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# THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

Vol. 59 Part 2 JULY 1966

## CONTENTS


Page

DECENTRALIZATION OF LONDON'S TRUNK AND TANDEM TELEPHONE EXCHANGES—H. E. Francis, O.B.E., M.I.E.E., and E. Davis, A.M.I.E.E. .... 75

GASES IN UNDERGROUND PLANT AND THEIR DETECTION—J. O. Colyer, B.Sc.(Eng.), A.M.I.E.E., R. Tharby and R. C. Senior .... 80

THE DEVELOPING RELATIONSHIP BETWEEN THE MAN AND THE COMPUTER—C. A. May, M.A., A.M.I.E.E. .... 85

BRITISH JOINT COMPUTER CONFERENCE, 1966—D. V. Davey, A.M.I.E.E., A.M.I.Mech.E., S. F. Denning, Dip.Tech.Eng., Graduate I.E.E., and F. C. Heward .... 91

THE USE OF X-RAY DIFFRACTION TO STUDY DEFECTS OCCURRING DURING SILICON-DEVICE MANUFACTURE—J. C. Henderson, B.Sc., A.Inst.P., and Mary A. Halliwell, B.Sc., Graduate Inst.P. .... 94

THE LONDON RADIOPHONE SERVICE—J. L. Hyatt, A.M.I.E.E. .... 98

LAYING PLASTIC DUCTS BY MOLEPLOUGH—S. L. F. Fagg and W. T. Wilson .... 104

ALUMINIUM CONDUCTORS FOR TELEPHONE CABLES—H. C. S. Hayes, C.G.I.A., M.I.E.E. 106

A MODEM FOR THE DATEL 600 SERVICE—DATEL MODEM No. 1A—L. W. Roberts and N. G. Smith .... 108

THE COMMONWEALTH TELECOMMUNICATIONS CONFERENCE 1965–1966—H. Williams, A.C.G.I., M.I.E.E. .... 116

INCOMING CORE-TYPE REGISTER-TRANSLATOR FOR DIRECTOR AREAS, Part 1—Principles of Design—C. K. Price and W. A. Ireland .... 119

THE NEW LEAFIELD RADIO STATION, Part 1—General Principles—D. E. Watt-Carter, M.I.E.E. 130

NOTES AND COMMENTS .... 135

INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS .... 138

REGIONAL NOTES .... 140

ASSOCIATE SECTION NOTES .... 142

STAFF CHANGES .... 146

BOOK REVIEWS .... 84, 93, 134



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THE POST OFFICE
ELECTRICAL ENGINEERS' JOURNAL

Vol. 59 Part 2 JULY 1966

# Decentralization of London's Trunk and Tandem Telephone Exchanges

H. E. FRANCIS, O.B.E., M.I.E.E., and E. DAVIS, A.M.I.E.E.†

U.D.C. 621.395.37:621.395.722

**A study of the long-term requirements of the London trunk and junction network by a Task Force of engineering, scientific and traffic staff has resulted in a plan for the partial decentralization of trunk and tandem exchanges. The director area is to be divided into a 4-mile radius central area and seven outer areas or sectors, each sector being served by a sector switching centre handling trunk and junction traffic. The existing trunk and tandem exchanges in central London are to be retained, though there will be changes in their functions.**

## INTRODUCTION

THE growth of London's telephone service in recent years, and particularly the rapid increase in trunk traffic, led to the setting up of a special team of engineering, scientific and traffic staff to prepare an outline long-term plan for the routing and switching of trunk and junction traffic. The team, which was known as the London Trunk and Junction Network Task Force, completed its study in August 1965 and recommended that there should be a measure of decentralization of trunk and tandem exchanges. The recommendations are being implemented, and this article describes the salient features of the long-term plan.

The study was concerned primarily with the period 1970–2000 and related to telephone traffic originating or terminating in the London director area.

## EXISTING ARRANGEMENT

The existing London trunk and junction network is based on a group of trunk, toll and tandem exchanges in central London. The trunk and toll exchanges at present handle some through traffic, but this is being transferred to the new zone centres that have recently been established at Cambridge, Reading and Tunbridge Wells. By about 1970 the central trunk and toll exchanges will be limited to switching traffic originating or terminating in the director area, and by this time nearly all inland telephone calls will be dialled by subscribers.

The London director area includes all exchanges within about 12½ miles of Oxford Circus. In this area there are at present some 1½ million exchange lines connected to nearly 250 director exchange units, each having a potential capacity of 10,000 subscribers' numbers. By 1970 there will be approximately 330 director exchange units in 173 buildings; there will also be two main tandem and five sub-tandem exchanges, as at present, and 14 trunk and toll exchanges, all in central London.

Approximately two-thirds of the telephone traffic between local exchanges within the director area is carried by direct junctions between individual exchanges, the remainder being indirectly routed via a tandem exchange; the principal routings are shown in Fig. 1.

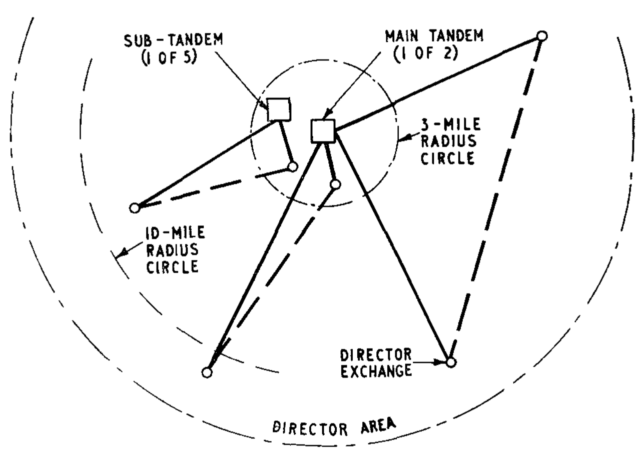
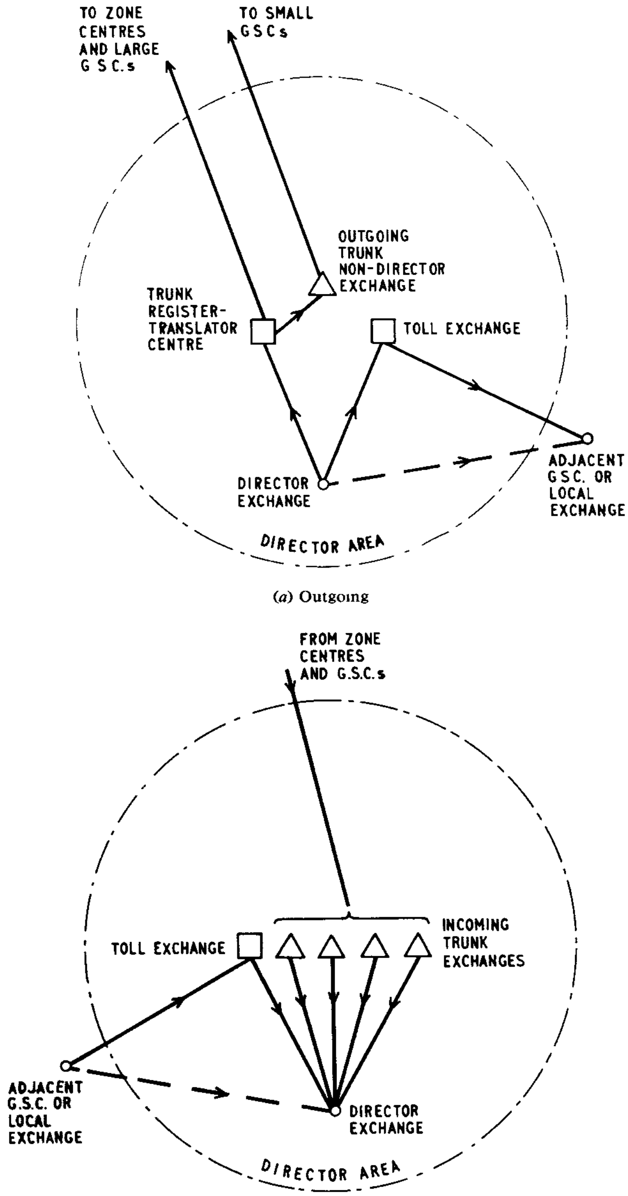



FIG. 1—PRINCIPAL EXISTING ROUTINGS FOR WITHIN-DIRECTOR-AREA CALLS

Traffic between London and the adjacent charging groups, which include nearly 100 exchanges between some 12½ and 20 miles from central London, is routed either over direct circuits or switched via a toll exchange; most of the traffic between London and exchanges beyond the adjacent charging groups is handled by separate trunk exchanges, though some of the shorter-distance trunk traffic incoming to London is still routed via one of the toll exchanges. The differences between trunk and toll exchanges are reducing and, in due course, the need for the distinction may disappear. The routing of sub-

†London Trunk and Junction Network Task Force.

scriber dialled trunk and adjacent-charging-group calls is broadly illustrated in Fig. 2; the majority of such calls are completed over single trunk links between London and the distant group switching centres (G.S.C.), nearly




(b) Incoming

FIG. 2—PRINCIPAL EXISTING ROUTINGS FOR TRUNK AND ADJACENT-CHARGING-GROUP CALLS

all the remainder being routed via 2-wire-switched provincial zone centres. A 4-wire-switched national transit network[1] is being provided for multi-link trunk calls and will eventually displace the zone-centre network.

A feature of the existing network is that trunk traffic outgoing from a director exchange can be carried by a single group of junction circuits, though the circuits in the group may be divided between two register-translator centres, but it is necessary for each incoming trunk exchange to have individual groups of circuits to every director exchange, resulting in many junction routes of only a few circuits, particularly to suburban exchanges.

