-out, and our party, restricted to 20, found that a 3-mile walk, 1,100 ft. underground, made for a first-class, though unusual, evening.

1 December: A talk on the "Traffic Division" was given by Mr. H. E. Morris, Chief Traffic Superintendent, Edinburgh. Among the guests present was Mr. R. M. Watson, Deputy Telephone Manager, Edinburgh. A most interesting talk was well received and a lively discussion followed.

J.M.D.

Ipswich Centre

Our winter program got away to a good start with a three-day visit to the Volkswagen factories in Germany. Trips around the Hanover and Wolfsburg works left us in no doubt as to the quality of the Volkswagen vehicles and to the progress that German industry has made. We were also guests for the evening of the German telephone service, and a tour of telephone installations at Hanover enabled us to draw comparisons with our own system. Our thanks must go to Mr. M. D. Rayner for arranging what was a most successful trip.

On 22 October we commenced our winter indoor session with a talk on "Fresh Water Creatures," by Mr. A. Eden. A most unusual subject but very interesting. In November a talk by Mr. A. Ruddock on the work of the Eastern Electricity Board was well received.

A quiz with our old enemies the Associate Section Centre at Colchester was held in December, victory coming to us by a very small margin. These quiz evenings seem to have become a regular thing and do enable the two Centres within the area to meet socially.

Future meetings include talks on "Communications Satellites," by Mr. H. E. Pearson, Space Communication Systems Branch, Engineering Department, and "The Next Forty Years," by Mr. E. Hoare, President of the Associate Section.

The annual dinner-dance was held on 27 February.

K.R.A.C.

Exeter Centre

The first meeting of this winter's session was held at Exeter University on 19 November. The lecture was "Global Telephony," by Mr. S. Welch, Telephone Exchange Systems Development Branch, Engineering Department. Sixty-two members and visitors were present to hear this most interesting lecture presented in a manner peculiar to this well-known and appreciated speaker.

Also at the University of Exeter on 9 December an interesting paper was given by Mr. T. F. A. Urben of Telephone Exchange Standards and Maintenance Branch, Engineering Department, on "Modern Maintenance—Serving the Subscriber." This paper caused considerable discussion both before and during the evening, and proceedings had to be called to a halt after we had overspent our time by 30 minutes.

Our January meeting was held at the South Devon Technical College at Torquay. Dr. A. W. M. Coombs of the Post Office Research Station presented his paper "Character Recognition." Members and visitors who travelled to Torquay for this excellent paper thoroughly enjoyed the evening. As well as the illustrations, the speaker displayed a machine capable of recognizing and memorizing shapes after a number of learning cycles. This was proof indeed of progress in one of the many complexities facing the research scientist in this field. Once again the enthusiasm and interest shown caused the meeting to overrun its allotted time.

The Committee are engaged in organizing the summer program, and, thanks to their enthusiasm, it is hoped we will shortly have a tentative one available.

A drive on recruitment is also in the offing, with an anticipated increase of 50 members to bring our total to 260.

T.F.K.

Ayr Centre

The session opened with a visit to Enterprise Scotland Exhibition. This was followed in October with a meeting and a lecture on "Judging and Printing Photographic Prints."

At the January meeting a talk was given by Mr. J. C. Evans, Area Engineer. His subject was "Local Line Planning."

The average attendance was approximately 19. However, since 15 new members have been enrolled in this session, we would hope for a better attendance in the future.

J.H.

Guildford Centre

Our 2[illegible]5 members enjoyed a successful session in the autumn of 1964 which consisted of family film shows at

Aldershot and Guildford, visits to the Ford motor company, and to factories making Firestone tyres, Osram lamps, Decca records, and K.L.G. plugs, and a lecture on "Thames Conservancy."

The program for the rest of the winter session has included visits to Whitefriars glassworks, Sanderson's wallpaper works, Guinness (Park Royal) plant, Southampton docks and Mullard's transistor factory. A technical film show was held on 23 March. The lectures have included "Pulse Code Modulation," by Mr. G. H. Bennett, Main Lines Development and Maintenance Branch, and "The Post Office Tower," by Mr. H. Knee, Exchange Equipment and Accommodation Branch, both of the Engineering Department.

The highlight of the season was the lecture on pulse code modulation. This is a method of transmitting a number of conversations over one pair of wires by converting samples of speech from each circuit to a binary code and transmitting the coded samples to line one after another.

The Centre offers its thanks for the help given by an active committee: *President:* Mr. E. C. Baxter (Area Engineer); *Vice-President:* Mr. E. J. Masters (Area Engineer); *Committee:* Mr. A. C. Anderson (E.E.), Mr. C. F. White (E.E.), and Mr. X. C. Richards (A.E.E.); *Film Secretary:* Mr. J. Moon.

The assistance given by Mr. X. C. Richards in our successful recruitment campaign will be duly noted in the minutes.

R.C.T. and W.G.D.H.

Canterbury Centre

The winter session opened with a film show on 24 November with an attendance of approximately 35 members and friends.

On 2 December a visit was made to the Reeds Group Paper Mills at Aylesford by 25 members, who had an interesting tour in spite of the noise.

On 8 December a visit was paid to Mackeson's Brewery at Hythe. Thirty members were given an insight into the methods of manufacture, and later on had the good fortune to find they were able to sample the product.

A very interesting and instructive talk was given on 15 December by Mr. A. F. G. Allan, Main Lines Development and Maintenance Branch, Engineering Department. His subject was "Small-Diameter Coaxial Cable Development." This talk was appreciated by some 52 members and visitors.

B.C.

Bedford Centre

The first two lectures of our 1964–65 session were extremely interesting. On 26 October, Mr. R. O. Boocock, Training Branch, Engineering Department, dealt with "Engineering Training in the P.O." and covered, in general terms, courses held at the Central Training School (C.T.S.), Regional Training Centres, City and Guilds Courses by classes and correspondence, and "National" courses. He also showed slides of the plans for the new C.T.S. and for the Management Training School at Bexhill. Questions were lively and developed almost into a miniature debate.

On 2 December we had a talk, slides and coloured film on "Space Communication" given by Mr. H. E. Pearson, Space Communication Systems Branch, Engineering Department. He told us in a simple but expert way of how this very exact science has developed and the possibilities in store for us in the future. He made places like "Goonhilly" and "Communications Satellites" sound very commonplace.

Three parties of our members have visited the B.B.C. Television Centre in London during the past few months and still more people want to go.

E.W.H.P.

Plymouth Centre

The annual general meeting, held in November, elected the following officers to serve for the 1964–65 session: *President:* Major C. P. Ingram, E.R.D. (Area Engineer); *Chairman:* Mr. A. C. Kingcombe; *Secretary:* Mr. S. W. Pateman; *Assistant Secretary:* Mr. D. H. Scoble; *Treasurer:* Mr. D. Grant; *Committee:* Messrs. K. Barlow, H. Bayly, J. Hambly, K. Scott, V. Martin and R. Williams.

Since then our secretary has taken up a new post on promotion to Assistant Executive Engineer and the assistant secretary has taken over.

During the latter part of 1964, visits were made to H.M. submarine *Otter*, the new water-purification plant serving Plymouth, and to the main city fire station. These visits were most interesting and it was regretted that the attendance at the latter two were disappointing.

Our program for 1965 commenced with a lecture in January from Mr. Young of the Radio Planning and Provision Branch, Engineering Department, on the new Post Office radio tower, and in February Mr. A. H. C. Knox, Past President, Associate Section, presented a lecture on "Promotion Procedure."

D.H.S.

Dundee Centre

The highlight of the 1964-part of our present winter session occurred during the afternoon of Saturday, 21 November, and all day Sunday, 22 November.

Forty members were guests of the R.N.R. Tay Division based at H.M.S. *Unicorn*, Dundee. The visit took the form of a trip out to sea on their Minesweeper H.M.S. *Montrose*. The weather, though cold, was just right for we "landlubbers."

During the voyage all aspects of the ship were explained, including a practical demonstration of the various types of sweep gear used and the armament installed. We virtually had the run of the ship from bridge to engine room; a most interesting and worth-while outing.

R.T.L.

Aberdeen Centre

The October meeting was held on 22 October, and two papers, both by Associate Section members, were read.

Mr. J. H. Lawrence was the first speaker of the evening and his subject was entitled "Novel Circuit Features of the P.A.B.X." Mr. Lawrence's talk dealt with circuits from the P.A.B.X. Nos. 1, 2, 3, and 4, and with the aid of diagrams he explained the features of the "Follow-on-Call Trap Circuit," "Level-9 Access," "Enquiry Call" and the "Principle of the Start Circuit." The talk, which was broadcast from Aberdeen to Elgin, Huntly, Inverness, Kirkwall, Lerwick, Thurso and Wick, was well received and very informative.

The second subject of the evening was broadcast from Thurso by Mr. A. Dunnet and was entitled "Some Developments in Subscribers' Apparatus." Mr. Dunnet described the introduction and design of the 700-type telephones and some of the weaknesses. He also mentioned one of the advantages of the new telephones—standardization. Mr. Dunnet dealt with some of the more recent plan numbers, switchboards, the Rapidial, etc., and concluded with the future trends both in this country and in America. The little touch of humour gave that extra something to make this talk an extremely interesting one.

On Saturday, 31 October, a party of members and guests paid visits to three places of interest in Pitlochry, Perthshire. The first of these was the central control of the North of Scotland Hydro-Electric Board. The party were shown how the controller was able to assess the state of the main line sub-stations from the continuous information fed in. The communication and telemetering equipments were also shown to tne party. Second on our list was Pitlochry power station, which is the seventh and last generating station in the Loch Tummel scheme. At this station an underwater viewing panel of the fish ladder has been installed, but no fish were seen while our party were there. We did see fish at our last port of call, the freshwater fish laboratories of the Department of Agriculture and Fisheries for Scotland, at Faskally. Here the party saw salmon and trout in various stages of growth, and also examples of the different types of net which have been used through the ages. It was a most instructive day's outing and helped everyone to appreciate the work done by other sections of the Civil Service and by Public Industries.

In November we had a lecture on "Auto Control of Machine Tools" by Mr. N. M. Levy of Aberdeen University. Mr. Levy introduced his paper by giving a brief historical background to the subject. Measurements are the whole key to automatic control, and Mr. Levy explained the two types—positional and rotational. With the aid of slides the lecturer progressed to actual working systems and machines. After commenting on the mechanical considerations of the machines, Mr. Levy explained how air-bearings and oil pressure were helping to overcome the inaccuracies of the mechanical system. Mr. Levy concluded his lecture by showing two films. "Numerical Control" and "Computer Controlled Cutting Machines." A very interesting lecture which was made all the more enjoyable by the clear diction of the lecturer.

D.W.

Book Reviews

"Single Sideband Principles and Circuits." E. W. Pappenfus, Warren B. Bruene and E. O. Schoenibe. McGraw-Hill Publishing Co., Ltd. xvi + 382 pp. 308 ill. £5 18s.

In view of the general use of single-sideband (s.s.b.) and independent-sideband (i.s.b.) techniques for point-to-point communication and the likelihood of the extended use of single-sideband for marine telephony, a book that deals with the subject comprehensively is welcome.

In addition to a treatment of the conventional filter method for generating s.s.b. and i.s.b. signals, accounts are given of the two methods by which the unwanted sideband is removed by applying appropriate phase shifts to the modulating signal and the carrier. Chapters on special topics such as modulators, filters, oscillators and linear amplifiers are included, as well as others on the features of complete transmitters and receivers.

The treatment of receivers is good in some respects, such as the importance of correct distribution of gain and automatic gain control (a.g.c.), but scanty in others, such as a.g.c. and automatic frequency control (a.f.c.) in receivers using a pilot carrier. Fairly comprehensive tests of transmitters and receivers are described.

In the tests of receiver sensitivity and a.g.c. performance no mention is made of the use of two signal generators, one providing a sideband component and the other providing the reduced carrier; the test of a.g.c. on page 350 would be satisfactory only if the control voltage were derived from the sideband.

The diagrams are numerous and good, though few circuits show transistors.

W.R.H.L.

"Semiconductor Circuit Analysis." P. Cutler. McGraw-Hill Publishing Co., Ltd. x + 640 pp. 358 ill. 77s 6d.

Despite its title, this book is intended more as a practical guide to circuit design than as a text-book on analysis, and it contains numerous exercises and problems to assist the reader.

There are nine chapters, of which the first is a simple description of the atomic structure and basic properties of semiconductors. The second chapter describes the p–n junction, and includes material on its use as a voltage-variable capacitance. It is a pity that the author describes the junction as "a slab of pure p-type material placed against a slab of n-type material"; the beginner might be misled. Chapter 3 is a good introduction to the electrical properties of transistors, but insufficient space is devoted to fabrication techniques. Fig. 3–6 shows a misleading approach to the amplifying properties of the transistor. The fourth chapter deals very thoroughly with the important topic of biasing and stabilization, though it dismisses without explanation the difference between $V_{BR(CBO)}$ and $V_{BR(CEO)}$. Chapter 5 describes the z, y and h-parameters of the transistor considered as a 2-port device, and chapter 6 is mainly concerned with frequency response. It deals with narrow-band and wide-band amplifiers, and contains a very good treatment of the factors controlling low-frequency cut-off. Chapter 7 describes power amplifiers, particularly the class B amplifier, and is followed by a chapter dealing with feedback; there is material on the control of input and output impedance and also on operational amplifiers. The final chapter is devoted to regulated power supplies.

Despite a few shortcomings (notably the absence of any significant material on noise) this book forms a valuable guide to the subject.

H.G.B.

"Theory and Application of the Z-Transform Method." Eliahu I. Jury. John Wiley and Sons, Ltd. 330 pp. 61 ill. 87s.

As the author of this book remarks, the "z-transform" is essentially a development of the "generating function" invented by DeMoivre and used extensively by Laplace in probability theory. Jury defines the z-transform of a time-function $f(t)$ as a generating function for the values of $f(t)$ at regularly spaced instants of time $t = nT$. From this definition he develops an extensive mathematical derivation of the properties of the transform, its relationship with other transforms commonly used in systems analysis, and its use in solving a wide range of problems. Exact or approximate solutions of various linear, non-linear and time-varying difference and differential equations are derived, and applications to problems of stability and limit-cycle analysis are also considered. A number of illustrative examples are given, ranging from analysis of the behaviour of non-linear sampled-data feedback systems and of aerial arrays to problems in economics. A suggestion is made for the treatment of first-order discrete Markov chains, and "linear sequential networks" (in which input and output consist of sequences of numbers belonging to modular fields) are briefly considered.