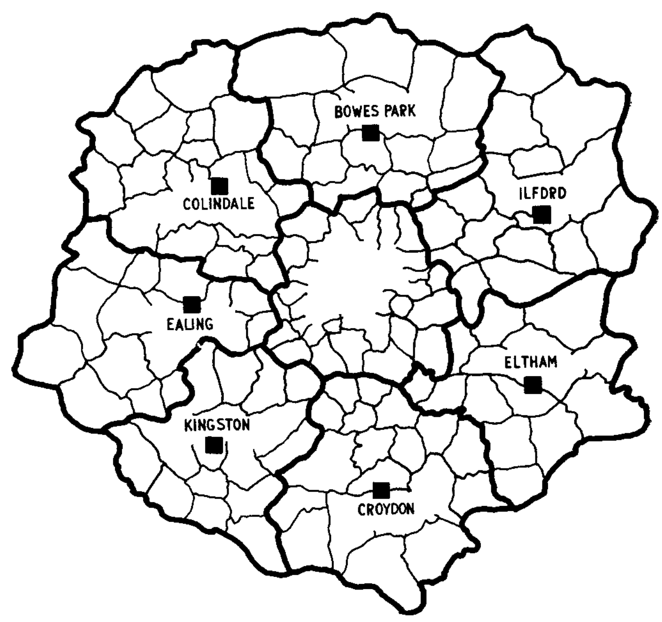
## TASK FORCE STUDY

The long-term plan described in this article was formulated by the Task Force after a detailed study of many alternative arrangements for the routing and switching of trunk and junction traffic. These were considered from the points of view of cost, transmission performance, managerial control, standard of service to the customer, and physical disposition of telephone switching equipment and line plant. The economic comparisons were based on forecasts of telephone traffic up to the year 2000 and on estimates of probable future technical advances and price trends; particular regard was paid to the high cost of building sites, and the difficulty of obtaining them, in central London for trunk and tandem exchanges.

Extensive use was made of computers for preparing detailed traffic forecasts, for calculating exchange-equipment and line-plant costs, and for routing traffic, as well as for analysing and summarizing various statistics.

## PLAN FOR DECENTRALIZATION

The study led to the conclusion that there were overall advantages to be gained from a measure of decentralization of switching equipment and line plant. The plan that was recommended and has now been adopted divides the director area into eight parts, comprising a central area of 4 miles radius surrounded by seven outer areas or sectors, as shown in outline in Fig. 3. About




■ Approximate locations of sector switching centres
FIG. 3—LAYOUT OF DIRECTOR AREA FOR LONG-TERM PLAN

two-thirds of London's subscribers and exchanges will be located in the seven sectors, the boundaries of which will largely coincide, so far as the director area is concerned, with those of the outer-London Telephone Managers' Areas.

The sectors will each be served by a multi-purpose sector switching centre (S.S.C.), the seven S.S.C.s together handling about half the within-director-area tandem traffic, one third of London's trunk traffic, and up to half the traffic between London and the adjacent charging groups. The existing trunk exchanges will be rearranged to serve the central area only, and there will be some limitation of the functions of the other existing 2-wire switching units in central London; these will be augmented as necessary. One or more 4-wire switching units will be provided in central London for handling multi-link traffic.

*Existing 2-Wire Switching Units*

The existing sub-tandem exchanges will be largely confined to switching traffic between central London and the inner suburbs, while one or both the main tandem exchanges will be retained, principally for switching traffic from one side of the director area to the other. The remaining within-director-area traffic not justifying direct junctions will be routed via the local-tandem portion of an S.S.C.

Each director exchange in the central area need have access to only one outgoing trunk exchange, but it will have to be directly connected to every incoming trunk exchange serving the area. Each outgoing and incoming trunk exchange will have direct high-usage and fully-provided routes to and from a large number of provincial G.S.C.s, with connexion to 4-wire switching units for the routing of residual inland traffic, and to the international exchanges for overseas traffic.

Most calls from adjacent-charging-group exchanges to the director area are now dialled by customers using the national-number dialling procedure, and there will be a progressive change to the same procedure for calls from the director area to the adjacent charging groups. The traffic will then be handled in a similar manner to trunk traffic and there will not be the same need as in the past for separate toll exchanges.

*Sector Switching Centres*

The seven S.S.C.s will be located some 8 or 9 miles from the centre of London, and sites for them are now being sought in the neighbourhood of Bowes Park, Ilford, Eltham, Croydon, Kingston, Ealing and Colindale. It is planned to bring the centres into use between 1971 and 1975.

The functions of the S.S.C.s will be closely analogous to those of provincial G.S.C.s. Nearly all the junction routes connecting each S.S.C. to the director exchanges in its sector should be less than 6 miles in route length, allowing the provision of 4·5 db circuits in 10 lb/mile loaded cables, without the need for amplification or long-distance signalling systems. Each S.S.C. will be connected, as economically justified, to director exchanges in the 4-mile circle and in other sectors to carry within-director-area traffic, and to G.S.C.s and local exchanges in the adjacent charging groups. For inland trunk traffic, each S.S.C. will be connected to provincial G.S.C.s, by high-usage and fully-provided routes, and to the 4-wire switching units in central London; for overseas traffic it will be connected to the international exchanges.

Each S.S.C. will incorporate a large automanual centre.

*Four-Wire Switching Units*

The 4-wire switching units in central London will handle the residual trunk traffic not carried by the high-usage and fully-provided direct routes between S.S.C.s or central trunk exchanges and provincial terminal G.S.C.s. These 4-wire units will switch traffic over direct routes between London and many of the smaller provincial G.S.C.s, and will, in addition, provide connexion to the national transit network. These two functions may be carried out by separate switching units or by a combined unit.

*Routing of Traffic*

The principal routings for subscriber-dialled calls within the director area are shown in Fig. 4, from which

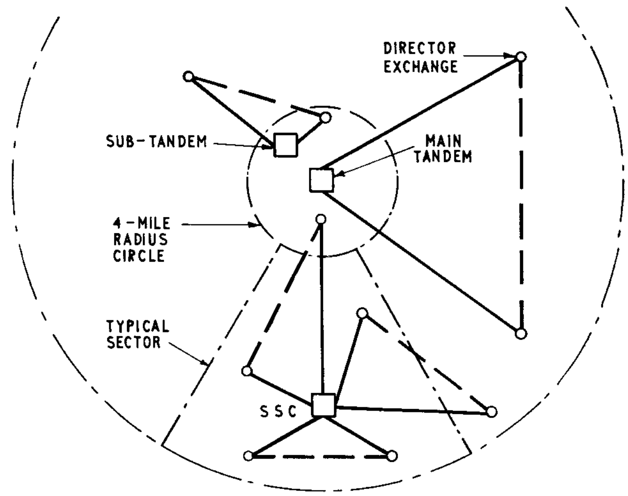



FIG. 4—LONG-TERM PLAN FOR WITHIN-DIRECTOR-AREA TRAFFIC

it will be seen that routing of calls via two tandem exchanges is not visualized, though it may be unavoidable for some operator-dialled calls.

The routing of subscriber-dialled traffic between a suburban sector and the provinces is shown in Fig. 5.

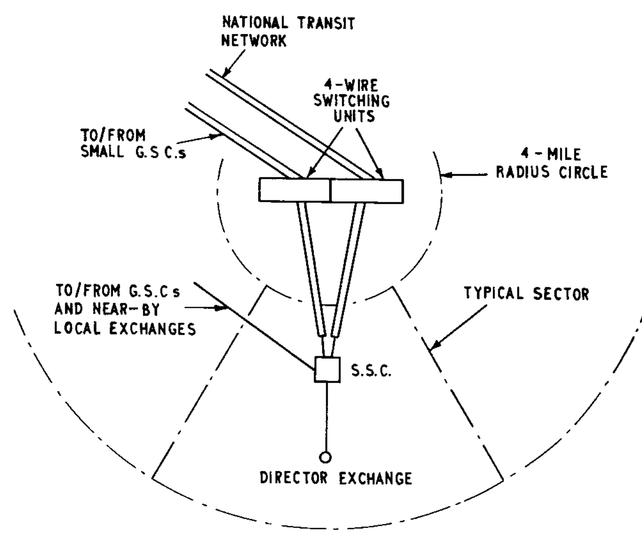



FIG. 5—PRINCIPAL ROUTINGS BETWEEN A LONDON S.S.C. AND THE PROVINCES

During the early years after the introduction of S.S.C.s some traffic will be routed via provincial zone centres; the diagram shows the long-term arrangement. The routing of traffic between the 4-mile circle and the provinces will be very similar to the existing arrangement (see Fig. 2), though, in due course, traffic not carried by direct trunk routes will be handled by the 4-wire switching units.

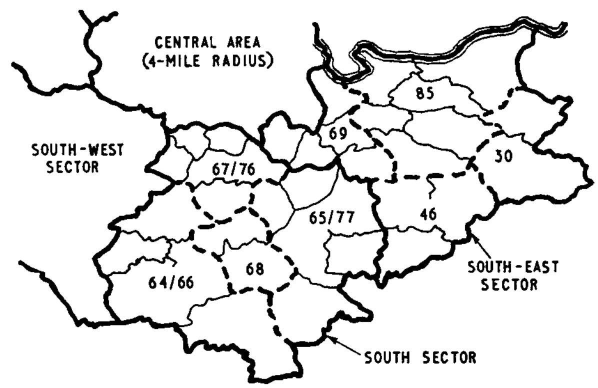
So far as traffic incoming to London is concerned, it is necessary for the register-translator at the provincial centre to identify the particular sector to which a call should be routed. Current types of controlling register-translator are designed to examine, for routing and charging purposes, the first three digits of the national number following the prefix digit 0. On calls to London the national number is of the form 01-ABC xxxx, and controlling register-translators normally examine only the 1AB digits. They can, if required, examine an extra one or two digits of up to 30 3-digit codes, though this facility is already used for a number of purposes, including determining the charge for a subscriber-dialled international call.