Readers of this book will require considerable mathematical equipment, including especially the theory of functions of complex variables. Not only are the arguments condensed, and sometimes obscure, but it is also left largely to the reader to compare the power of the z-transform with that of other possible techniques. Systems engineers will find Jury's earlier book "Analysis and Synthesis of Sampled-Data Control Systems" (Wiley, 1958) a simpler and more immediately applicable introduction to the treatment of physical systems. The present book contains a very good summary (Chapter 1) of basic definitions and theorems, but otherwise will be useful only to those willing to subject it to detailed and critical study.

L.W.H.

Staff Changes

Promotions

Name	Region, etc.	Date
Deputy Engineer-in-Chief to Engineer-in-Chief		
Barron, D. A.	E.-in-C.O.	22.3.65
Assistant Engineer-in-Chief to Deputy Engineer-in-Chief		
Merriman, J. H. H.	E.-in-C.O.	22.3.65
Assistant Staff Engineer to Staff Engineer		
White, R. W.	E.-in-C.O.	16.11.64
Efficiency Engineer to Regional Engineer		
Barker, A. J.	H.C. Reg.	12.11.64
Senior Executive Engineer to Assistant Staff Engineer		
Little, S. J.	E.-in-C.O.	16.11.64
Hix, K. W.	E.-in-C.O.	16.11.64
Morris, D. W.	E.-in-C.O.	23.11.64
Thirsk, R. D.	E.-in-C.O.	30.11.64
Hannant, K. A.	E.-in-C.O.	8.12.64
Kelly, P. T. F.	E.-in-C.O.	8.12.64
Partington, E. V. (*in absentia*)	E.-in-C.O.	8.12.64
Senior Executive Engineer to Regional Engineer		
Davis, E.	L.T. Reg.	8.12.64
Breary, D.	L.T. Reg.	8.12.64
Roberts, W. G.	H.C. Reg. to L.T. Reg.	16.12.64
Executive Engineer to Area Engineer		
Cheesbrough, J. W. H.	Mid. Reg.	5.10.64
Ward, C. V.	H.C. Reg.	26.10.64
Executive Engineer to Efficiency Engineer		
Wilson, A. A.	Scot.	16.11.64
Executive Engineer to Senior Executive Engineer		
Morton, W. D.	E.-in-C.O.	5.10.64
Turner, G. E.	N.W. Reg. to W.B.C.	12.10.64
Drinkwater, M.	N.W. Reg.	12.11.64
Mackay, A. C.	L.P. Reg.	12.11.64
Beck, I. H.	E.-in-C.O.	14.12.64
Marshall, F. K.	L.T. Reg.	4.12.64
Naylor, H. C.	E.-in-C.O.	17.11.64
Executive Engineer (Open Competition)		
Hempseed, P. H.	E.-in-C.O.	26.10.64
Thomas, A.	E.-in-C.O.	5.10.64
Reed, A. G.	E.-in-C.O.	28.10.64
Assistant Executive Engineer to Executive Engineer		
Howe, R. F.	S.W. Reg. to H.C. Reg.	12.10.64
Lawrenson, S.	E.-in-C.O.	1.10.64
Dunn, R. J.	E.-in-C.O.	5.10.64
Barton, P.	N.E. Reg. to Mid. Reg.	26.10.64
Murray, R. E. A.	L.T. Reg.	27.10.64
Shurrock, P. F. J.	H.C. Reg.	27.10.64
Bourne, W. E.	L.T. Reg.	27.10.64
Williamson, H. E.	L.T. Reg.	27.10.64
Horne, F. T. H.	L.T. Reg.	27.10.64
Jelliffe, C. A.	H.C. Reg. to S.W. Reg.	9.11.64
Jones, J. E.	W.B.C. to N.W. Reg.	16.11.64
Thraves, C. M.	E.-in-C.O.	16.11.64
Hearnden, A. H.	E.-in-C.O.	16.11.64
Metcalfe, F. C.	L.T. Reg.	9.11.64
Pullen, A. E.	E.-in-C.O.	30.11.64
Bell, C. (*in absentia*)	E.-in-C.O.	19.11.64
Clayton, A. D.	S.W. Reg.	23.11.64
Nash, L. C.	E.-in-C.O.	7.12.64
Finch, D. W.	E.-in-C.O.	7.12.64
Hayton, F.	E.-in-C.O.	10.12.64
Donn, G. S.	E.-in-C.O.	11.12.64
Gibbs, T. B. (*in absentia*)	H.C. Reg.	2.12.64
Horner, H. T.	N.E. Reg.	9.12.64
Brown, D. F.	Mid. Reg.	3.12.64
Noble, W. A.	Scot.	21.12.64
Dutch, G. C.	Scot. to N.W. Reg.	29.12.64
Hayton, C. E.	H.C. Reg.	21.12.64

Name	Region, etc.	Date
Assistant Executive Engineer to Executive Engineer—continued		
West, W. R.	H.C. Reg.	21.12.64
Hambling, J. B.	H.C. Reg.	21.12.64
Knight, B. S.	Mid. Reg.	21.12.64
Assistant Executive Engineer (Open Competition)		
Garside, R.	L.T. Reg.	23.11.64
Elliott, J. A.	E.-in-C.O.	19.9.64
Renton, P. F.	E.-in-C.O.	4.8.64
Yull, E. R.	E.-in-C.O.	1.9.64
Smith, A. J.	E.-in-C.O.	1.9.64
Williams, D. L.	E.-in-C.O.	4.8.64
Cook, S. J.	E.-in-C.O.	1.9.64
Baggs, J. H.	E.-in-C.O.	1.9.64
Chamberlain, L. J.	E.-in-C.O.	1.9.64
Robertson, J. S. H.	E.-in-C.O.	1.9.64
Inspector to Assistant Executive Engineer		
Mehrtens, R. N.	N.I.	1.9.64
Callaghan, J.	Scot.	1.10.64
Taylor, L.	Mid. Reg.	26.10.64
McCool, R. C.	Mid. Reg.	6.11.64
Ricketts, J. C.	L.T. Reg.	25.11.64
Smith, W. J.	H.C. Reg.	11.12.64
Chappell, J. J.	H.C. Reg.	11.12.64
Austin, G. W.	H.C. Reg.	11.12.64
Granger, N. F.	H.C. Reg.	11.12.64
Martin, L. J.	H.C. Reg.	11.12.64
Goatley, R. E. J.	H.C. Reg.	11.12.64
Woolterton, J. L.	H.C. Reg.	11.12.64
Tomkins, K. G. H.	H.C. Reg.	11.12.64
Moth, R. S.	H.C. Reg.	11.12.64
Rowland, D. D.	H.C. Reg.	11.12.64
Kenyon, J. D.	H.C. Reg.	11.12.64
Parham, M. R.	S.W. Reg.	20.11.64
Roberts, J. M.	N.W. Reg.	7.12.64
Technical Officer to Assistant Executive Engineer		
Teale, H.	N.E. Reg.	6.10.64
Richmond, T. A.	N.E. Reg.	6.10.64
Francis, M. H.	N.E. Reg.	6.10.64
Hibbitt, R.	N.E. Reg.	6.10.64
Beddoe, W. C.	W.B.C.	12.10.64
Hubbard, W. J.	W.B.C.	12.10.64
Martin, J. S.	E.T.E.	1.10.64
Page, F. E. R.	W.B.C.	26.10.64
Pickett, F. S. R.	Mid. Reg.	19.10.64
Moorfield, A. W. O.	Mid. Reg.	19.10.64
Lowe, E. S.	Mid. Reg.	26.10.64
Savery, R.	Mid. Reg.	19.10.64
Blatchley, H. F. M.	S.W. Reg.	7.10.64
Standen, F. R.	S.W. Reg.	7.10.64
Berry, D. W.	S.W. Reg.	7.10.64
Blagg, C. A.	S.W. Reg.	7.10.64
Smith, R. M.	Scot.	1.10.64
Wheeler, D. J.	E.-in-C.O.	26.10.64
Osman, W. E.	S.W. Reg.	20.10.64
Good, R. E.	W.B.C.	26.10.64
Henderson, J.	W.B.C.	30.10.64
Elliott, C.	N.W. Reg.	27.10.64
Cartwright, R. J.	N.W. Reg.	6.11.64
Shelland, J. H.	N.W. Reg.	6.11.64
Alty, C.	N.W. Reg.	6.11.64
Bullock, I. H.	S.W. Reg.	7.10.64
Loosemore, A. W.	S.W. Reg.	9.11.64
Harris, J.	N.E. Reg.	3.11.64
Horlington, R.	N.E. Reg.	3.11.64
Mooney, M. K.	N.W. Reg.	2.11.64
Budd, C. A.	W.B.C.	2.11.64
Orange, M. R.	Mid. Reg.	6.11.64
Webber, K. C.	W.B.C.	2.11.64
Tipple, J. R.	Mid. Reg.	6.11.64
Williams, G. T.	Mid. Reg.	6.11.64
Savage, D. R. W.	Mid. Reg.	6.11.64
Grove, D. L.	Mid. Reg.	6.11.64

Name	Region, etc.	Date
Technical Officer to Assistant Executive Engineer—continued		
Barber, A. H.	W.B.C.	17.11.64
Parsons, E. H.	S.W. Reg.	6.11.64
Loveless, J. K.	S.W. Reg.	6.11.64
Dowling, E. N.	L.T. Reg.	25.11.64
Jones, H. H. S.	L.T. Reg.	25.11.64
Barber, L. F.	L.T. Reg.	25.11.64
Chainey, A.	L.T. Reg.	25.11.64
Skingle, A. N.	L.T. Reg.	25.11.64
Moore, L. E.	L.T. Reg.	25.11.64
Whiting, D. R.	L.T. Reg.	25.11.64
Gillard, V. T.	L.T. Reg.	25.11.64
Wells, T. R.	L.T. Reg.	25.11.64
Scott, J.	L.T. Reg.	25.11.64
Mallinder, A. L. E.	L.T. Reg.	25.11.64
Nottingham, S. W.	L.T. Reg.	25.11.64
Saywell, S. A.	L.T. Reg.	25.11.64
Gregson, R. M.	N.W. Reg.	25.11.64
Price, A. H.	N.W. Reg.	25.11.64
Speakman, J. A.	N.W. Reg.	25.11.64
Scanes, R.	N.W. Reg.	25.11.64
Spink, I. P.	N.W. Reg.	25.11.64
Jones, J.	L.T. Reg.	25.11.64
Kennady, L.	N.E. Reg.	9.12.64
Hodgson, H.	N.E. Reg.	9.12.64
McDougle, A.	N.E. Reg.	9.12.64
Rowe, E. R.	S.W. Reg.	7.12.64
Dennis, R. G.	S.W. Reg.	7.12.64
Bott, R.	Mid. Reg.	2.12.64
Christmas, H.	W.B.C.	4.12.64
Byron, E.	N.W. Reg.	14.12.64
Robinson, J.	N.W. Reg.	7.12.64
Pollard, J.	N.W. Reg.	7.12.64
Dixon, H.	N.W. Reg.	7.12.64
Coar, F.	N.W. Reg.	7.12.64
Technical Officer to Inspector		
Dobson, T. R.	L.T. Reg.	25.11.64
Oakley, E. R.	L.T. Reg.	25.11.64
Richardson, W. J. T.	L.T. Reg.	25.11.64
Southgate, A. H.	L.T. Reg.	25.11.64
Mann, J. L.	N.W. Reg.	27.11.64
Technician I to Inspector		
Miller, R. M.	Scot.	18.9.64
Miller, J.	Scot.	12.10.64
Barr, J.	Scot.	28.9.64
Carberry, P.	Scot.	29.9.64
Rowan, G. K.	Scot.	5.10.64
Muirhead, J. L.	Scot.	5.10.64
Feist, J. G.	Scot.	1.10.64
Lloyd, D. R.	W.B.C.	16.10.64
Bean, A. F.	W.B.C.	15.10.64
Randall, P. J.	W.B.C.	19.10.64
Rose, W. S.	W.B.C.	15.10.64
Williams, I. J.	W.B.C.	26.10.64
Hunter, A. E.	N.E. Reg.	3.11.64
Brown, H. N.	N.W. Reg.	6.11.64
Truscott, S. F.	S.W. Reg.	5.10.64
McCann, S.	Scot.	12.10.64
Gigg, G. A.	H.C. Reg.	27.11.64
Fuller, R. H.	H.C. Reg.	27.11.64
Honey, W. T.	H.C. Reg.	27.11.64
Hughes, H. G.	H.C. Reg.	27.11.64
Dove, H.	H.C. Reg.	27.11.64
Harrington, E.	N.E. Reg.	3.11.64
Binns, A.	N.E. Reg.	3.11.64
Hollinworth, E. G.	N.E. Reg.	3.11.64
Whiteside, R. W.	N.E. Reg.	3.11.64
Price, J.	W.B.C.	2.11.64
Furniss, L.	N.E. Reg.	3.11.64
Chatfield, E. H. R.	N.E. Reg.	3.11.64
Stansfield, K.	N.E. Reg.	3.11.64
Prickett, K. E.	H.C. Reg.	27.11.64
Grant, R. H.	H.C. Reg.	27.11.64
Warden, J. F.	L.T. Reg.	25.11.64
Bright, W. C. S.	L.T. Reg.	25.11.64
Technician I to Inspector—continued		
Farrell, R.	N.W. Reg.	25.11.64
Booth, H.	N.W. Reg.	30.11.64
Fisher, W.	N.W. Reg.	25.11.64
Crosbie, C. S.	N.W. Reg.	25.11.64
Mullen, L. E.	S.W. Reg.	15.12.64
Lemm, R. B.	H.C. Reg.	27.11.64
Westgate, J. F.	H.C. Reg.	27.11.64
Downs, M. R. F.	H.C. Reg.	27.11.64
Jackson, T.	Mid. Reg.	14.12.64
Hamilton, G. K.	N.W. Reg.	7.12.64
Thompson, E.	N.W. Reg.	7.12.64
Cartmel, R.	N.W. Reg.	7.12.64
McConnochie, C.	N.W. Reg.	7.12.64
Green, J.	N.W. Reg.	7.12.64
Senior Principal Scientific Officer to Deputy Director of Research		
Tillman, J. R.	E.-in-C.O.	25.1.65
Senior Assistant (Scientific) to Experimental Officer		
Bird, W. H.	E.-in-C.O.	2.10.64
Frost, W. G. T.	E.-in-C.O.	2.10.64
Assistant Experimental Officer (Open Competition)		
Samuels, P. M. H.	E.-in-C.O.	10.9.64
Patel, B. R.	E.-in-C.O.	5.10.64
Hanks, R.	E.-in-C.O.	12.10.64
McPherson, J. M.	E.-in-C.O.	8.12.64
Lazell, M. R.	E.-in-C.O.	9.12.64
Ballingall, R. A.	E.-in-C.O.	16.12.64
Technical Assistant to Assistant Regional Motor Transport Officer		
Riches, S. J. W.	Mid. Reg.	12.10.64
Workshop Supervisor I to Technical Assistant		
Gall, J.	Scot.	16.10.64
Workshop Supervisor II to Technical Assistant		
Barham, R. J.	Mid. Reg.	1.9.64
Folwell, N.	H.C. Reg.	7.12.64
Jarvis, G. W. G.	Mid. Reg.	24.12.64
Leading Draughtsman to Senior Draughtsman		
Burr, R. E. J.	E.-in-C.O.	1.12.64
Wattis, J. H. S.	N.I.	16.12.64
Draughtsman to Leading Draughtsman		
Liebermann, N. C.	H.C. Reg.	22.11.64
Harris, R. J.	N.E. Reg.	22.11.64
Thompson, A. G.	N.I.	22.11.64
Harrison, J. E.	N.I.	22.11.64
Hoggarth, L.	N.W. Reg.	22.11.64
Dauncey, H. J.	Mid. Reg.	22.11.64
West, H. F.	S.W. Reg.	22.11.64
Johnson, J. A.	N.E. Reg. to S.W. Reg.	22.11.64
Mathers, K. R.	H.C. Reg.	22.11.64
Simpson, D. W.	Mid. Reg.	22.11.64
Ralph, T. H.	L.T. Reg.	22.11.64
Stevens, A.	S.W. Reg. to W.B.C.	22.11.64
Knight, P. A.	S.W. Reg.	22.11.64
McLennan, K. G.	Scot.	22.11.64
Smith, L. A.	L.T. Reg.	22.11.64
Barker, M. R. C.	H.C. Reg.	22.11.64
Sturges, W. H.	H.C. Reg.	22.11.64
Relf, A. O.	H.C. Reg.	22.11.64
Lovejoy, C. J.	N.W. Reg. to H.C. Reg.	22.11.64
Olney, J. P.	H.C. Reg.	22.11.64
Sizeland, D. S.	H.C. Reg.	22.11.64
Batchelor, P. L.	H.C. Reg.	22.11.64
Needham, A. M.	N.W. Reg.	22.11.64
Cave, W. C.	L.T. Reg.	22.11.64
Halliday, J. P.	Mid. Reg.	22.11.64
Thornbury, W. E.	N.W. Reg.	22.11.64
Searle, A.	Mid. Reg.	22.11.64
MacFarlane, A.	Scot. to W.B.C.	22.11.64
Hendricks, R. P.	L.T. Reg.	22.11.64
McCabe, M. A.	H.C. Reg.	22.11.64
Albiston, J. H.	N.W. Reg. to Scot.	22.11.64

Promotions—*continued*

Name	Region, etc.	Date
Draughtsman to Leading Draughtsman—continued		
Harris, A. W.	N.E. Reg. to H.C. Reg.	22.11.64
Craven, P. G.	N.W. Reg.	22.11.64
Thame, A.	L.T. Reg.	22.11.64
Lewis, R.	N.W. Reg.	22.11.64
Ketley, K. V.	L.T. Reg.	22.11.64
Whetter, G.	L.T. Reg.	22.11.64
Clarke, J. C.	H.C. Reg. to Mid. Reg.	22.11.64
Wyett, J. A. C.	H.C. Reg.	22.11.64
Watling, A. R.	H.C. Reg. to L.T. Reg.	22.11.64
Executive Officer to Higher Executive Officer		
Bellinger, C. W.	E.-in-C.O.	30.11.64
Executive Officer to Higher Executive Officer—continued		
Offord, E. C.	E.-in-C.O.	7.12.64
Gurdus, S.	E.-in-C.O.	7.12.64
Executive Officer (Open Competition)		
Brown, D. A.	E.-in-C.O.	7.12.64
Doherty, E.	E.-in-C.O.	7.12.64
O'Brien, M. T. (Miss)	E.-in-C.O.	7.12.64
Clerical Officer to Executive Officer		
Abrahams, F. B. (Mrs.)	E.-in-C.O.	30.11.64
Cash, D. A.	E.-in-C.O.	30.11.64
Walker, M. T. (Mrs.)	E.-in-C.O.	30.11.64

Retirements and Resignations

Name	Region, etc.	Date
Engineer-in-Chief		
Mumford, Sir Albert H.	E.-in-C.O.	19.3.65
Staff Engineer		
Flowers, T. H.	E.-in-C.O.	31.10.64
Senior Executive Engineer		
Arman, L. T.	E.-in-C.O.	30.9.64
Guy, L.	Scot.	14.11.64
Whitmore, L. H.	E.-in-C.O.	31.12.64
Executive Engineer		
Reynolds, W. H.	E.-in-C.O.	1.8.64
Myers, H. G.	E.-in-C.O.	10.10.64
Davis, H. C.	L.T. Reg.	3.10.64
Harden, P.	L.T. Reg.	14.11.64
Rowlands, E. J.	N.W. Reg.	6.11.64
Bass, N. K.	E.-in-C.O.	22.11.64
McVeigh, N. (*Resigned*)	E.-in-C.O.	20.11.64
Wright, A. (*Resigned*)	E.-in-C.O.	13.11.64
Wilson, K. E.	E.-in-C.O.	31.12.64
Ray, M. A. (*Resigned*)	E.-in-C.O.	31.12.64
Assistant Executive Engineer		
Edwards, J. R.	Mid. Reg.	31.10.64
Cheetwood, E.	N.W. Reg.	31.10.64
D'Arcy, A. W.	L.T. Reg	31.10.64
Bowles, L. C.	Mid. Reg.	4.10.64
Child, H. J.	E.T.E.	7.10.64
Dulk, R. F.	E.-in-C.O.	16.10.64
Thomas, A. J. K. (*Resigned*)	Scot.	14.8.64
Hatchett, S. F. (*Resigned*)	E.-in-C.O.	31.10.64
Jempson, R. B.	H.C. Reg.	1.11.64
Webb, F. H.	N.E. Reg.	3.11.64
Gray, A.	L.P. Reg.	11.11.64
Myers, T. R.	E.-in-C.O.	13.11.64
Holder, W.	Mid. Reg.	14.11.64
Shepheard, J. B.	L.T. Reg.	16.11.64
Smith, S. W.	N.E. Reg.	19.11.64
Walker, E. H.	L.T. Reg.	28.11.64
Assistant Executive Engineer—continued		
Fisher, T.	L.T. Reg.	30.11.64
Grispo, G. V. (*Resigned*)	E.-in-C.O.	27.11.64
Trumper, D. A.	E.-in-C.O.	30.11.64
Costigan, T.	N.E. Reg.	3.11.64
Johnson, J. F.	Mid. Reg.	3.12.64
Martland, A. R.	N.W. Reg.	18.12.64
Pugh, J. H. A.	L.T. Reg.	31.12.64
Green, L. A. (*Resigned*)	E.-in-C.O.	18.12.64
Marlow, D. (*Resigned*)	E.-in-C.O.	29.12.64
Allenby, R. G. (*Resigned*)	E.-in-C.O.	31.12.64
Inspector		
McGandy, W. L.	N.I.	3.7.64
Woods, J. S.	N.W. Reg.	30.9.64
Marsden, J.	N.E. Reg.	14.10.64
Ribbeck, P. C. W.	Scot.	19.10.64
Moore, J.	L.T. Reg.	26.10.64
Davidson, C. F. T.	L.T. Reg.	20.11.64
Bright, A. J.	N.E. Reg.	28.11.64
Best, J. A.	N.W. Reg.	18.12.64
Dowden, R. B.	L.T. Reg.	30.12.64
Hill, W. E.	L.T. Reg.	31.12.64
Senior Experimental Officer		
Minster, J. T.	E.-in-C.O.	28.10.64
Technical Assistant		
Booth, A. W.	E.-in-C.O.	13.11.64
Weston, J.	W.B.C.	13.11.64
Senior Draughtsman		
Jones, H. E.	N.I.	30.11.64
Draughtsman		
Thomson, T. J.	E.-in-C.O.	7.10.64
Eakins, G. W. A.	E.-in-C.O.	31.12.64
McCready, J. P. (*Resigned*)	E.-in-C.O.	31.12.64
Ongaro, M. (*Resigned*)	E.-in-C.O.	31.12.64

Transfers

Name	Region, etc.	Date
Assistant Staff Engineer		
Hall, A. W.	Joint P.O./M.O.W. R. & D.G. to E.-in-C.O.	9.11.64
Chappel, A. J.	E.-in-C.O. to L.T. Reg.	14.12.64
Alston, G. J.	E.-in-C.O. to Mid. Reg.	14.12.64
Senior Executive Engineer		
Burton, A. J. I.	Approved Employment to E.-in-C.O.	21.9.64
Stotesbury, K. E.	S.A.D.T.C. to E.-in-C.O.	9.11.64
Bastow, F. J.	E.-in-C.O. to S.W. Reg.	9.11.64

Transfers—*continued*

Name	Region, etc.	Date
Executive Engineer		
Hussey, E. D. F.	E.-in-C.O. to Ministry of Transport	1.10.64
Sheldrake, R. J.	S.W. Reg. to Fiji	5.10.64
Brough, R.	Scot. to E.-in-C.O.	10.10.64
Carter, P. E.	L.T. Reg. to S.H.A.P.E.	1.11.64
Tavener, A.	E.-in-C.O. to New Zealand	4.12.64
Watkins, A. H.	E.-in-C.O. to H.C. Reg.	1.12.64
Assistant Executive Engineer		
Drury, C. B.	British Railways to E.-in-C.O.	1.10.64
Dickenson, P.	British Railways to E.-in-C.O.	1.10.64
Barnes, H. E.	East Africa to E.-in-C.O.	1.10.64
Hunt, G. V.	Hong Kong to E.-in-C.O.	5.10.64
Burns, A. P.	E.-in-C.O. to W.B.C.	5.10.64
Holloway, E. E.	E.-in-C.O. to Ministry of Defence	2.11.64
Stock, L. A.	L.T. Reg. to Ministry of Public Buildings and Works	2.11.64
Hawes, B. A.	E.-in-C.O. to East Africa	4.11.64
Sheppard, K. W. C.	E.-in-C.O. to East Africa	10.11.64
Assistant Executive Engineer—continued		
Roberts, D.	E.T.E. to E.-in-C.O.	16.11.64
Todhunter, J. S.	N.W. Reg. to East Africa	19.11.64
Hayes, D. W.	E.-in-C.O. to Ministry of Aviation	1.12.64
Hall, T.	E.-in-C.O. to Ministry of Defence	14.12.64
Norris, H. J.	Ministry of Defence to E.-in-C.O.	14.12.64
Howorth, P. W.	E.-in-C.O. to N.W. Reg.	28.12.64
Experimental Officer		
Muswell, A. N.	Ministry of Aviation to E.-in-C.O.	2.11.64
Scientific Officer		
Bacon, M. D.	D.S.I.R. to E.-in-C.O.	2.11.64
Assistant (Scientific)		
Hollingdale-Smith, G. V. R. (Mrs.)	E.-in-C.O. to Ministry of Defence	5.10.64

Deaths

Name	Region, etc.	Date
Executive Engineer		
Freeman, A. W.	E.-in-C.O.	16.10.64
Assistant Executive Engineer		
Bridge, A.	N.E. Reg.	24.10.64
Neale, E. W.	S.W. Reg.	30.10.64
Assistant Executive Engineer—continued		
Robinson, H.	E.-in-C.O.	1.11.64
Connell, A.	E.-in-C.O.	2.11.64
Smith, G. O.	H.C. Reg.	11.11.64
Johnson, R. W. K.	L.T. Reg.	17.11.64
Silcox, W. G.	S.W. Reg.	11.12.64
Hitch, F.	E.-in-C.O.	27.12.64

Papers and Articles on Telecommunications and Other Scientific Subjects

The following is a list of the authors, titles and places of publication of papers and articles written by Post Office staff (sometimes in association with members of other organizations) and published during 1964.

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Young, A.,* see Collingwood, J. D.

*Mr. Walker is with Ericsson Telephones, Ltd., Dr. Lancaster is with the Royal Aircraft Establishment, Farnborough, and Mr. Young is with Associated Automation.