The C digit which, together with the AB digits, identifies a particular London exchange, is the fourth digit received by the controlling register-translator. There are a possible 80 AB codes in the numbering range 20–99 and all of these will eventually be needed in London with all-figure numbering, though, with the current use of 3-letter codes forming the first three letters of the exchange name, only some 60 of the AB codes are in use or can be allocated. With the present facility of examining the C digit restricted, in practice, to less than 30 AB codes, it follows that a controlling register-translator cannot separately identify every director exchange in London, and expensive alterations to working equipment would be necessary to provide the facility. However, with the change to all-figure telephone numbers[2] that is now being made, it is possible to rearrange the director-exchange codes so that all exchanges sharing a common AB code are located within the same sector, and this is being done.

*Allocation of All-Figure Codes*

A number of alternative ways of allocating all-figure numbering codes to director exchanges were examined; the one adopted minimizes both inconvenience to the public and the engineering work prior to its introduction, and also provides a reasonable degree of flexibility for the future. The numerical equivalents of the present letter codes have been used wherever possible, and particularly for the large central London exchanges which carry most traffic. For example, the AB digits 62 are among the codes allocated to the central 4-mile radius area, and for the central exchanges MACaulay, MAIda Vale, MANsion House, NATional and MAYfair the numerical equivalents 622, 624, 626, 628 and 629, respectively, can be used. New codes must, however, be allocated for MALden (625) and MARyland (627), which are located in suburban sectors. Where it was not possible to use the numerical equivalent of an existing letter code, an attempt was made to use a code in the same director group to minimize disturbance to traffic distribution among the various groups of directors; e.g. for WEMbley (936) the code 902 has been allocated. The allocation of numbering codes for part of the director area is illustrated in Fig. 6. It was not possible to allocate the first digits of the exchange codes on a geographical basis as insufficient spare codes would have been available to cover requirements during the change-over period.

For an exchange where the new all-figure code differs from the numerical equivalent of the old letter code, both codes will exist side by side for a number of years, the




Note: 46, 66, etc., denote the first two digits of exchange codes

FIG. 6—ALLOCATION OF ALL-FIGURE NUMBERING CODES IN LONDON

dialling of either code routing a call to the same point. This will minimize difficulties during the change-over period while telephones are still fitted with lettered dials.

LINE PLANT AND SPEECH TRANSMISSION

The existing London junction network consists mainly of 20 lb/mile audio cables, many of them unloaded. There are substantial economic advantages in using lighter-gauge cables, and the new plan is arranged to facilitate the widespread use of 10 lb/mile loaded cables. The provision of a homogeneous loaded-cable network in the director area, coupled with the shorter junctions resulting from the arrangement of S.S.C.s and central trunk exchanges, will lead to improved speech transmission with minimum need for amplifiers, while adhering to the maximum allowable losses of the current national transmission plan.[1]

The shorter junctions will also largely avoid the need to use expensive long-distance signalling systems as a result of the higher resistance of 10 lb/mile cables.

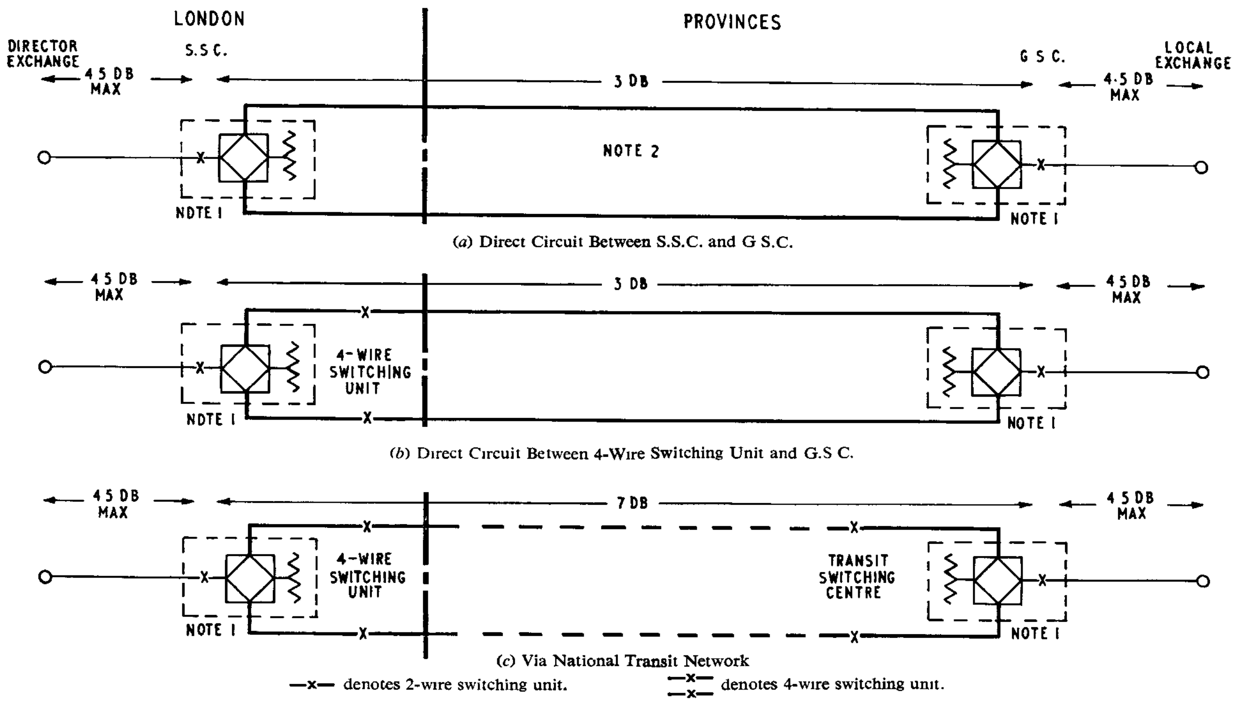
Calls within the director area will nearly all be routed either over direct junction circuits or via a single intermediate tandem exchange, and further improvements of transmission can be effected when considered necessary by more widespread use of 2-wire amplifiers, with multiplex junction systems (giving circuits of 3 db transmission loss) where economic for the longer junctions.

Most trunk calls will be routed on direct 3 db trunk circuits between S.S.C.s or central London trunk exchanges and provincial terminal G.S.C.s; the remaining calls will be routed via the 4-wire switching units, either over direct routes between London and small G.S.C.s (again giving 3 db loss) or via the transit network (which is at present planned to give 7 db loss). These routings are shown in Fig. 7. The transmission loss of the trunk-junctions* between the director exchanges and S.S.C.s or central trunk exchanges would be kept within the present national maximum allowable 4·5 db, instead of the former relaxed London limit of 6·5 db, if only 10 lb/mile loaded cable were used by amplifying about 2 per cent of the junctions; most of the junctions should, in fact, have less than 3 db loss.

AUTOMANUAL CENTRES

At present the director area is served by some 75 automanual centres (A.M.C.s), mostly with sleeve-control switchboards. The small size of many of these

*Trunk-junction—a junction used for completing trunk calls.




Notes 1: Exchange equipment at the S.S.C. and G.S.C. will each introduce some transmission loss but this need not exceed about 1 db.
2: Most direct circuits will be 4-wire circuits, as shown, but circuits to nearby G.S.C.s could be 2-wire amplified audio circuits.

FIG. 7—TRANSMISSION LOSSES ON CALLS BETWEEN LONDON S.S.C.s AND THE PROVINCES

switchboards is incompatible with good management and service, and, in addition, the space occupied by a large proportion of them will be required for extending local automatic exchanges. These factors will result in the provision of a much smaller number of large A.M.C.s, requirements being met as far as practicable by switchboards at S.S.C.s and central trunk exchanges, or in association with them by using the detached-working facilities of new cordless switchboards. There are equipment, accommodation, and cost advantages of locating A.M.C.s in S.S.C. and central trunk exchange buildings, and such an arrangement results in the most satisfactory speech transmission. Where the A.M.C. is in a separate building and the detached working facility can be used, the transmission path between subscribers during conversation is direct via the automatic equipment and transmission is not worsened.

## LONG-TERM DEVELOPMENTS

It is visualized that fast-operating electronic switching equipment will be provided at S.S.C.s and central switching units, and that in the early years of the new plan it will be of the space-division type using reed relays. Audio junction cables will, in general, have 10 lb/mile loaded conductors, as mentioned earlier, and there will be widespread provision of multiplex junction systems. Such systems, using pulse-code modulation (p.c.m.), are now being developed, and will provide 24 junction circuits on two audio-cable pairs;[3] these systems will initially be used for the longer circuits between London and adjacent-charging-group exchanges, and later for junctions within the director area.

In the longer term it seems probable that there will be an integrated p.c.m. switching and transmission network, particularly for tandem-routed traffic within the director area but also for some traffic between the director area and surrounding exchanges. When choosing the arrangement of S.S.C.s account was taken of this possibility.

With an integrated p.c.m. system the digital-transmission mode of the multiplex junction system is preserved through a tandem exchange, avoiding the cost and transmission disadvantage of conversion to audio signals at the tandem exchange. The link between the originating and terminating director exchanges via the tandem exchange is, in effect, a single circuit from a transmission point of view and can have an overall transmission loss between 2-wire audio points as low as 3 db, if desired.

## CONCLUSIONS

The partial decentralization of trunk and tandem exchanges will reduce the need for sites and buildings in central London, and will avoid the provision of separate junction routes from many central trunk exchanges to every suburban director exchange. The plan will also give Telephone Managers a larger measure of control over the plant serving their own customers, and, by bringing the switching units nearer to the source of traffic, will make it easier to use cheaper audio junction cables with 10 lb/mile conductors. Speech transmission will be improved initially and further improvement will be facilitated.

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[1]Tobin, W. J. E., and Stratton, J. A New Switching and Transmission Plan for the Inland Trunk Network. *P.O.E.E.J.*, Vol. 53, p. 75, July 1960.

[2]All-Figure Telephone Numbers. *P.O.E.E.J.*, Vol. 59, p. 40, Apr. 1966.

[3]Development of Pulse-Code-Modulation Systems. *P.O.E.E.J.*, Vol. 59, p. 10, Apr. 1966.

# Gases in Underground Plant and Their Detection

J. O. COLYER, B.Sc.(Eng.), A.M.I.E.E., R. THARBY and R. C. SENIOR†

U.D.C. 613.63:614.83

**The risks due to gases in underground plant are considered, and the reasons for a change of the standard detecting instrument are discussed. A new portable gas indicator and two types of fixed gas-alarm equipment are described.**

## INTRODUCTION

ABOUT 8 a.m. on 20 December 1928 a violent explosion occurred in the centre of London. A Post Office jointer was killed, 13 people were injured and 700 yards of High Holborn and St. Giles High St. from Kingsway to St. Giles Circus were torn up. In the words of the Commission of Enquiry[1] appointed by the Home Secretary "the situation was without precedent." As a result of this and other less-disastrous explosions, a committee was set up in the Post Office to review gas precautionary procedure. This committee reported in 1934 and recommended amongst other things that, every time a manhole was entered, tests for coal gas should be made with a palladium-chloride detector. A detector of this type[2] had been developed by the Post Office Research Station and was suitable for general issue to all external staff. The recommendation was accepted, and the procedure and equipment introduced have remained in use with only minor changes to the present time. The detector, known as the Indicator, Gas Leak, No. 2 (I.G.L. No. 2), now uses sodium chlorpalladite instead of palladium chloride.

## PRINCIPLES OF GAS DETECTION

Gases can have three undesirable characteristics: they may be

(*a*) flammable, i.e. they may burn or explode,
(*b*) toxic, i.e. poisonous, or
(*c*) asphyxiating.

The difference between toxic and asphyxiating gases may appear academic, but is important in practice. Toxic gases, such as carbon monoxide and the various war gases, are harmful in very small quantities and have a cumulative effect when breathed over a long period. In higher concentrations they can have a very rapid effect. Asphyxiating gases, on the other hand, are harmless in themselves but do not support life. If their concentration is large they reduce the quantity of oxygen reaching the lungs and so cause suffocation. This is not to say that they cannot act quickly; carbon dioxide, for example, because of its high density, can collect at an almost 100 per cent concentration at the bottom of a shaft, and under these conditions can cause very rapid loss of consciousness. It would obviously be ideal for a gas detector to test the air in a manhole directly for the three properties described but, unfortunately, this is not practicable.

### *Flammable Gases*

The flammability of a gas can readily be measured by creating the necessary conditions for combustion inside a suitable instrument and detecting from the heat produced, or otherwise, whether any combustion has occurred. The Indicator, Gas, No. 5, to be described later, works on this principle.

The flame of a miner's safety lamp changes in appearance when put in an atmosphere containing flammable gas, and a skilled operator can use the lamp as a detector of flammable gas. This is not practicable in the Post Office, however, as the angle of viewing the lamp usually makes it impossible to see the flame, daylight may mask the change in appearance, and flammable gas is too rarely encountered for the operator to retain the necessary skill. There is also a slight possibility of the lamp igniting certain explosive mixtures, and for safe use in Post Office plant special gauzes would be required. The Lamp, Safety, No. 1A should, therefore, only be used after other tests have shown that no flammable gas is present.

### *Toxic Gases*

It is not possible to measure toxicity directly by an instrument, since poisons can act in so many different ways (the miners' canary is an effective indicator but hardly practicable in the Post Office). There are, however, a number of chemical indicators which detect one or two particular gases, and these may be toxic gases such as carbon monoxide or hydrogen sulphide. These instruments, of which the I.G.L. No. 2 is a good example, are simple, cheap and very sensitive. Although they only detect one particular gas, as long as any flammable gas which may obtain access to Post Office plant contains some of this gas mixed with it, chemical detectors will give warning of danger from explosion as well as poisoning. The only toxic gas liable to be found in Post Office plant is carbon monoxide, occurring as a constituent of town gas. This can be detected by an instrument measuring flammability, provided the proportion of flammable to toxic gas is high enough and the detector has suitable sensitivity.

The protection against toxic gas afforded by a flammable gas-detector can be calculated by considering the effect of a mixture such as town gas present in the air in just sufficient concentration to be detected.

If $t$ = volume of toxic gas per 100 volumes of town gas,
$e$ = lower explosive limit (l.e.l.)* of town gas,
$d$ = percentage of l.e.l. at which detector gives warning, and
$w$ = volume of toxic gas per $10^6$ volumes of atmosphere,

then the volume of town gas $= ed$ volumes per $10^4$ volumes of air,

i.e. $w = edt$.

For typical town gas, $t = 10$ per cent, $e = 5$ per cent, and, for the new Indicator, Gas, No. 5, $d = 10$ per cent. Hence, it gives an indication when the toxic gas reaches 500 parts in $10^6$. This sensitivity is similar to that of the I.G.L. No. 2 and improves as the carbon-monoxide level in town gas is reduced, whereas the sensitivity of a sodium-

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

*Lower explosive limit—the lower explosive limit of gas (or a mixture of gases) is the minimum volume of it that must be present in 100 volumes of the gas-air mixture to enable combustion to occur.

chlorpalladite indicator to flammable gas diminishes as the carbon-monoxide content falls.

*Asphyxiating Gases*

The occurrence of asphyxiating gas in underground plant is rare now that carbon dioxide is no longer used for desiccating cables, but concentrations of carbon dioxide are sometimes produced by decaying vegetation, and certain soils remove oxygen from the air and, in deep unventilated subways, occasionally give rise to atmospheres consisting mainly of nitrogen. It is necessary to obtain oxygen from the air to breathe, and a flame also requires oxygen to continue burning; asphyxiating atmospheres, therefore, affect combustion, and this fact has been used for many years as a basis of testing. The miner's safety lamp has a flame so adjusted that it goes out if the oxygen content of the air falls to about 16 per cent. The safety lamp is inconvenient to use, and the flame must be carefully adjusted to give adequate sensitivity, but no satisfactory alternative has been found, and the Lamp, Safety, No. 1A remains part of the Post Office gas-testing equipment.

*Detection by Smell*

The best known method of gas detection is probably by smell, and some gases are deliberately odourized to aid their detection, but in practice this is a most unreliable method. Many flammable or toxic gases have no smell, and added odourants may be absorbed or changed in passing through the soil or even through pipes. Many people have an impaired sense of smell, and even a normal person becomes accustomed to a persistent scent and ceases to notice it after a time.

### CAUSES OF GAS CONTAMINATION

For economic reasons Post Office ductlines are not generally constructed in a gas-tight manner, and the design of telecommunication cables does not require them to be so. Gas or fluids leaking from underground pipes or tanks near the ducts may, therefore, enter and spread along some considerable length of the duct network. The main causes of contamination are

(*a*) leaks from faulty town-gas pipelines,

(*b*) leaks from faulty storage plant at petrol-filling stations or similar industrial installations,

(*c*) leaks from propane equipment used by cable jointers, and

(*d*) natural sources of methane (which occurs in marsh gas, firedamp, sewer gas and natural gas, in coal-bearing or oil-bearing soils, or districts with extensive areas of decaying vegetation).

*Town-Gas Supplies*

Faulty town-gas supplies provide the main hazard to staff working underground, and the detection of this gas has become increasingly difficult in recent years due to the modernization of the production and distribution methods used by the gas industry.

Before 1950 town gas was produced almost exclusively by the heat treatment of coal at sites closely adjoining the localities in which gas was consumed, and due to its origin it became known as "coal gas". The pipelines between the producing plant and the consumers were only a few miles long and were operated at relatively low pressures (e.g. 0·2 lb/in$^2$ above atmospheric pressure). Each town usually had its own producing plant, due no doubt to the earlier private ownership of the gas industry. The producing plants varied in size between vast sites in large cities to very small units in small towns. The gas produced conformed to a national specification with respect to its calorific value (450–500 B.t.u./ft$^3$) and specific gravity (0·4–0·5 relative to air). Carbon monoxide was normally present in the gas to a level of 10–20 per cent by volume. Leaks which occurred usually affected only a local area of Post Office plant due to the low pressure of the gas system.

Since 1950 the gas industry has been reorganizing its production methods to obtain more ecomonic operation of its producing plant and to take advantage of more convenient sources of energy. Production is being centralized in a small number of large installations, many of which use light oil distillates or imported liquified petroleum gases (e.g. methane, butane, propane) which are reformed (i.e. chemically changed) to town gas, or used to enrich gas produced by conventional methods. Town gas produced by reforming plant conforms to the original national specification, but the proportion of carbon monoxide in the gas may only be 2–3 per cent. Other modern producing plant uses coal, and gasifies it by the Lurgi system to produce town gas with a carbon monoxide proportion of 4–5 per cent. In some remote districts, where eventual connexion to a major production source is unlikely for economic reasons, a direct distribution of propane or butane is made through the distribution mains.