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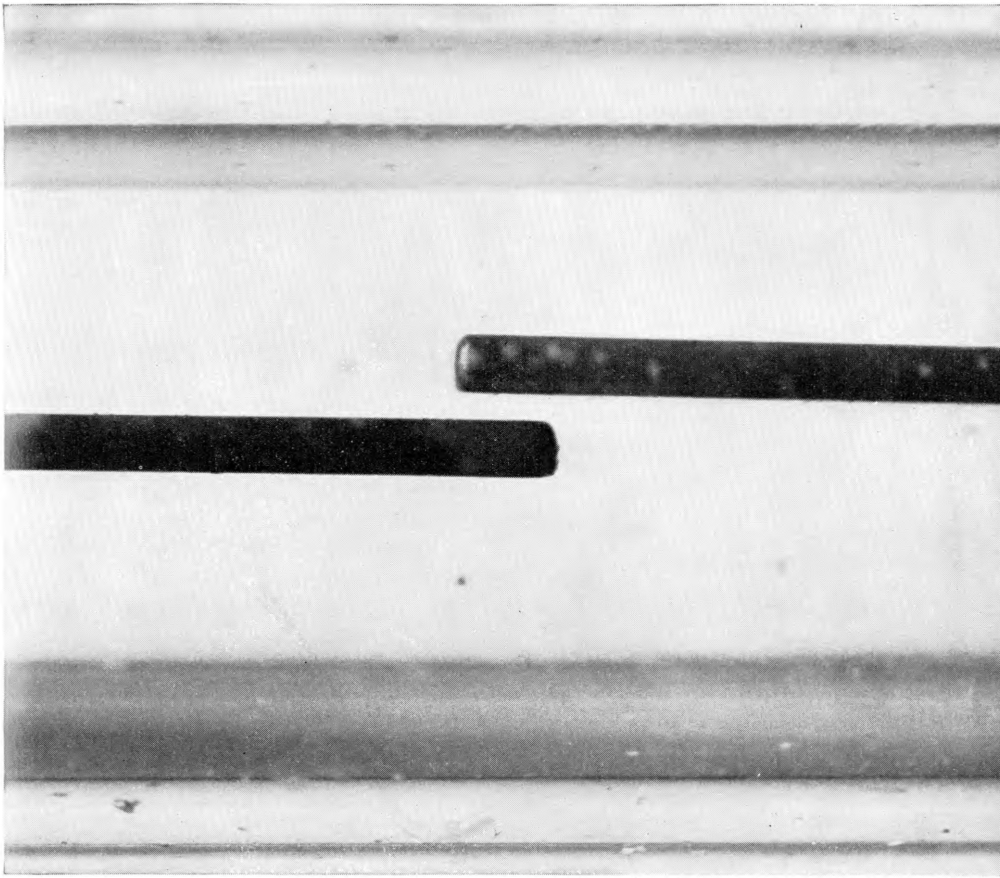

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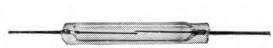

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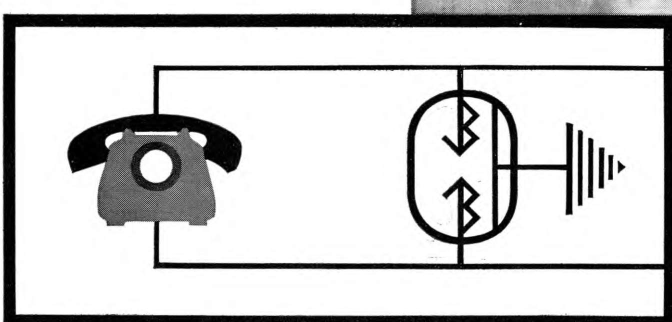

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Telecommunications Division Woolwich London SE18

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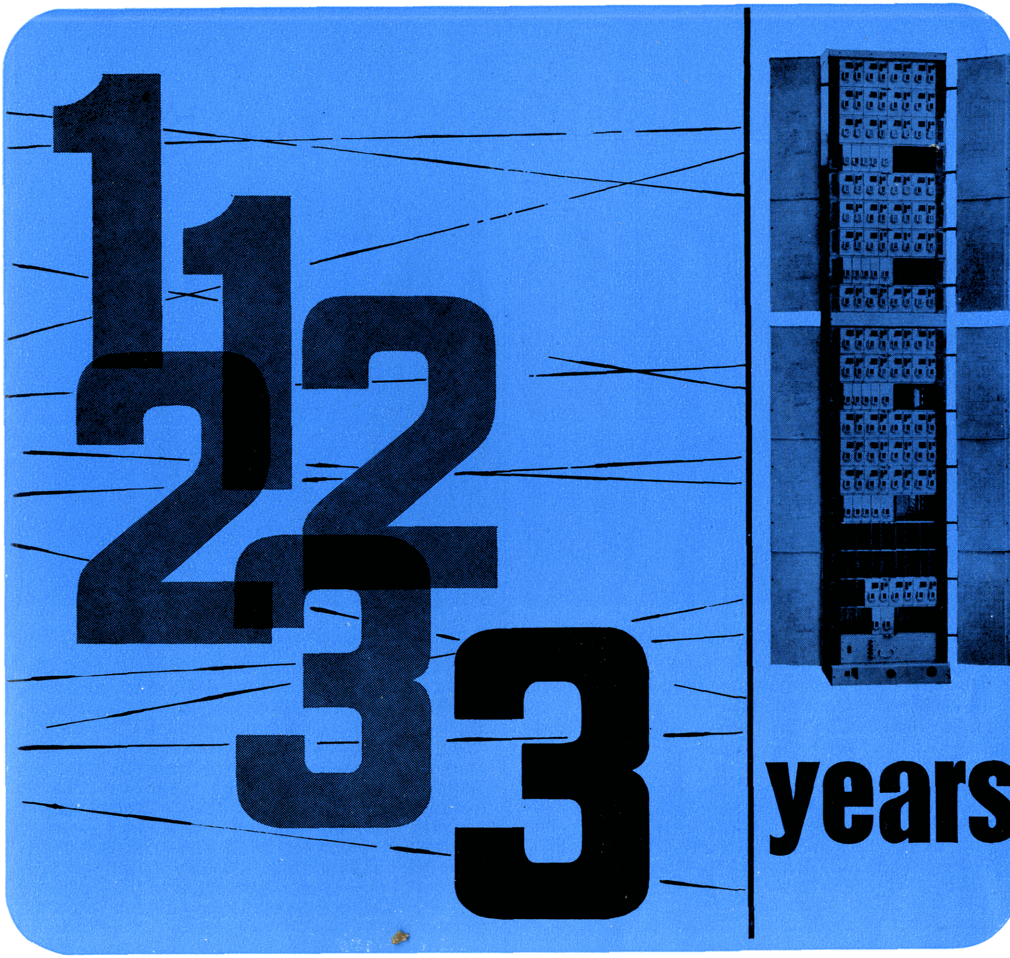


3 years of proven performance –
means you can specify transistorised AT&E/CM carrier systems with confidence

A range of transistorised carrier equipment that has an established operational performance — in actual telephone and telegraph networks — that's Type CM. With this equipment, AT&E engineers pioneered new standards of reliability, low power consumption, compactness and flexibility. Type CM is designed for, and operating in, tropical and other environmental extremes. It is completely compatible with existing carrier telephone equipment. For more information about this performance-proven transistorised carrier equipment — AT&E's Type CM — please write to:
Automatic Telephone & Electric Co. Ltd, 8 Arundel Street, London, W.C.2, England. Telephone: Temple Bar 9262.

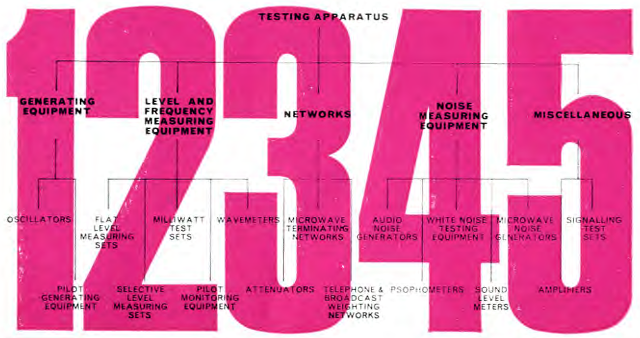
Performance standards:
CCITT
Transmission medium:
open wire, paired cable, coaxial cable, radio.
Input power:
mains or batteries.

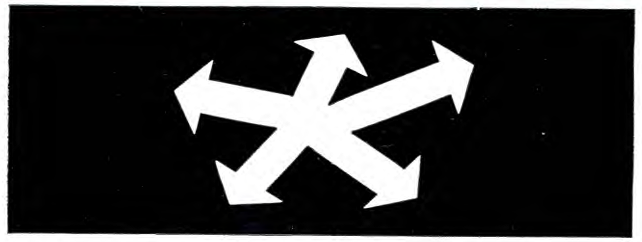
aTe

PLESSEY GROUP

STC TELECOMMUNICATIONS REVIEW

APRIL 1965



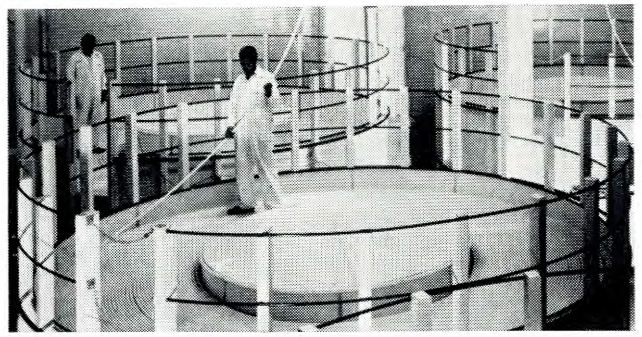


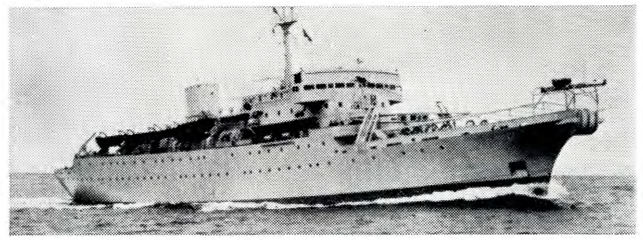
Testing! . . . One, two, three, four, five . . .

Five classifications span the whole range of transmission testing apparatus; five main sections cover the needs of science and industry.

Flexible, reliable, comprehensive. Continually being extended in all directions, this range of high quality, general purpose apparatus is designed and produced to strict specifications to meet BPO and other administration requirements throughout the world. However, if special-purpose equipment is called for—we'll make it for you. Whatever the job, STC Testing Apparatus can meet the demand.

Standard Telephones and Cables Limited, Testing Apparatus Division, Corporation Road, Newport, Mon. Telephone: Newport 72281 (STD One 3 72281). Telex: 49367. London Office: Telephone: CLErkenwell 4511.





STC and the world's longest cable . . .

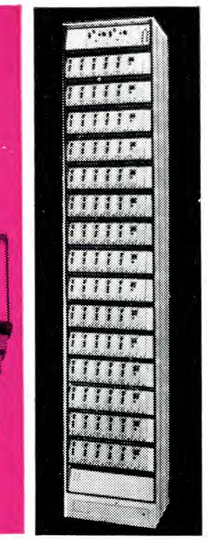
At the two Southampton factories of STC the world's longest submarine cable was produced, costing £5 million and providing 128 transatlantic voice circuits between Britain and the US. Specially designed vessels visit these factories to load cable in up to 1,000 nautical mile consignments. In the late Spring of 1965 a vessel will be calling in to load 750 nautical miles of cable for Spain's first cable link between the Peninsula and the Canary Islands—a £2½ million order for STC. The STC submarine cable factories have a production capacity exceeding that of any other manufacturer in the world and they can supply a transatlantic cable in less than 12 months.

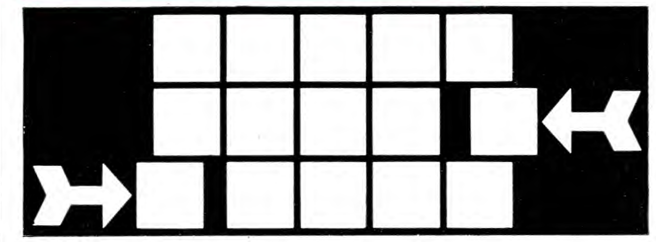
Standard Telephones and Cables Limited, Submarine Cable Division, West Bay Road, Southampton, Hants. Telephone: Southampton 74751.

Lightweights ahead!

STC lightweight headsets are designed for use by private and public telephone operators. These are fast superseding the use of the older breast-type instruments. Main advantages are: Extraordinary light weight, high degree of comfort, stability and manoeuvrability and constant level of transmission regardless of head movement. Made of nylon plastic, and virtually unbreakable, the headsets are available in black and grey (colours approved by the British Post Office) and also in ivory. The "Rocking Armature" principle—an important STC development in telephone receiver design—which gives improved sensitivity and frequency response has been incorporated into these instruments.

Standard Telephones and Cables Limited, Telephone Switching Division, Oakleigh Road, New Southgate, London, N.11. Telephone: ENTerprise 1234. Telex: 21612.



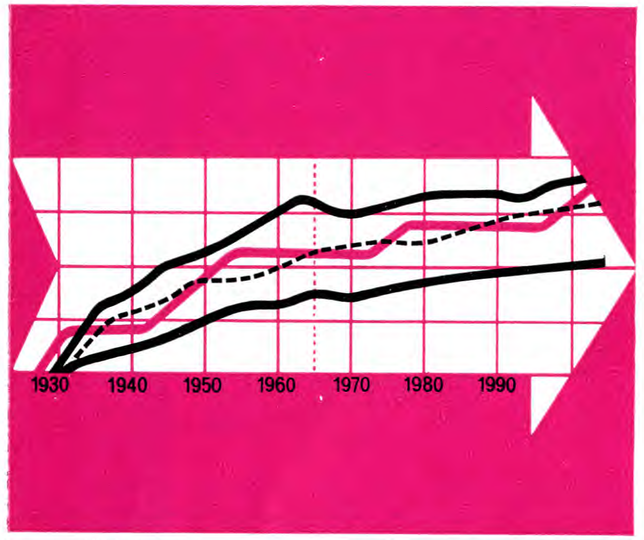


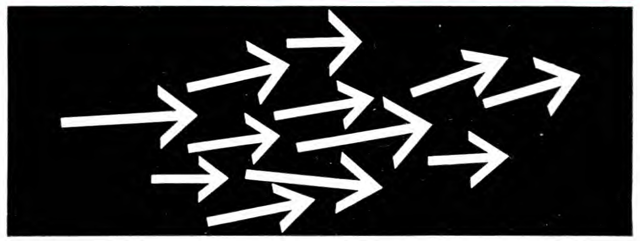
Standard Mark 6 Multiplex

The Standard Mark 6 range of multiplex equipment from STC is for use with all coaxial, carrier-on-cable and radio transmission systems planned to CCITT recommendations for international telephone circuits. Both STC Channel Translating Equipment type XCL2 and STC Group Translating Equipment type XGR1 are high performance transistor equipments which are easy to install and economical on cost and space. Full depth (450mm) racks accommodate equipment shelves which house plug-in apparatus cards and units. Each shelf is a complete wired assembly which provides equipment for a 12-circuit group in the XCL2 and one super group in the XGR1. Fourteen XCL2 shelves (168 circuits) or fifteen XGR1 shelves (75 groups) can be mounted on a 9 ft. (2·74m) rack. Rear access to intershelf and station wiring allows unequipped positions in the racks to be fitted with shelves at any time without disturbing existing circuits.

XCL2 is described in leaflet C/AE48 and XGR1 in leaflet C/AE50.

Standard Telephones and Cables Limited, Transmission Systems Group, Basildon, Essex. Telephone: Basildon 3040. Telex: 1911.