The liquidified petroleum gas is imported by tanker at a few specialized terminals and conveyed to the production plants through high-pressure pipelines. These may be very long: one of the longest conveys methane from the Thames Estuary to Yorkshire. They are constructed of high-quality steel pipes, 0·4 in. wall thickness, butt welded, and operate at pressures up to 1,000 lb/in$^2$. The pipelines take direct routes, avoiding population centres where possible, and rarely follow roads. Similar high-pressure pipelines also carry town gas from the production plant to consumer areas many miles from the plant.

Gas is also supplied from production plants to neighbouring towns through medium-pressure mains operating at pressures up to 30 lb/in$^2$ above atmospheric pressure. Similar mains also interconnect various producing centres to form a gas grid for the area. These medium-pressure mains are frequently constructed of cast iron and usually follow roads. In the consumer areas the gas flows from these various higher-pressure mains into the original low-pressure distribution networks.

As the pipelines may be laid in districts far away from gas-producing or gas-consuming localities, leaks of gas into Post Office ducts may occur in any district, rural or urban. The origin of the leak may be a faulty joint in a low-pressure distribution pipe, causing a gradual accumulation of gas in a short length of duct, or it may be a major break in a higher-pressure main, causing a rapid build-up of gas over a wide area of the duct network. Where such a break occurs under a continuous metalled surface, gas pressures may develop in the Post Office ducts and test the effectiveness of duct seals at nearby exchanges. If the leak exists in a methane, propane or butane main no carbon monoxide is present, and if the leak occurs in a main carrying reformed gas the carbon-monoxide level will be low. Detection of such leaks by an instrument sensitive only to carbon monoxide is not, therefore, reliable, and no other suitable alternative chemical trace is present in all these gases.

*Petrol Leaks*

Leaks in petrol-storage tanks at filling stations or industrial premises are becoming more common due to the increasing age of the earlier installations. Owing to the inaccurate methods used to measure the contents of these tanks the leaks are not usually noticed by the owners of the tanks at an early stage, and in consequence the leaks persist for some time. During this time the leaking petrol floats on the surface of standing water and is carried through Post Office ducts and manholes as the level of the water varies, damaging cable sheaths and protection. Vapours rise from the surface of the petrol to create an explosion hazard.

*Propane Leaks*

Propane leaks from gas plumbing equipment may arise through accident or misuse during the course of work in a manhole, or concentrations of the gas may have been left in a manhole by staff working there previously. Propane is 1·52 times as heavy as air, and any gas which leaks tends to linger at low levels in the manhole.

*Methane Leaks*

Methane occurs naturally in some parts of the country with coal or oil-shale deposits, or with extensive areas of made-up ground and decaying vegetation. In localities where the ingress of this gas becomes troublesome the ducts are sealed-off from the remainder of the underground plant and only opened for use after thorough forced ventilation and testing.

## INDICATOR, GAS, NO. 5

*Description*

In order to protect staff working underground from all the above possible sources of gas contamination an instrument, sensitive to their common property of flammability, has been developed. This instrument, known as Indicator, Gas, No. 5 (I.G. No. 5), is illustrated in Fig. 1.

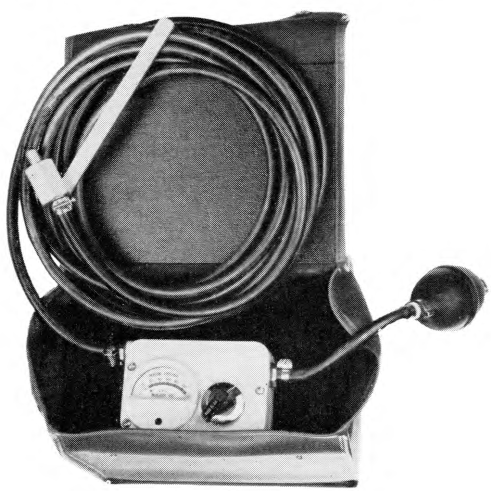


FIG. 1—INDICATOR, GAS, No. 5

The indicator consists of a device for obtaining samples of the atmosphere to be tested and an electrical circuit for testing the gas for flammability. The electrical parts are housed in the top of a diecast aluminium case, and a dry battery to operate the indicator is located in a separate compartment in the base. An aspirator bulb and neoprene-rubber inlet hose are provided to draw samples of atmosphere through the indicator, past flame traps fitted at inlet and outlet ports. The inlet hose is terminated with a metal probe having a hinged dipper, which serves to weight the hose, to indicate the surface of water when testing manholes from above ground, or to act as a short probe when testing at the mouths of ducts (Fig. 2).

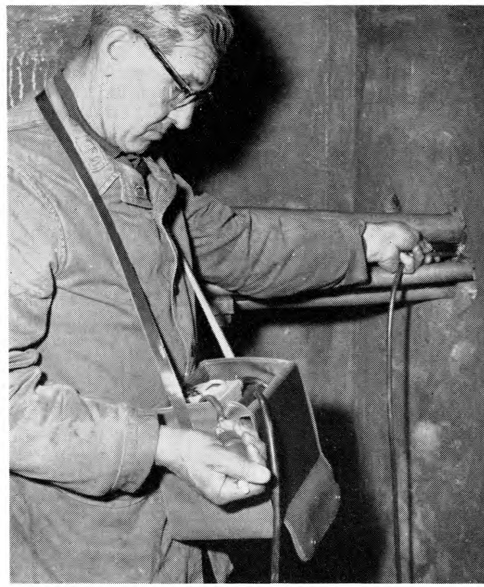


FIG. 2—TESTING FOR GAS AT A DUCT MOUTH

The indicator is operated inside its waterproof-canvas case, and the inlet hose, probe and aspirator may be stored in a separate compartment of the case after use, without disconnexion from the indicator.

*Principle of Operation*

Samples of the atmosphere being tested are passed over a catalytic platinum-wire filament in one arm of a Wheatstone bridge circuit (Fig. 3). This filament is heated to a carefully-chosen temperature by current from a battery. When any flammable gas passes over the filament, the effects of the catalyst and the temperature of the wire cause the gas to burn, thus raising the filament temperature and causing an out-of-balance current to flow in the meter.

When a gas burns completely it combines with a fixed proportion of oxygen known as the stoichiometric proportion, and gas-air mixtures will only burn with a flame or explosion if they are within a certain range of this proportion. The lower limit of this range corresponds to

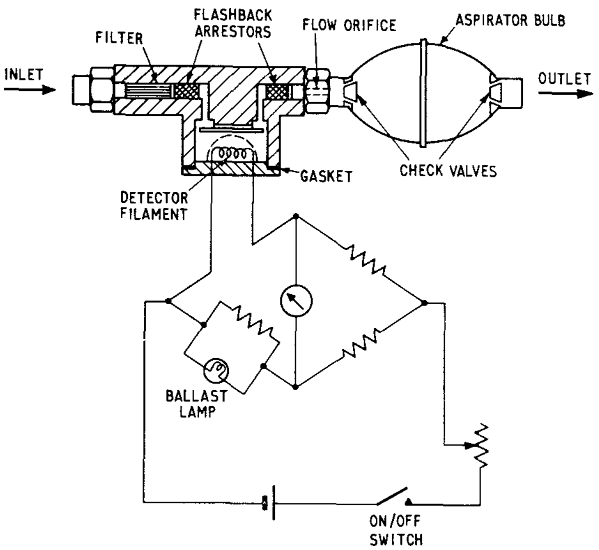


FIG. 3—SCHEMATIC DIAGRAM OF INDICATOR, GAS, No. 5

the l.e.l. already mentioned, though lower flammability limit might be a more correct term since mixtures near to the lower or upper limits may not burn explosively. Although the gas in a mixture outside the explosive limits will not ignite in the normal way it will burn while in contact with the heated catalyst of the detecting filament, and so the instrument can give warning of the presence of gas before it reaches an explosive concentration. The meter of the indicator is calibrated from 0 to 100 per cent of the l.e.l. of flammable gas. The calibration is approximately correct for a variety of gases, because the heat of combustion of a gas is inversely proportional to its lower flammability limit, since the l.e.l. is largely determined by the capability of the heat of combustion to maintain the flame front. The table indicates typical values for a number of gases.

Combustion Properties of Gases

| Gas | Lower Explosive Limit (per cent) | Lower Calorific Value of 1 ft$^3$ of Gas (B.t.u.) | Lower Calorific Value of Gas-Air Mixture at Lower Explosive Limit (B.t.u.) |
|---|---|---|---|
| Methane | 5·3 | 912 | 4,835 |
| Ethane | 3·12 | 1,778 | 5,549 |
| Propane | 2·37 | 2,309 | 5,471 |
| Butane | 1·6 | 3,010 | 4,817 |

For correct operation of the indicator two conditions are necessary:

(*a*) the filament must be at the correct temperature, and

(*b*) the bridge must balance when no flammable gas is present.

Since the filament resistance depends on its temperature the bridge can be arranged to balance when the temperature is correct, and a single rheostat in the battery circuit can control both temperature and balance. Actually it is found that such an indicator is too sensitive to ambient-temperature change and to battery-voltage variations, so a 6-volt bulb is included as a temperature-sensitive element in the bridge arm balancing the filament. This produces a more stable zero adjustment while still permitting the zero and the filament current to be adjusted by a single control. The bulb is conservatively-rated to give a long life. Over 90 per cent of the power consumed in the circuit is used to heat the detecting filament, only a small proportion being required for the rest of the bridge circuit.

The user of the indicator switches on the bridge, adjusts it for balance, aspirates samples of atmosphere over the filament and observes any out-of-balance indication on the meter. Any deflexion on the meter scale of 10 per cent l.e.l. or more is generally taken as a positive indication of the presence of flammable gas. A more sensitive interpretation of the reaction of the indicator may be developed with experience. The indicator will reliably detect gas-air concentrations of 10 per cent l.e.l. of all flammable gases likely to be met by Post Office staff.