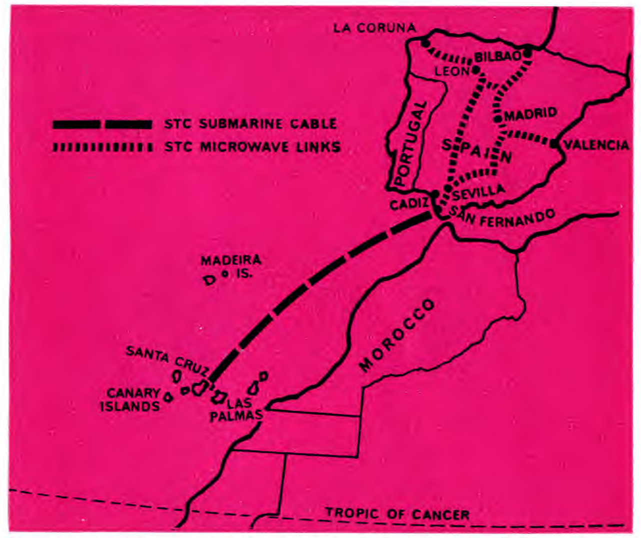


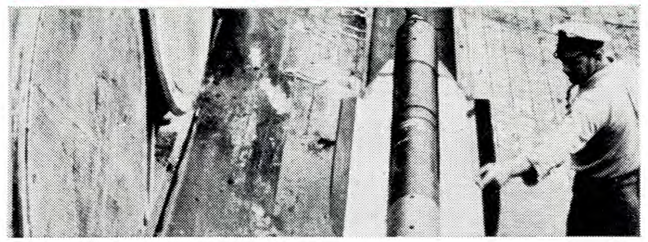


Way ahead

Planning to meet future national and international needs in telecommunications requires wide experience and highly specialized know-how. STC has both. It calls for a team in possession of all the facts, with the ability and understanding to interpret them—assessing requirements for up to twenty years ahead. STC has such a team.
The Market Development Department of the Transmission Systems Group maintains a steadily growing storehouse of network and relevant data—social and economic characteristics, equipment design trends, population growth and movement, industrial and agricultural development—all under constant review. This process of continuous assessment and interpretation of maximum information, aided by special surveys, enables STC to forecast trends and requirements . . . to meet tomorrow's problems halfway. Administrations interested in 5-year or long term planning are invited to contact STC for further information on the available services.

Standard Telephones and Cables Limited, Transmission Systems Group, Basildon, Essex. Telephone: Basildon 3040. Telex: 1911.

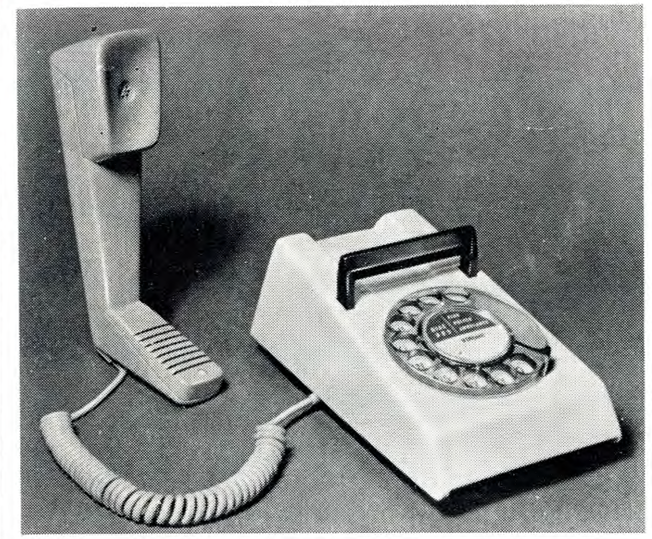


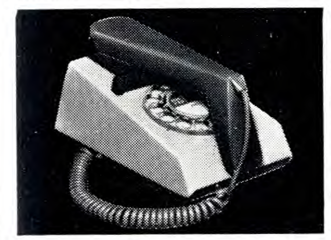


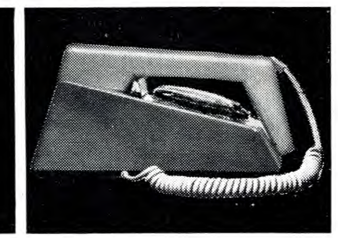
Canaries on the line

STC are manufacturing and laying Spain's first-ever submarine telephone cable link between the Peninsula and Canary Islands. The system is designed for 160 telephone circuits in both directions over a single cable and thus is the highest capacity long-distance cable yet installed. This £2,500,000 order represents a key feature of Spain's major expansion in telecommunications. Service will open later this year. The link, measuring 750 nautical miles—710 miles of deep-sea lightweight cable and 20 miles of shallow-water armoured cable at each end—will connect San Fernando, 10 miles south of Cadiz with Santa Cruz de Tenerife. 45 STC deep-sea repeaters, 3 adjustable submarine equalizers and terminal equipment are being supplied with the cable. STC with its associated company, Standard Electrica S.A., is also providing a microwave link between Tenerife and Las Palmas which will form part of the service. High-quality speech circuits will be provided, day and night, with Europe (direct dialling to Madrid) and North America.

Standard Telephones and Cables Limited, Submarine Cable Division, West Bay Road, Southampton, Hants. Telephone: Southampton 74751. Transmission Systems Group, Basildon, Essex. Telephone: Basildon 3040. Telex: 1911.



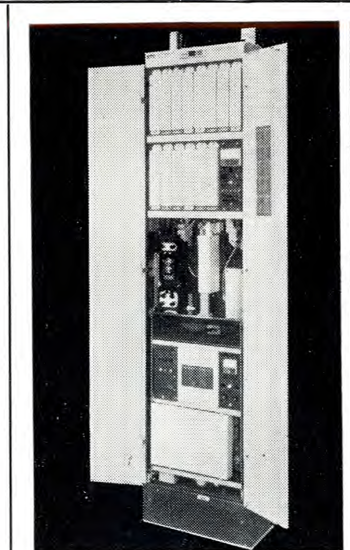


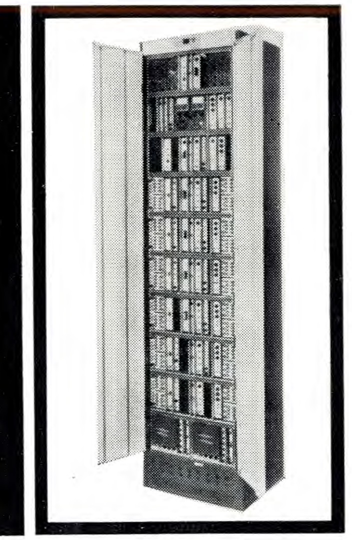


Talking point

Design conscious but supremely functional—the new STC Deltaphone represents an entirely new approach to telephone design. A choice of restrained colours, lightweight handset, electronic tone caller with volume control, optional dial illumination, compactness . . . everything new!
The STC Deltaphone is particularly suited for use in homes, hotels, reception lounges and 'front offices', where harmony of design, functional elegance and prestige are essential. As well as its superb modern appearance, fit to grace any expensive service flat, the basic economies of space and effort give this new telephone utmost utility in offices and other business premises.
High technical specifications match the trend-setting symmetry of this truly new telephone.

Standard Telephones and Cables Limited, Telephone Switching Division, Oakleigh Road, New Southgate, London, N.11. Telephone: ENTerprise 1234. Telex: 21612.





RL6B MICROWAVE RADIO LINK

1800 telephone circuits/maximum transistorization

The 6Gc/s microwave transmission system, RL6-B, can transmit 1800 telephone channels or colour T.V. plus sound per radio channel. Designed to use the C.C.I.R. frequency plan, it will provide up to 8 broadband radio channels on one route. Maximum use of transistors, high performance level, and all-round operational economy are the essential features of the RL6-B.
Main features of the RL6-B:—8 broadband radio channels. C.C.I.R. performance. 10 watt output power from periodic permanent magnet focusing TWT.
Transistorized throughout except TWA and the modem cubicle.
Switching systems available for N+1 or 2 protection channels. Aerials and towers can be supplied.
All solid state narrow-band auxiliary link.
Cassegrain antenna for single or bi-polar operation.
By extensive prefabrication, and simplification of space and installation requirements, considerable savings in commissioning time and a lower overall cost have been achieved. Systems for mains and battery operation can be supplied and a 960 telephone circuit version is also available for lower density traffic routes.

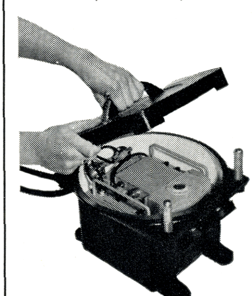
Standard Telephones and Cables Limited, Transmission Systems Group, Basildon, Essex. Telephone: Basildon 3040. Telex: 1911.

world-wide telecommunications and electronics STC

An economical 120-channel coaxial system using a single tube

The ATE/C120A Line Transmission Equipment transmits 120 speech channels in both directions over a single aerial or underground 0.375″ coaxial tube; power feeding, regulation, alarm and monitoring facilities are all included without subsidiary cable paths. Fully transistorised, the C120A is inexpensive to operate—'power feed' is needed only every 200 miles. Installation and maintenance are simple, and can be carried out by staff unfamiliar with coaxial systems. For full details of this economical coaxial line transmission equipment, please write to: Automatic Telephone & Electric Co. Ltd., 8 Arundel St., London, W.C.2, England. Telephone: Temple Bar 9262. *A Principal Operating Company of the Plessey Group.*

Intermediate power feed repeater

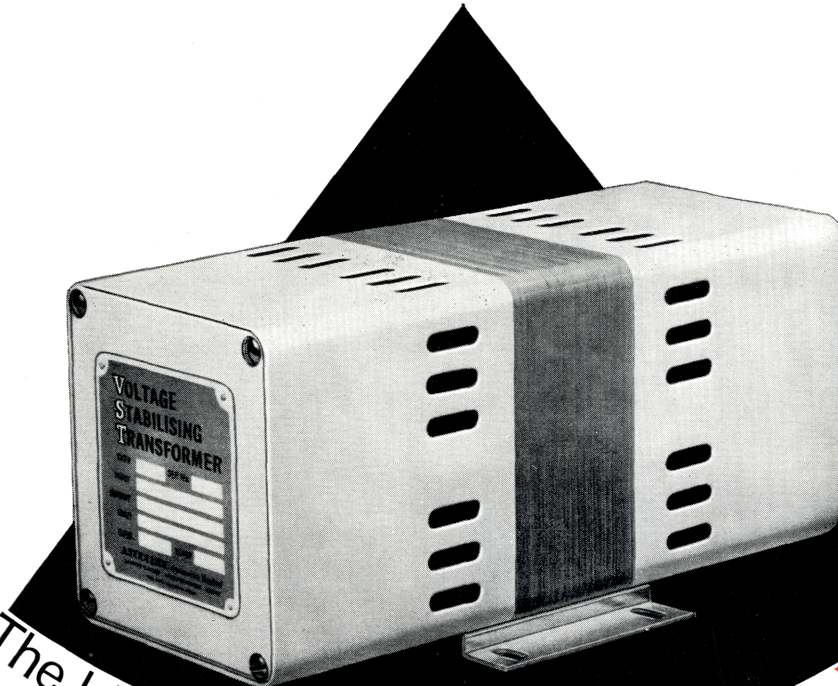


Number of speech channels: 120.
Type of transmission: 2-wire.
Baseband frequency:
- H.F. direction 812-1304 kc/s.
- L.F. direction 60-552 kc/s.

Terminal and main repeaters:
- Input from STE —45 dbr (min).
- Output to STE —20 dbr (max).

ATE(E)23

WHAT'S TRANSFORMER MATION?



The big swing from C.V.T. to Astralux V.S.T.

NEW ASTRALUX VOLTAGE STABILISING TRANSFORMERS OUTNUMBER, OUTPERFORM AND OUTDATE CONVENTIONAL C.V.T. SYSTEMS

Improved Output Voltage Stability. Output voltage maintained within ±0.5% for input voltage changes of +10% —20%. Even when the input voltage fluctuation is as great as +10% —30% the V.S.T. will maintain the output voltage to within ±1%.

Latest Materials. High temperature (Class F) materials used to give optimum reliability and increased safety margins on operating temperatures.

Low External Field. The latest techniques in magnetic core designs are employed to give improved performance coupled with high efficiency and still offer low external fields.

Stable Voltage—Stable Prices. When it comes to cost, you know just where you are with the V.S.T. Astralux make sure their prices don't jump about. You can arrange your costings far more accurately with this new, advanced Voltage Stabilising Transformer.

The Biggest Range—consists of over 9000 Models. The Astralux V.S.T. standard range consists of nine basic models with over a thousand variations on each. No other manufacturer offers such a wide choice—nor such economical prices.

Astralux specialise in low-price 'specials' too. Astralux are geared to produce V.S.T. 'specials' at little more cost than the standard units. The design department will be glad to prepare prototypes to your specification, for incorporation into equipment under development.

FOR ALL YOU WANT TO KNOW ABOUT ASTRALUX V.S.T. write for free illustrated booklet.

ASTRALUX *dynamics limited*

TRANSFORMER DIVISION · BRIGHTLINGSEA · COLCHESTER · ESSEX · TELEPHONE: BRIGHTLINGSEA 417

THE G.E.C. SERIES OF ELECTRONIC EXCHANGES

RS 31 – *now operational*
RS 41
RGS 41
RS 42
RGS 42

G.E.C. introduces a new series of electronic exchanges. All are space-division reed relay systems using modern centralised control techniques.

The first of the series, the RS 31, is now in commission in the United Kingdom Post Office's national network.

The RS and RGS 40 series are fully compatible with existing crossbar and step-by-step systems. They are mounted on G.E.C.'s new 3E equipment practice – shown on the right – which has been specially developed for electronic systems.

Electronics have many advantages over electro-mechanical systems. They are smaller. They are faster, yet quieter. Above all, they are more reliable. And no extra maintenance effort is needed – existing staff can learn the new principles quickly and easily.

Electronics also enable improved subscriber facilities – features such as multi-frequency signalling (whether between subscriber and exchange or from one exchange to another) and short-code dialling can be used to full advantage.