Power is supplied to the bridge from six dry cells in parallel. The current consumption of the bridge is 600 mA, and the useful life of the cells ends when the terminal voltage on load falls to 1·0 volt. Tests of the indicator with standard-type cells (commercial type U2 or Post Office Cells, Dry, R20) and high-power cells (commercial HP2 or Post Office Cells, Dry, R20 PF) (Fig. 4) showed that the greater cost of the high-power cells was more than offset by their extended life, and the high-power cells are, therefore, used.

The reliability of the aspiration system may be checked before use by aspirating with the probe open at first and then blocked by the finger. The electrical circuit is automatically checked by observing the correct movement of the meter pointer when the bridge is balanced before use.

Although the Indicator, Gas, No. 5 does not provide a permanent record of a test as does I.G.L. No. 2, the following advantages afford much more protection and convenience to staff.

(*i*) It will detect combustible gases which do not necessarily contain carbon monoxide.

(*ii*) A test only takes 2 minutes compared with 12 minutes with the sodium-chlorpalladite tester. Numerous tests may therefore be taken at various points on the plant, increasing the chance of detecting slight leaks of gas.

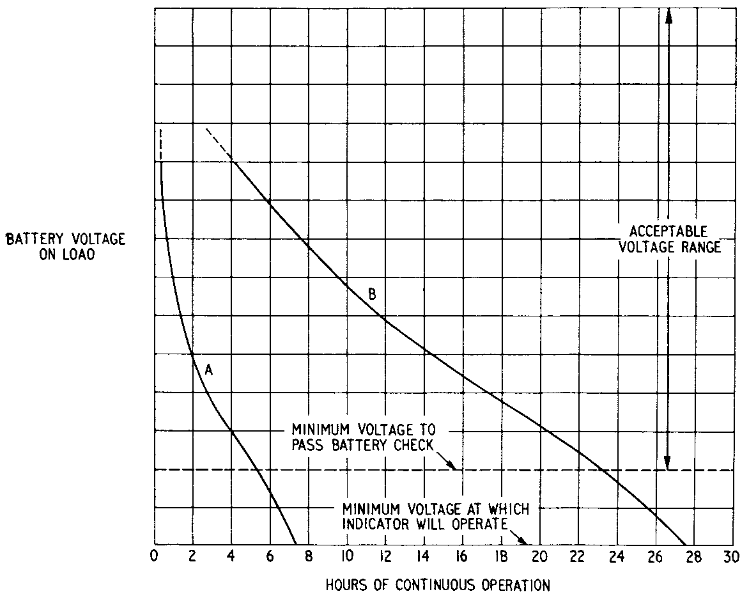
(*iii*) The positive indication is clearly defined on the meter scale, whereas some difficulty may be experienced in comparing the shade of the sodium-chlorpalladite stain with a reference button.

(*iv*) Unlike the sodium-chlorpalladite tester, it is not affected by low temperatures.

### GAS-SENTINEL INSTALLATIONS

The catalytic-combustion principle of gas detection may also be applied to permanent installations where immediate warning of gas is necessary due to the serious consequences that might result from an explosion. Typical locations where such protection is desirable are cable tunnels in which the volume of plant liable to contamination is great, telephone exchanges where for some reason it has not been possible to construct an effective duct seal, and bulk propane stores in densely-populated districts.

In some small installations now in operation two catalytic filaments are heated in flameproof diffusion heads at the points where the tests are required. The filaments are wired to a mains-powered Wheatstone bridge circuit in a controller situated at some convenient nearby point away from the area likely to be contaminated with gas. Flammable gas reaching a filament through natural diffusion burns on the filament surface, raising its resist-




A—Cells, Dry, No. R20. B—Cells, Dry, No. R20PF

FIG. 4—COMPARISON OF BATTERY ENDURANCE FOR INDICATOR, GAS, No. 5

ance and altering the bridge balance. The out-of-balance current operates a moving-coil relay, which provides local and extended alarms.

In larger installations samples of the atmosphere for test are drawn through remotely-situated filters, along small-bore tubes to a mains-operated controller situated at a central point in a safe location. One controller may operate up to 20 remote test points, and these points may be situated up to 2,000 yd from the controller. The controller has a gas-detection chamber in which a platinum filament in a Wheatstone bridge is fitted, and an automatic sample-point selector. This selector draws samples of atmosphere continuously from all remote test points through contact flowmeters, and connects each point in turn to the gas-detection chamber. The flowmeters provide an alarm if any marked change of flow rate occurs. Each point is connected for test of its atmosphere for 17 seconds, after which the chamber is flushed with fresh air before the next point is tested. On a 20-point system each point is thus tested each 8 minutes. As the cycle of tests proceeds, a panel of lights indicates the point currently under test. If flammable gas is detected an alarm is provided by a moving-coil relay operated by the out-of-balance current in the Wheatstone bridge, and a panel light indicates the point from which the flammable sample was received. The controller continues to sample atmosphere from each point in turn, so that the spread of gas through the ducts is monitored continuously.

Sentinel installations may have pre-set sensitivities at various values of l.e.l., and, if required, may incorporate a 2-stage alarm at different values. To combine reliability in service with maximum sensitivity, operation at 20 per cent l.e.l. is normally chosen.

CONCLUSIONS

The greatest risk from gases in Post Office plant is explosion, and the I.G. No. 5 gives a direct measurement of the flammability of the atmosphere tested. Hence it gives protection against the major risk from all gases at present known or likely to occur in future. In this respect it is greatly superior to the I.G.L. No. 2, which only detects one gas (carbon monoxide) directly. The I.G. No. 5 also detects carbon monoxide indirectly with a sensitivity similar to that of the I.G.L. No. 2.

The new indicator is the result of careful study by the Post Office of the characteristics required of a gas detector. It uses well-tried principles and is in fact very similar in appearance to the Indicator, Gas Leak, No. 3,[3] but has a considerably better performance than the earlier instrument.

In view of the increasing risk from gases not detectable by the I.G.L. No. 2 this detector is being superseded by the I.G. No. 5. The new detector will be issued to all staff on the same basis as the superseded one, and new testing procedures to take advantage of the increased speed and convenience of testing will be introduced at the same time. It is hoped that a substantial improvement in safety underground will result.

ACKNOWLEDGEMENT

Acknowledgement is made to Messrs. Mine Safety Appliances, Ltd., who designed the new instrument to a Post Office specification.

*References*

[1]Report of Commission of Enquiry into the Holborn Explosions and Fires, 1929. Her Majesty's Stationery Office. Cmd. 3306.

[2]RICHARDS, C. E. The Detection of Poisonous Gases in Underground Workings. *P.O.E.E.J.*, Vol. 30, p. 110, July 1937.

[3]DONOVAN, J. G., and THARBY R. An Experimental Gas Plumbing Outfit for Cable Jointers. *P.O.E.E.J.*, Vol. 50, p. 88, July 1957.

# Book Received

"Michael Faraday." L. Pearce Williams, Ph.D. Chapman & Hall, Ltd. xvi + 531 pp. 122 ill. 70s.

Professor Williams, who is Associate Professor of the History of Science at Cornell University in Ithaca, N.Y., started his researches into the life and work of Michael Faraday in 1958. The results of his labours have culminated in the recent publication of this biography of Faraday. The book throws considerable fresh light on Faraday both as a man and as a scientist, for the author has drawn on all available sources of information, including many that have never before been published: the text includes many extracts from these sources, all of which are clearly indicated in references supplied at the end of each chapter.

The evidence of Faraday as the master of experimental techniques is supplied in full, but Professor Williams has not allowed this to hide the Faraday who was the leading theorist of the early nineteenth century. The book describes his development of ideas when confronted with empirical evidence and the ways in which they led him to discoveries beyond the conception of his more orthodox contemporaries. Michael Faraday showed tenacity and courage in the face of increasing official opposition to his work, and this alone makes for a story which will appeal as much to the general reader as to those with a more specialized interest in the subject.

# The Developing Relationship Between the Man and the Computer

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U.D.C. 681.142

**Communication between man and computer has evolved considerably. The salient features of this process, the development of computer languages and of more efficient operating methods, including time-sharing and multi-processing systems, are described.**

## INTRODUCTION

BEFORE two people can communicate meaningfully with each other, two conditions must be fulfilled:

(*a*) the "language" to be used must be agreed, and must be understood by both parties, and

(*b*) a "communication channel" must exist between the parties.

Until 150 years ago most men spent their entire lives in the surroundings in which they were born. Few people could read or write, and fewer still knew a language other than their own. The normal means by which ideas were interchanged was, therefore, by word of mouth, using, often, a local dialect understood by both parties.

Today, variations on this simple pattern are accepted as normal, as illustrated by the following examples.

(*a*) Speakers no longer expect to be within a few feet of each other: the use of the telephone enables intelligent communication to be carried on at any distance.

(*b*) Men are reconciled to learning, for purposes of their work or their leisure activities, a language other than their own. It is worth noting, at this stage, that efforts to introduce universal languages, such as Esperanto, have been singularly unsuccessful.

(*c*) The power of the written word has vastly increased and has become a powerful means of communication, suffering only from a very slow response time. The author of an article such as this can only expect to receive a reaction to it several months after writing it; if he were lecturing on the subject the response time could be measured in minutes. If he were taking part in a discussion the time would be reduced to seconds.

The history of communication between man and computer has also undergone considerable evolution, and this article attempts to point out the main landmarks of the process: somewhat paradoxically, the main movement today is towards a "conversational" mode of communication.