G.E.C. **everything for telecommunications** EXCHANGE DIVISION, G.E.C. (TELECOMMUNICATIONS) LTD · TELEPHONE WORKS · COVENTRY ENGLAND

SP26

we can always pass your message on

M E L

Telecommunications –
The Pulse of Progress

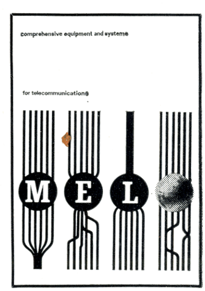
The M.E.L. range of Broadcast Link Equipment contains systems capable of relaying or repeating any type of broadcast signal. There are V.H.F. music links suitable for a fixed link service between studios and broadcast transmitter, and as O.B. links.

In the microwave bands, there are a fixed 4Gc/s radio relay designed for remote and unattended operation as a repeater or terminal station for long distance operation, and a link specially designed for relaying high quality T.V. sound.

The latest addition to our range is a portable broadband link in the 11Gc/s frequency band, transmitting 625 line signals in black and white or colour and permitting two-way failsafe working from one bowl.

But radio links cover only one area in which we specialise. M.E.L. equipment also includes a series of Building Brick type H.F. Transmitters ranging in output from 1 kW to 30 kW, and Lower Power Transmitters with outputs of 100W to 300W, there are also 50W and 250W transmitters and transceivers for ground-to-air communication. Recently introduced is the M.E.L. Transistorised Automatic Error Detection and Correction Equipment based on the use of the 7 unit Code No. 3, for detecting and counter-acting errors in Telegraph Traffic over Radio caused by noise and fading.

Needless to say, we also produce a comprehensive range of ancillary equipment, including radio terminals for telephony, tone modulators, line amplifiers, aerial matching units and transformers, and variable and crystal oscillators.
This interesting, illustrated booklet will tell you much more about our activities in the field of telecommunications. Broadcast Link Equipment, for instance, is fully described on page 6. Make sure of receiving your copy now by dropping us a line today.

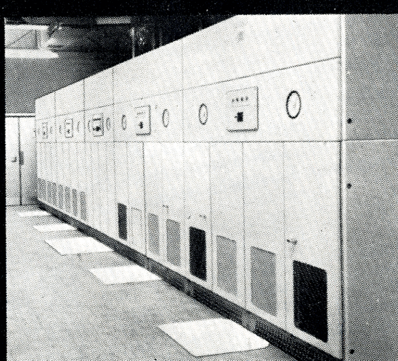


M E L

The M.E.L. Equipment Company Ltd.,
Manor Royal, Crawley, Sussex.
Telephone : Crawley 28787, Telex : 87267.

WESTINGHOUSE

SILICON RECTIFIER POWER PLANT for telecommunications



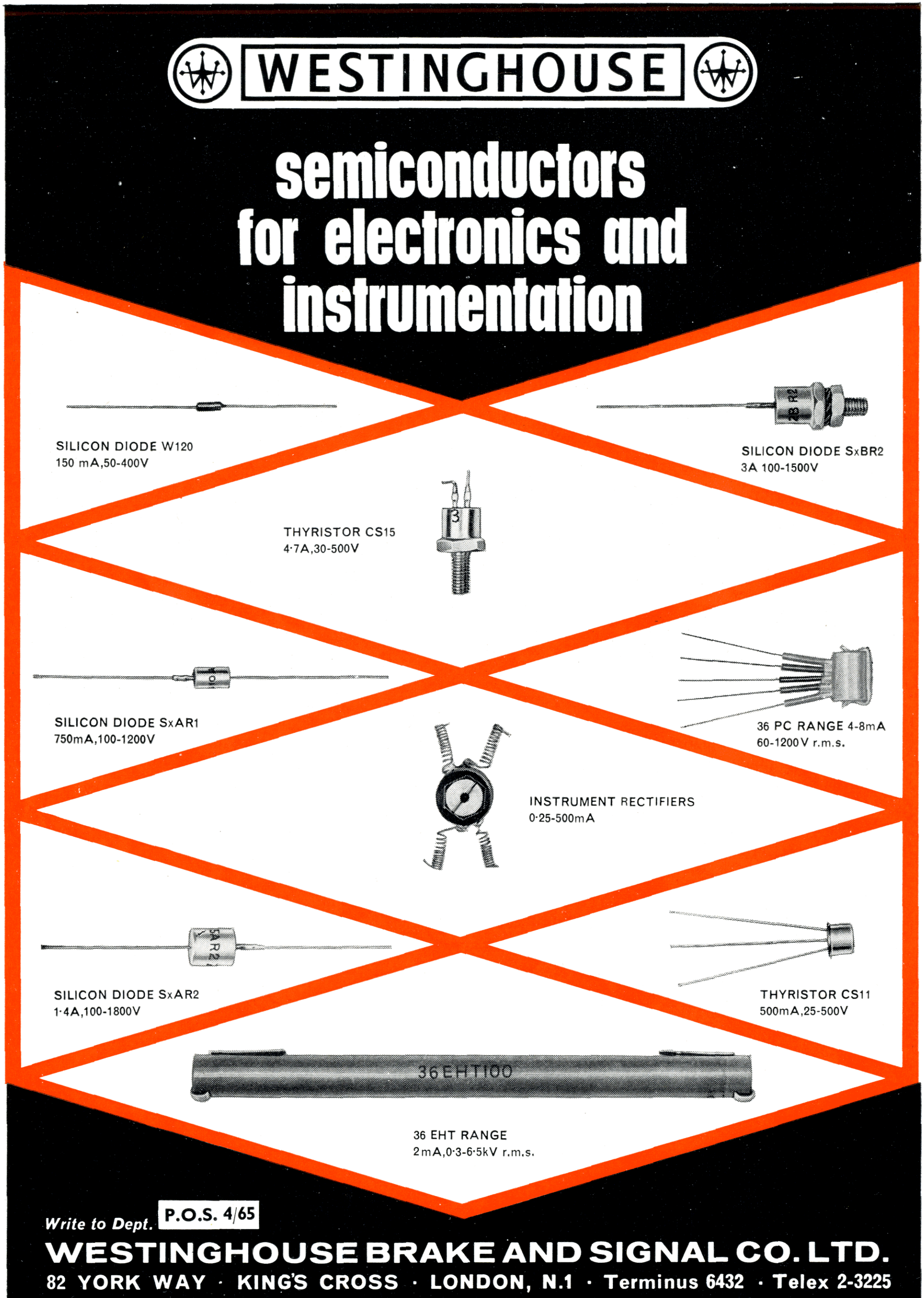
Mechanically regulated constant voltage silicon rectifier equipments as power plant in the Holborn Telephone Exchange of the British Post Office. By courtesy of H.M. Postmaster General.

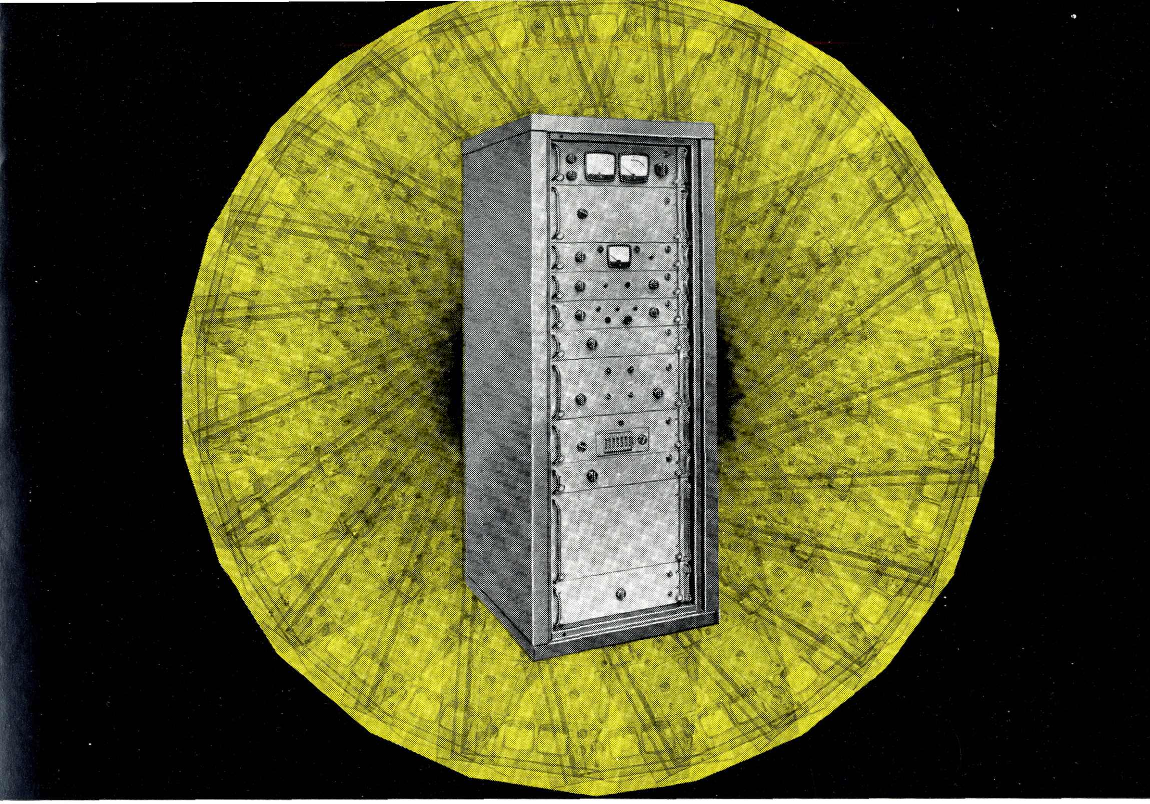
- High overall efficiency down to well below quarter full load
- Close limits of voltage regulation, i.e. less than ±1 per cent from no load to full load
- Sequential switching to ensure that the number of rectifier cubicles feeding the exchange is closely related to the load demands
- Inbuilt smoothing filter associated with each rectifier cubicle to permit maximum flexibility
- Similar power plant of either mechanical or static control can be manufactured to meet all climatic conditions likely to be encountered

WESTINGHOUSE BRAKE AND SIGNAL CO. LTD.

82 YORK WAY, KING'S CROSS, LONDON, N.1.

TERMINUS 6432 · TELEX 2-3225


WESTINGHOUSE
semiconductors
for electronics and
instrumentation
SILICON DIODE W120
150 mA,50-400V
SILICON DIODE SxBR2
3A 100-1500V
THYRISTOR CS15
4·7A,30-500V
SILICON DIODE SxAR1
750mA,100-1200V
36 PC RANGE 4-8mA
60-1200V r.m.s.
INSTRUMENT RECTIFIERS
0·25-500mA
SILICON DIODE SxAR2
1·4A,100-1800V
THYRISTOR CS11
500mA,25-500V
36EHT100
36 EHT RANGE
2mA,0·3-6·5kV r.m.s.
Write to Dept. P.O.S. 4/65
WESTINGHOUSE BRAKE AND SIGNAL CO. LTD.
82 YORK WAY · KING'S CROSS · LONDON, N.1 · Terminus 6432 · Telex 2-3225



Plessey UK PVR 800 receiving system

A range of six basic receivers covering all types of reception over the range 3-27.5 Mc/s.

This all-transistor equipment provides a choice of six basic terminals which are arranged for the reception of Multitone telegraph, FSK, SSB, ISB, DSB.

1. Single path FSK reception
2. Dual diversity FSK reception
3. Single path SSB reception for speech or telegraphy
4. Dual diversity SSB reception for telegraphy
5. Single path ISB reception for speech or telegraphy
6. Dual diversity or twin path ISB reception for speech or telegraphy.

All the receivers have six pre-set crystal controlled channels in the frequency range 3 to 27.5 Mc/s. A synthesiser is also available.

MODULAR CONSTRUCTION Each receiver comprises units built up from transistor modules, standard modules being used throughout where practical.

ANCILLARY UNITS Optional ancillary units are available for all receivers. These include PG 331 Frequency Synthesiser, PV 419 Six-channel Synthesiser Memory, PV 332 Automatic Frequency Control. For multi-channel SSB or ISB Telegraph Service, the PV 182 Telegraph Demodulator and the PV 117 Synchronous Regenerative Repeaters are available either as separate units or built into the PVR 800.

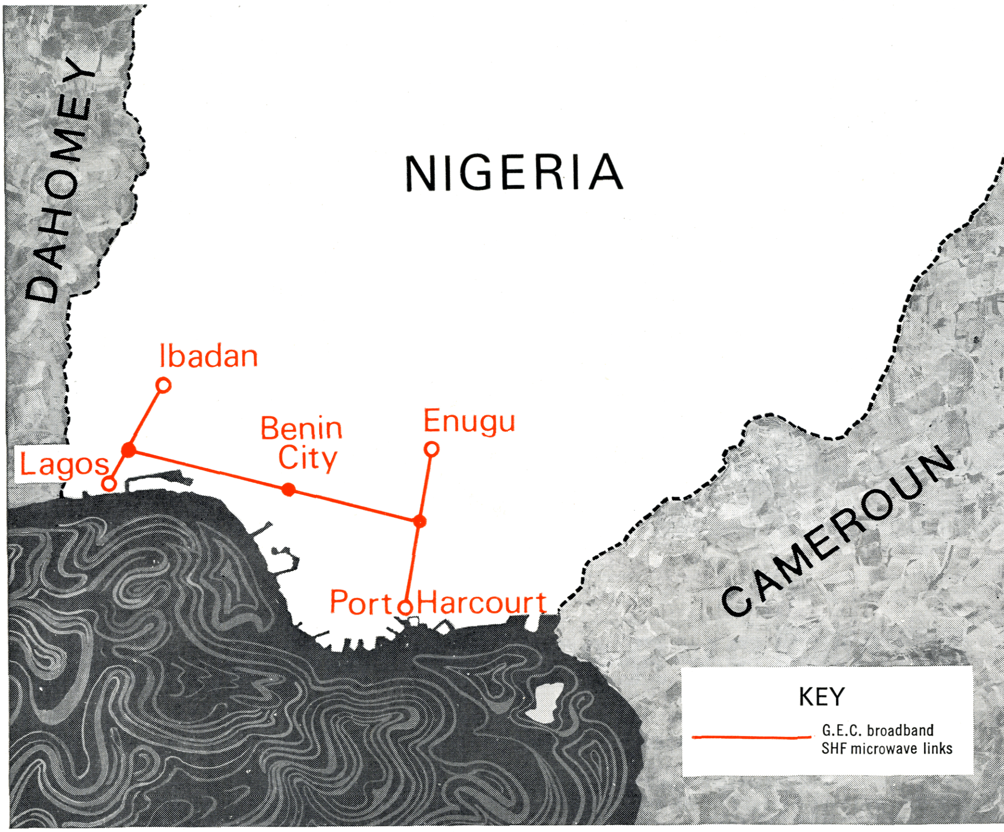
STABLE PERFORMANCE The units in PVR 800 receivers are designed so that their performance is virtually independent of variations in component characteristics. Extensive use of negative feedback reduces spurious signal components, improves linearity, and ensures specified performance over a wide temperature range.