## DEVELOPMENT OF COMPUTER LANGUAGES

A previous article[1] described how the steps of a program are held, in binary form, in the store of a computer. In general, each instruction consists of two parts, one defining the operation to be carried out, the other consisting of a number defining a location in the store. This store position may, for example, contain data on which the operation is to be performed. Table 1 shows some typical machine-code instructions. To carry out a program, the central processor of the computer calls for the instructions one after another in sequence; these are passed from the main store in the form of binary pulse patterns. The duty of the programmer is to ensure that the correct binary patterns are held in the store so that they can be called for, in the right order and at the right time, by the central processor. The five instructions shown in Table 1 would be needed to perform the calculation

$$x = a + b + c - d,$$

where the value of $a$ is stored in location 2000,
$b$ is stored in location 2001,
$c$ is stored in location 2002,
$d$ is stored in location 2003,
and $x$ is to be stored in location 2004.

TABLE 1
Typical Machine-Code Instructions

| Example | Binary Stored Information (With decimal equivalents in brackets) | | | Effect |
|---|---|---|---|---|
| | Operation | | Location | |
| 1 | 011 (3) | 000 (0) | 0011111010000 (2000) | Transfer to the accumulator the number stored in location 2000 |
| 2 | 000 (0) | 100 (4) | 0011111010001 (2001) | Add to the accumulator the number stored in location 2001 |
| 3 | 000 (0) | 100 (4) | 0011111010010 (2002) | Add to the accumulator the number stored in location 2002 |
| 4 | 000 (0) | 101 (5) | 0011111010011 (2003) | Subtract from the accumulator the number stored in location 2003 |
| 5 | 010 (2) | 000 (0) | 0011111010100 (2004) | Transfer the accumulator contents to store location 2004 |

### *Machine-Oriented Languages*

In the early days, computers were only understood by the engineers who had designed and made them, and their first consideration was to make such devices work. Ease of program writing was not considered of prime importance, and programs had to be written with the instructions expressed directly in their binary form. Apart from the difficulty and tedium of remembering and interpreting long strings of binary numbers, the programmer of those early days had to maintain, meticulously, a complete record of where each item of data, each intermediate result, each program instruction, etc., was being held at every stage throughout the program. The programmer had to think and work, in effect, in the basic language of the machine. Programming languages of this type are known as "machine-oriented;" working in them gives a programmer a

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remarkable feel for his machine; some of this liaison has been lost by the later developments which will be described below.

It soon became evident that programs would need to be written by people other than the computer designers themselves. In particular, there was a demand from engineers and scientists faced with problems, in their everyday work, which a computer could help to solve. These people did not wish to spend weeks, or perhaps months, learning the tedious work of programming in binary code and maintaining the store-location directory. It was realized that much of the work of programming was purely routine and that it could well be done by computers themselves, thus freeing the programmer to concentrate on the aspects of the program which were specific to the problem in hand.

The first step away from the computer (though not necessarily the first in chronological order) was the introduction of symbolic assembly languages. In these languages each different type of instruction is given a mnemonic code, consisting of a group of easily remembered alphabetic and numeric characters. Means are also provided to enable the computer itself to maintain the running record of the contents of each store location. Table 2 shows typical symbolic assembly language

TABLE 2
Typical Symbolic Assembly Language Instructions

| Instruction | Effect |
|---|---|
| 30 $a$ | Transfer contents of location holding item $a$ to the accumulator |
| 04 $b$ | Add contents of location holding item $b$ to the accumulator |
| 04 $c$ | Add contents of location holding item $c$ to the accumulator |
| 05 $d$ | Subtract contents of location holding item $d$ from the accumulator |
| 20 $x$ | Transfer accumulator contents (i.e. $a + b + c - d$) to location reserved for holding item $x$ |

instructions for performing the same manipulation as that carried out by the machine-code instructions of Table 1. During the program the computer maintains a list of where each item is stored, and the programmer need only call for the item by its previously defined code instead of having to remember, himself, where the item is stored at any one time. A program written in a symbolic assembly language cannot be directly run by the computer. An elementary process of translation has to take place first, the outcome of which is the production of a further program in the binary form referred to above.

Each instruction in a symbolic assembly language is translated into a single instruction in the basic machine language. To write a program in a symbolic assembly language, therefore, still entails analysing the problem to be solved into a large number of elementary operations, each one being represented by a single instruction. During the middle 1950s much effort was applied to further reducing this tedious part of a programmer's work by the development of "problem-oriented languages."

*Problem-Oriented Languages*

As its name suggests, a problem-oriented language is one in which the instructions can be defined by the programmer in terms having an affinity with the problem being tackled. Instead of each statement written by the programmer becoming one instruction held in the computer store, relatively complicated statements may be written, each being translated into several machine-code instructions. The translation process is carried out by the computer itself and is known as "autocoding;" the languages in which the original statements are written by the programmer have become known as "autocodes."

A single autocode statement

$$A = B + C$$

specifies that the numbers held in locations B and C must be added together and the result placed in location A. This will be translated by the computer into probably three basic machine-code instructions. Table 3 shows a selection of autocode statements together with their effect, and an indication of the number of machine-code instructions which would result from each. The first three instructions in Table 3 have the same effect as the

TABLE 3
Typical Autocode Instructions

| Autocode Instructions | Number of Resulting Machine Instructions | Effect |
|---|---|---|
| $x = a + b$ | 3 | Add contents of locations holding items $a$ and $b$, and store result in location reserved for item $x$ |
| $x = x + c$ | 3 | Add contents of locations holding items $x$ and $c$, and store result as a new value of $x$ |
| $x = x - d$ | 3 | Subtract contents of location holding item $d$ from contents of location holding item $x$ and store result as a new value of $x$ |
| Jump if $x = 0$ to 7<br>Jump if $x = 10$ to 8 | 4 | Test the contents of location holding item $x$. If this equals zero, jump to instruction number 7; if it equals ten, jump to instruction number 8. If neither, move to the next instruction in sequence, as usual. |

five instructions shown in Tables 1 and 2, i.e. $x = a + b + c - d$.

It has been mentioned that programs written in any language other than the basic machine code must go through a preliminary process of translation before the program proper can be run. This process is shown diagrammatically in Fig. 1, and, briefly, the operation is as follows.

For each language which a particular computer can accept, a master program known as a "compiler" is available. This is written in machine-code language, and its purpose is to read in a program written in some other language, carry out a translating function on it, and produce as an output a program written in machine-code

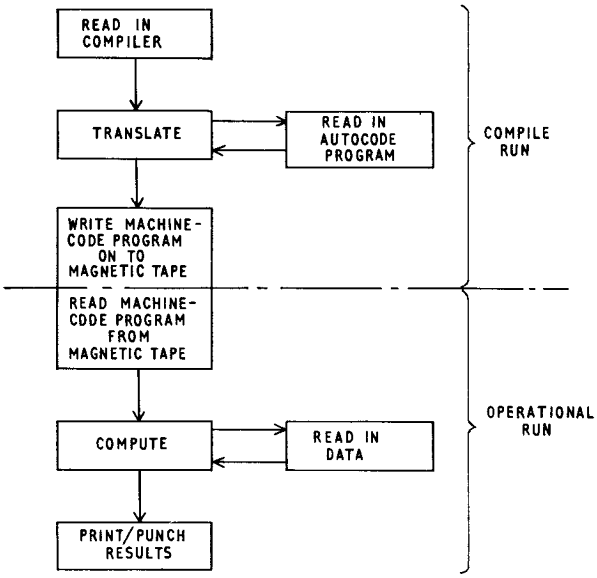


FIG. 1—PROCESSING AN AUTOCODE PROGRAM

language. It is this program which is now capable of carrying out the operations originally specified by the programmer. In smaller machines, this program is punched out on paper tape. In larger ones it is written directly on to magnetic tape or held in the main computer store. This process is known as compiling.

The data on which the computation is required are then offered to the input device, and the instructions of the newly produced program are carried out.

The ability to write programs in autocode can be acquired in a few hours study. The price which must be paid for the added simplicity is made up of two factors:

(*a*) the cost of the additional computer running-time required for compiling, and

(*b*) the cost of the compiler itself.

Computers are continually increasing in speed, and many modern machines are capable of carrying out a number of programs simultaneously. The additional running time is, therefore, a small price to pay for the improved facilities provided for programmers. Compilers themselves, however, are the outcome of specialized programming effort, measured in man-years, and are never cheap.

*Universal Languages*

Like machine-code languages and symbolic assembly languages, autocodes are specific to individual types of computer; this is a distinct disadvantage from the flexibility point of view since a program written in one particular autocode can only be run on a machine of one particular type. Over the last few years considerable effort has been put into producing "universal" languages. Because of the different requirements of the mathematical and the commercial worlds, progress has been along two separate lines.

For mathematical, scientific and engineering work a language known as ALGOL[2] has been introduced. A main feature of this language is that it allows the programmer to use more complex statements in writing his program, but it makes correspondingly more complicated the compiler which the computer manufacturer must provide with his machine. Table 4 shows a number of

TABLE 4
Typical ALGOL Instructions

| ALGOL Instructions | Number of Resulting Machine Instructions | Effect |
|---|---|---|
| $x := a + b + c - d$ | 5 | Store in the location reserved for item $x$ the result obtained by subtracting the contents of the location holding item $d$ from the sum of the contents of the locations holding items $a$, $b$, and $c$ |
| If $x = 0$, then go to "here"<br>If $x = 10$, then go to "there" | 4 | Test the contents of the location holding item $x$. If this equals zero, jump to an instruction labelled "here"; if it equals ten, jump to an instruction labelled "there". If neither, move to the next instruction in sequence, as usual. |

ALGOL statements, their effects and an indication of the number of machine instructions which might result from the compile run. The first instruction in Table 4 has the same effect as the five instructions shown in Table 1, i.e. $x = a + b + c - d$.