INTERCHANGEABLE UNITS In stations where more than one receiver is in use the modular construction of the PVR 800 brings valuable economies in maintenance, servicing and spare parts holding. Modules can be interchanged between units and equipments, and fault finding can be carried out on a substitution basis—by relatively unskilled personnel—cutting overheads and reducing 'off the air' time to a minimum.

For more details of this series of
versatile HF Receiving Systems, write to :—

PLESSEY-UK LIMITED
Telecommunications Division,
Ilford, Essex. Telephone: Ilford 3040
Telex: Plessey Ilford 23166
Telegrams: Plessey Ilford Telex.

NIGERIA -AND G.E.C.



Against strong international competition G.E.C. has secured the contract for the first step of the new Nigeria Telecommunications System Development Programme. This £$1\frac{3}{4}$ million contract provides for 472 route miles of modern broadband SHF microwave equipment, together with the associated carrier multiplex equipment, all of it fully transistored. This will link Lagos, Ibadan, Enugu and Port Harcourt.

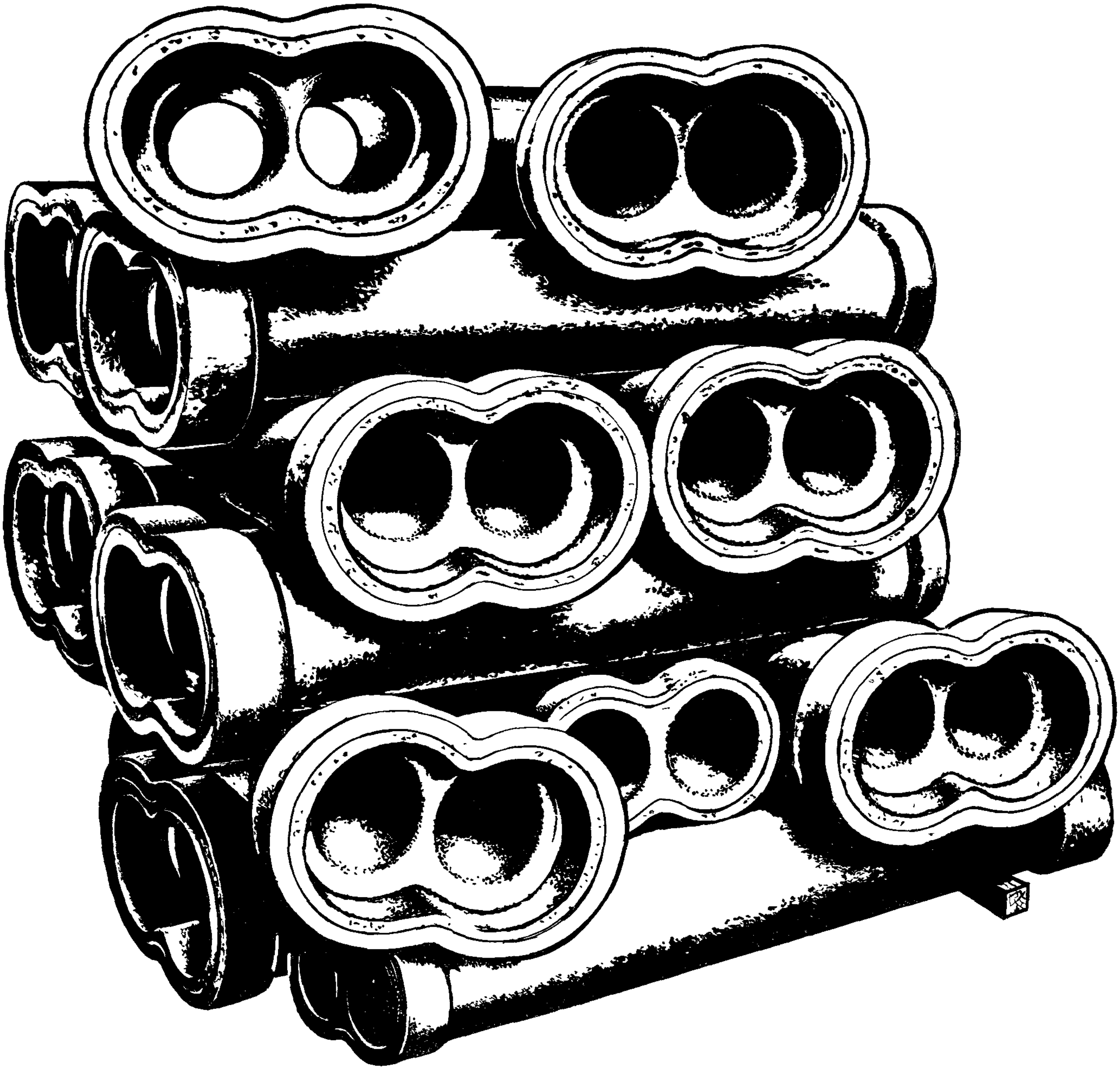
The part of the network linking Lagos with Port Harcourt will be completed by the end of September 1965, and the spurs to Enugu and Ibadan one month later. In addition, G.E.C. will be responsible for building access roads, erecting station buildings and furnishing power plant.

Recent orders for G.E.C. Telecommunications' equipment received from Iceland, Tunisia and El Salvador emphasise its reliability under all climatic conditions and make it the natural choice for any new telecommunication development programme.

G.E.C. everything for telecommunications

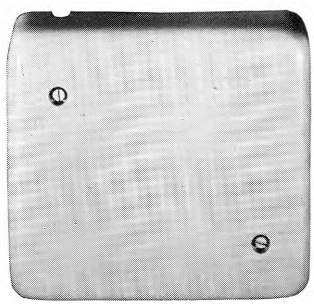
Transmission Division, G.E.C. (Telecommunications) Ltd · Telephone Works · Coventry · England

SP25



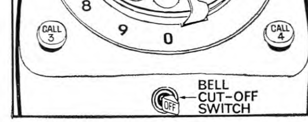
take five of these...

and one of these...



and you have a complete 2+5 Keymaster system

In the modern, compact business, the surrender of space to a switchboard, and the allocation of staff duties for its surveillance, are equally unacceptable.
The 2+5 'Keymaster' system provides a basis of communication free from these disadvantages.
The development of the 2+5 'Keymaster' has resulted in a notably compact system, simpler to operate than its predecessors and of unusually low installed cost.
The facilities offered include all those likely to be required by an intermediate-sized business and are comparable with those hitherto associated with appreciably larger desk units and much more complex central apparatus.
An important feature of the system is the low operating voltage.
Six-volt power requirements may be derived from dry batteries or a mains operated power unit.
Normally, provision is made for 5 stations, but 7 stations and other variations are available.
For further information please contact Sales Dept. Ericsson Telephones Ltd., Beeston, Nottingham.



ERICSSON TELEPHONES LTD • ETELCO LTD

A Principal Operating Company of the Plessey Group

Head Office and Main Works: Beeston, Nottingham. Tel: 254831. Telex: 37666
Registered Office: 22 Lincoln's Inn Fields, London W.C.2. Tel: HOLborn 6936

ER102

✱ 60-CHANNEL 'COMPAC' LINK ✱ 120-CHANNEL 'CANTAT B' LINK ✱ 420-CHANNEL U.K-BELGIUM LINK

and now transistorised terminal equipment

Provides 480 channels on new North Sea Cable Systems | U.K-Norway | U.K-Holland | Norway-Denmark

A.E.I. is to supply fully transistorised terminal equipment for new 480-channel North Sea Cable systems for shore installations in the U.K, Norway, Denmark and Holland. The channel capacity can be increased by one third with the use of 3 Kc/s channelling equipment. This new contract follows A.E.I.'s substantial contributions to CANTAT B, COMPAC and SEACOM 1 sections of the Commonwealth cable system, and the recent 420-channel U.K-Belgium project. It provides striking endorsement of A.E.I.'s specialised experience.

Where reliability matters – AEI equipment is used.

- Fully transistorised.
- C.C.I.T.T. performance on 480 channels at 4 Kc/s spacing.
- 640 channels at 3Kc/s spacing.
- Frequency range 300-4800 Kc/s.
- At least four 2 Kc/s engineering service circuits can be provided independently.
- System equalised with provision for adjustment.
- Compensated for sea temperature variation.
- With repeater supervisory and system monitoring facilities.
- Constant current equipment to power the submerged repeaters, with full protection.

AEI
COMMUNICATIONS

ASSOCIATED ELECTRICAL INDUSTRIES LIMITED
TELECOMMUNICATIONS TRANSMISSION DEPARTMENT
WOOLWICH, LONDON, SE18

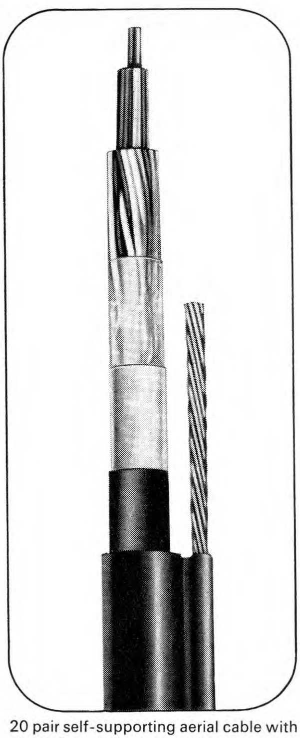
AEI EXPERIENCE SPANS THE WORLD

TA-(8-1) 668

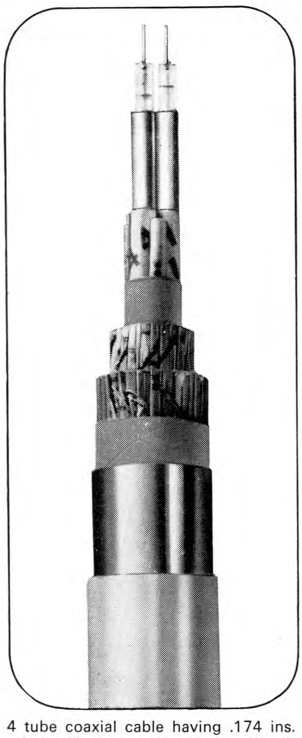
telephone cables from

TCL

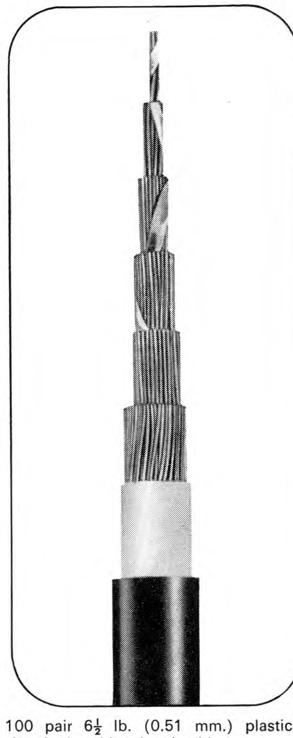
TCL are the largest company in Europe exclusively concerned with the manufacture and supply of telephone cables. The range is extremely comprehensive covering dry-core and plastic cables for every purpose. A selection of TCL cables is shown below. A complete technical advisory service is at your disposal.



20 pair self-supporting aerial cable with aluminium foil screen. Plastic sheath and insulation.



4 tube coaxial cable having .174 ins. tubes and audio pairs with lead sheath and plastic protection.



100 pair $6\frac{1}{2}$ lb. (0.51 mm.) plastic sheathed and insulated cable.

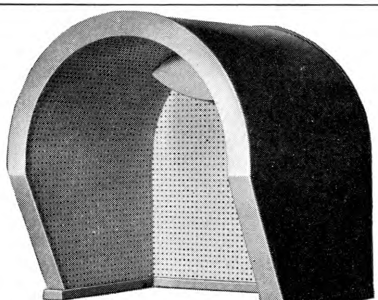
TELEPHONE CABLES LIMITED Dagenham England. Telephone: DOMinion 6611. Cables: Drycore Dagenham.

THE ORGANISATION WITH 125 YEARS' EXPERIENCE.

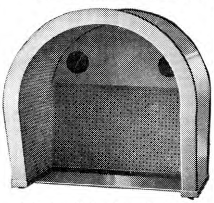
WHITELEY

for acoustic hoods

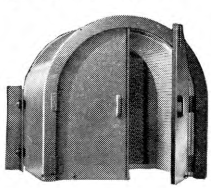
All noisy environments such as factories, workshops, department stores and hotels require the facility of an acoustic hood which permits telephone conversations to be held without the interference of annoying background noises. Whiteley acoustic hoods are strongly made from resin bonded ply and finished in a cellulose enamel which makes these suitable for indoor or outdoor use.



Standard Hood Dimensions 25″ high x 20¼″ deep x 24½″ wide



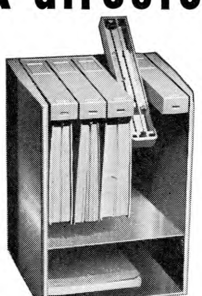
Fitted with loudspeakers



Fitted with doors for outdoor use

Also available with internal light and/or a storage shelf below hood

& directory holders



These attractive, and extremely functional, directory holders will hold five directories neatly and securely, in individual swivel holders permitting easy identification and reference. The lower shelf provides additional storage space. The units are of cast alloy and are finished in an attractive grey epoxy resin enamel and constructed to strict G.P.O. design specifications.

Directory Holder Dimensions
17¼″ high x 13½″ wide x 13⅜″ deep

For further details please write or telephone.

WHITELEY ELECTRICAL RADIO CO. LTD
Mansfield · Notts. Telephone: Mansfield 1762-5

WB178

Tape Sealing No. 3 (DENSOPOL ZN) being used to protect a joint in thin lead sheathed, polythene oversheathed cables by the G.P.O. Experimental Jointing Division. Winn & Coales Ltd. have been suppliers to the Post Office of waterproofing and anti-corrosion tapes for over 25 years.

SECURELY SEALED WITH

DENSO

The DENSO system is the efficient, simple and economic answer to many needs of telecommunications systems—waterproofing, sealing, corrosion prevention above ground, below ground and under water.

These DENSO PRODUCTS conform with Post Office Specifications:

DENSO Tape—Tape Sealing
DENSELT Tape—Tape Protecting No. 1
DENSO Paste—Paste Sealing
DENSO Mastic (Plast.)—Compound No. 16
DENSOPOL ZN—Tape Sealing No. 3

WINN & COALES LTD.

Denso House, Chapel Road, London, S.E.27
Tel: GIPsy Hill 7511

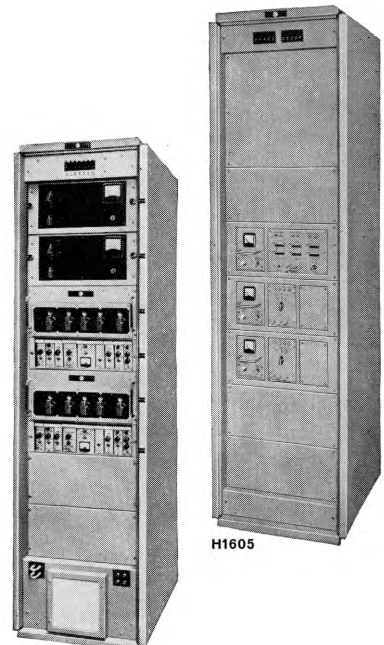
Also at Manchester, Belfast and Dublin. Agents throughout the Commonwealth.

Marconi Self-Tuning H.F System
—the first in the world to be station
planned from input to output

breakthrough

MST drive systems for h.f transmitters

MST drive systems meet all CCIR Recommendations



H1605

H1601

H1601

Comprehensive synthesizer drive assembly for two independent transmitter channels
Inputs: audio frequencies (6 kc/s bandwidth) or d.c
Outputs: modulated signals at radiated frequencies, 2 W p.e.p
Types of modulation: i.s.b with floating carrier, pilot carrier or fully suppressed carrier; d.s.b; c.w 400 bauds; f.s.k 200 bauds or 3500 bauds; frequency shift diplex
Frequency range: 2—27.9999 Mc/s
Frequency selection by decade dials on frequency synthesizers
Stability: determined by 1 Mc/s master frequency

H1605

1 Mc/s master frequency source
Frequency stability: $\pm$ 1 part in 10^8

one-man control

With the compact MST drive system, self-tuning transmitters and MST control and monitoring equipment, one man can operate an entire transmitting station from a central point.

reliability

All units (except the distributed amplifier) are fully transistorized and use printed wiring. Each unit has a separate power supply. The 1 Mc/s master signal distribution is duplicated, and the master frequency source uses three oscillators to ensure immediate automatic changeover in the event of output failure or excessive frequency drift.

versatility

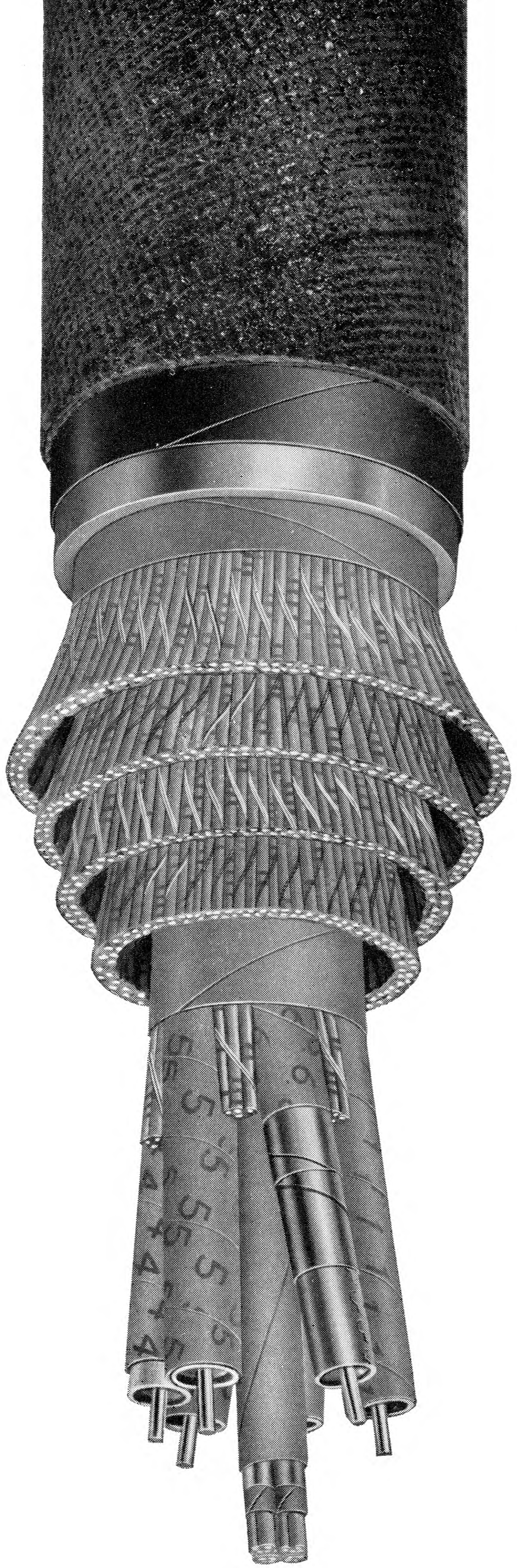
Any drive channel can generate any type of modulation. F.S.K and f.s diplex signals are generated by shifting the frequency of 2 kc/s or 4 kc/s tones—thus one transmitter can radiate simultaneously two or more telegraph channels and an s.s.b channel.

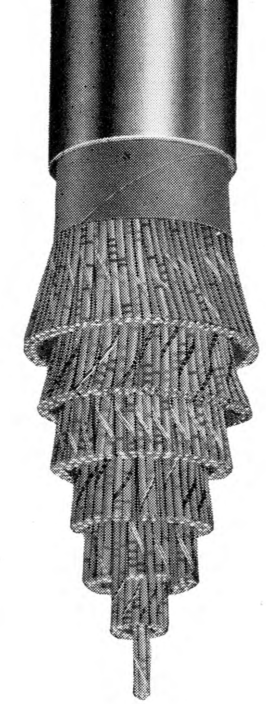
Plug-in modules give switch selection of services normally required. Logic circuits prevent selection of two conflicting services. Extra plug-in modules can be supplied for any other types of modulation. A wideband amplifier simplifies frequency selection to a single operation—adjustment of the synthesizer decade dials.

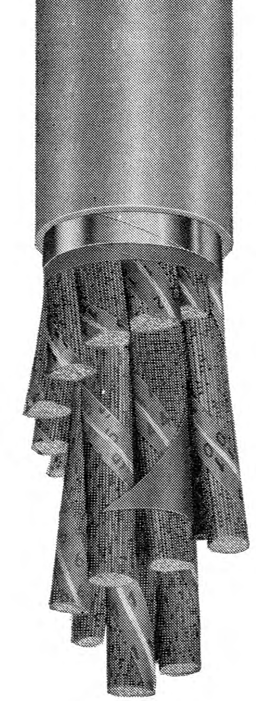
Marconi telecommunications systems

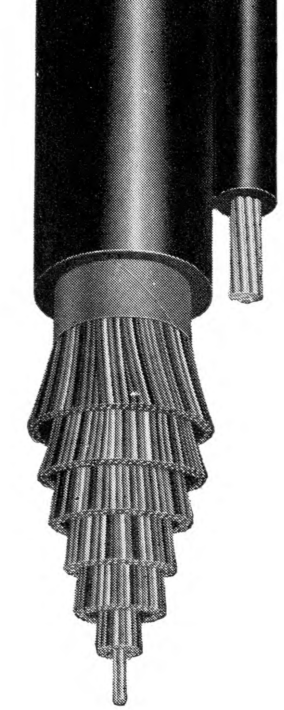
The Marconi Company Limited, Communications Division, Chelmsford, Essex, England

LTD/H52









INDEX TO ADVERTISERS

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When measuring transmission quality, too much information on the spectrum clouds the issue.
This Gresham Waveform Generator tells you all you want to know about *the system under test* – and cuts out all extraneous information. Based on a design developed by the B.B.C., it employs the 'sine-squared' pulse technique; the pulse contains no energy other than that within the pass-band of the system.
You have the choice, when operating, between a free-running non-composite waveform and a full composite video waveform locked to station synchronising pulses. In either case your waveform is a clear and true expression of transmission qualities – quick and easy to interpret by the engineer.

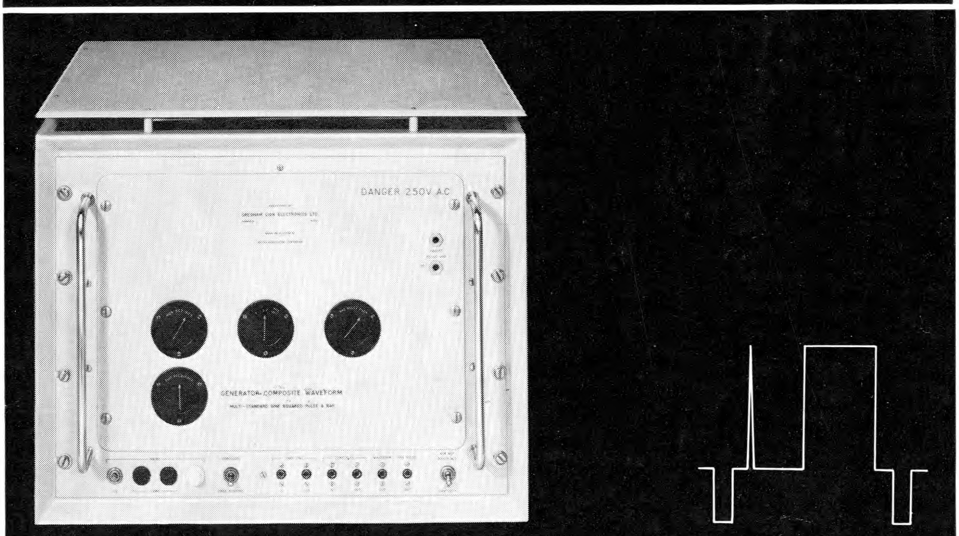
Supplied as a portable unit, or for standard 19″ rack mounting. Indicates variation in gain with frequency; phase distortion; insertion gain; ringing and reflections. Can also be used for measuring field-time waveform distortion, and for examining non-linear distortion. Multi-standard for 405, 525 or 625-line operation.

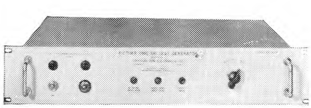
GRESHAM LION ELECTRONICS LIMITED
Twickenham Road, Hanworth, Middlesex, England
TWIckenham Green 5511. Cables: Gresham, Feltham, Middlesex

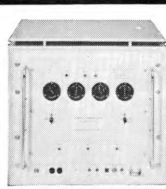
GRESHAM

TV Test Waveform

the truth and nothing but...







ABOVE Gresham Type CPB2 sine-squared pulse and bar composite waveform generator.

LEFT PL4 Picture line up generator.

RIGHT SL3 'Staircase' linearity waveform generator.

ERICSSON

FLOOR PATTERN P.M.B.X. CORD-TYPE SWITCHBOARD

Introduced to meet the need for a switchboard in contemporary idiom, this new design incorporates many exceptional features made possible by forward thinking, new materials and modern manufacturing techniques. Already serving with distinction in many offices, reception areas and similar locations, these switchboards set new standards in functional efficiency and visual appeal and will give completely trouble-free service for many years ☐ Available as Magneto and C.B. types, they are designed for use as single or multiple units. The standard colour scheme is light buff with a faint pattern for the main surfaces, pale mushroom for the top of the keyshelf and black for the plug-shelf and face equipment ☐ The main panels which are removeable for easy access to equipment, are held in position by aluminium trimmer strips in anodized bronze, thus making alternative colour schemes readily available ☐ For further information write to Head Office, Beeston, Nottingham.

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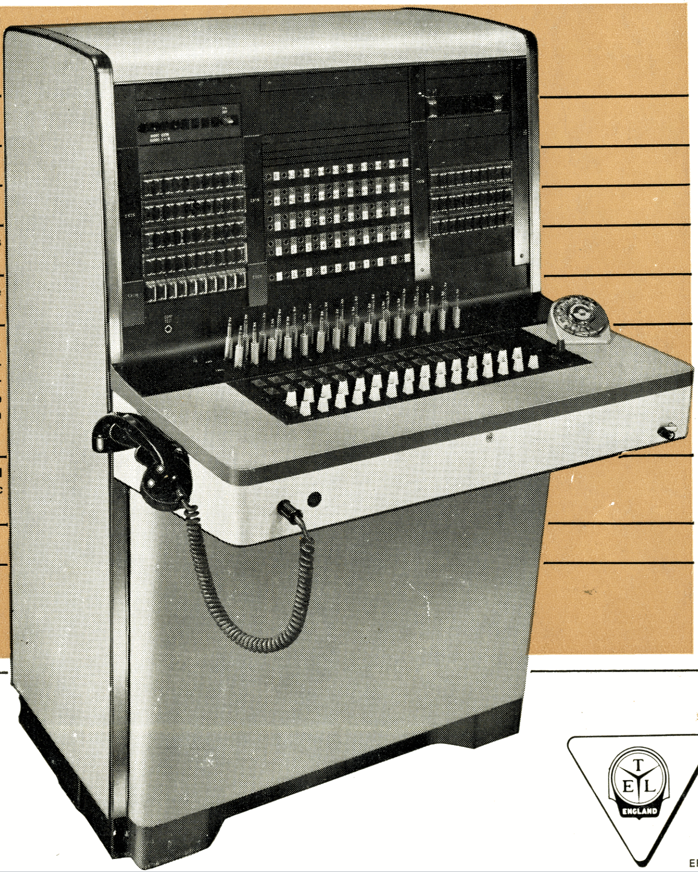
- Cord test and night service facilities on C.B. switchboards.
- Magneto switchboards have single positive supervision.
- C.B. switchboards have through dialling and clearing, double positive or double negative supervision, operator re-call, follow-on call signal, exchange prohibition. A lamp signalling version is also available.
- Welded pressed steel frame covered by replaceable laminate plastic panels.
- Fully tropicalized.



ER91