ALGOL is, unfortunately, by no means universally accepted. Although widely used in Europe its penetration into the United States has not been as deep as that of the language known as FORTRAN. One advantage of ALGOL, however, that is widely exploited is its ability to act as a language for the interchange of information between mathematicians, since it provides a well-defined and disciplined way in which complex mathematical operations can be written down. The word ALGOL itself is derived from ALGorithmic Oriented Language, an algorithm being a statement of the steps to be taken to solve a mathematical problem.

In the commercial world, a less successful attempt has been made to introduce a universal autocode known as COBOL, which is derived from COmmon Business Oriented Language.

*Prospects for the Future*

The computer industry is dominated by one manufacturer who, in 1964, announced a complete new range of computers and, at the same time, let it be known that a new programming language was being introduced. This, which was claimed to include the best features of ALGOL, FORTRAN and COBOL, has not yet been fully specified. Despite the fact that the development of this language is in the hands of one manufacturer, it seems likely that most other computer manufacturers will be prepared to accept it as a standard and will, therefore, write the necessary compilers to handle it.

Programming Language No. 1, as the new language is to be known, is intended to be a completely universal programming language for mathematical and commercial-type work. The effort which has already gone into its development, if this could be totalled, must amount to some hundreds of man-years already: before it is finally available for everyday use probably a similar amount of labour will go into the production of the necessary compilers and operating systems required to use it efficiently. Very broadly, it is estimated that only half of the cost of a modern computer is in the form of "hardware" (circuits, storage medium, etc.): the remaining cost is the manufacturer's charges for developing the "software," which is the name commonly given to the programming languages, the compilers and the operating systems, which are needed to make the hardware work and to make the task of the programmer and machine operator as simple and straightforward as possible.

### DEVELOPMENT OF OPERATING METHODS

Just as in the early days programming could only be done by the computer designer, so also was he the best—sometimes the only—person capable of operating the machine. Since users were few, and fault-free operation for periods of more than a few minutes was a matter for self congratulation, smooth and efficient operating methods were not of prime importance.

One of the things known, only too well, to programmers, but sometimes not appreciated by others, is that it is extremely rare for a program to work first time. The programmer himself may have made errors, either in the problem-analysis stage or in the actual coding operation; other errors may have been introduced during the data-preparation stage. Before a live run, therefore, a program will have undergone a series of trials resulting in several stages of modifications: this process is colloquially called "de-bugging." After each trial the programer will have had to spend some time investigating the reason for failure and incorporating the various modifications he thought necessary. It soon became evident that, in order to exploit the computer to the full, its time should be allocated or scheduled so that it could be shared equitably between all the various programmers wishing to use it. While this introduced the advantage that the computer was used more efficiently, there were disadvantages from the programmer's point of view in that, having made his modifications, he might have to wait minutes, or possibly hours, before being allocated another trial period on the machine itself.

With the development of more complex computers it became necessary to use specialized operating staff: computer managers were introduced to control the staff and to schedule the work through the machine. Coupled with the changes in computer languages, described above, these developments had the effect of divorcing the programmer (or user) from the machine. A modern programmer needs to know little about the hardware on which his program is going to run and still less about how it works: he merely knows that, if he obeys the rules laid down in his programming manual, his program should operate successfully.

Despite all the developments which have gone on, aimed at simplifying the programmer's task, these rules are still manifold and must be obeyed meticulously. In a program of several thousand instructions the opportunities for "grammatical" errors are many (in addition to probable errors in the logic of the program itself), and debugging still takes a large proportion of a programmer's time. A modern computer, provided it has good software, is capable of giving considerable help to the programmer in deciding where and of what type the errors are: it still falls, however, to a human being to decide just what action to take, and to initiate the various modifications to the program which he concludes are desirable.

Program writing, therefore, is still an art which entails the use of trial-and-error methods, and it can be extremely frustrating to a programmer, who wishes to try out, rapidly, a modification which he has made, to find that he must wait several hours, or even a day or two, before he can be allocated more computer running-time.

For operational efficiency, jobs arriving in a computer centre are normally classified and formed into batches, each batch taking its turn to pass through the computer. There is, thus, an element of luck in determining the length of time between the arrival of a program at the computer centre and its return to the originator. This may vary from a few minutes to perhaps a day and, in the latter case, merely adds to the frustration of the programmer who may, by then, have forgotten the finer points of his program.

### ON-LINE OPERATION OF COMPUTERS

For the reasons outlined above, many users hanker after the days when they could operate the computer themselves and obtain virtually an immediate response from it. This particularly applies to workers in the scientific and engineering fields, who are often using a computer to assist them in a design function. However, a modern computer may well cost £100 or more per hour to run, and it would not be economic to allow a programmer exclusive use of a computer since, in all the periods when he was thinking what to do next, the computer would not be earning its keep.

#### *Multi-Processing*

A computer consists of some cabinets of high-speed electronic equipment and a varying number of much-slower-speed peripheral devices, such as paper-tape readers and punches, magnetic-tape handlers, printers, graph plotters, data terminals, etc. Data are usually transferred to or from these devices through special intermediate buffer areas of storage. These areas can be filled or emptied, as the case may be, at very high speed, by the computer electronic equipment, but transfer of information between the buffers and the peripheral devices is relatively very slow and, while this is going on, the main computer electronic equipment may be idle. Today this is the position on most small-size and medium-size machines; many large machines, however, possess the facility of "multi-processing."

In the description given earlier of the running of a typical program, only one program was assumed to be held in the computer store at any one time. In a multi-processing system several programs are held simultaneously in the computer store, the computer operating on one of them until it reaches a stage where transfer to or from a peripheral device is required. This transfer is essentially a simple slow-speed process which can continue independently, a signal being sent to the central processor when the transfer is complete. Thus, while this transfer is going on, the central processor turns its attention to another program and operates similarly on that until a further interruption takes place. This may cause a third program to be selected for attention, or the first program may be resumed, providing the slow-speed transfer has finished. The control of this multi-processing operation is vested in a master program variously known as Executive, Monitor, Supervisor, etc.

The function of the master program is to control the switching between programs and to retain, at every stage, a record of the progress of each program so that any one can be selected for attention. Programs may be run in a true cyclic order, or different priorities may be allocated to each, the master program selecting that which has the highest priority from among those which can be processed at any time. Since the master program itself occupies quite a substantial part of the main storage, and also uses a certain amount of computer time in controlling the switching operations, true multi-processing can only be achieved on a large, fast machine. Fig. 2

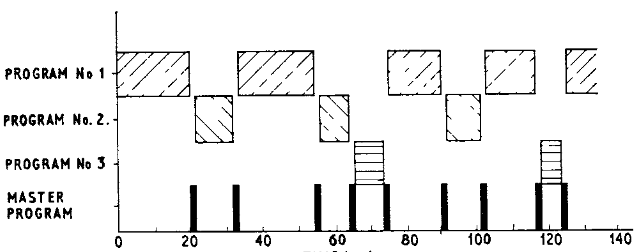


FIG. 2—ALLOCATION OF CENTRAL-PROCESSOR TIME BETWEEN PROGRAMS

shows a typical allocation of central-processor time between three programs, having different degrees of priority, and the master program; the percentage division of time is shown in Table 5.

TABLE 5
Typical Percentage Allocation of Central-Processor Time

| Program | Percentage of Time |
|---|---|
| 1 | 58 |
| 2 | 27 |
| 3 | 8 |
| Master | 7 |

*Time-Sharing*

In effect, multi-processing permits the sharing of the central processor of a computer among the various peripheral devices which are fitted to it, hence overcoming the inconsistency in the speed of operation of electronic and electromechanical equipment. One of the slowest peripheral devices fitted to a computer is an electric typewriter, the medium through which the computer and the operator can interchange comments. This is normally used, among other things, for error indications to be given by the computer or for warning the operator when the available storage capacity is almost full. In the other direction, the electric typewriter enables an operator to pass simple instructions into the computer; these instructions enable the operator to tell the computer what action to take when an error condition has been indicated (for example, the computer can be told to "try again"). The typewriter is also used to instruct the computer to read-in a new program or to extract a compiler from magnetic tape.

The combined response time of the typewriter and the operator is far longer than that of any other peripheral equipment attached to a computer, and this fact is exploited in a new method of computer operation which is, at present, receiving a great deal of attention. This system, which is (perhaps unwisely) known as time-sharing,[3] enables a computer to give service simultaneously to a large number of users. Provided the required software is available, each user can effectively be given complete control of the computer. Fig. 3 shows, in schematic form, the basic system.

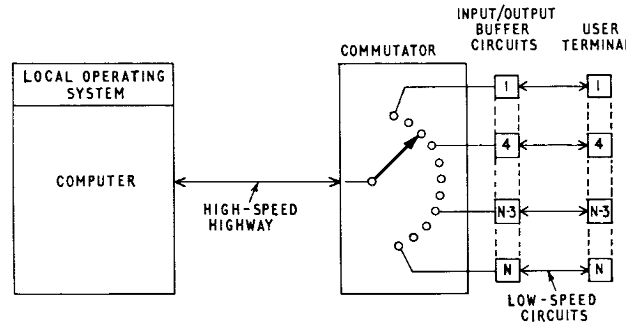


FIG. 3—BASIC TIME-SHARING SYSTEM

The similarity to a common-control type of telephone exchange is evident: in the latter, a line scanner is normally continually looking at all the subscribers' and junction lines, pausing momentarily whenever it is necessary to pass information to and from the central control. Just as, in a telephone exchange, each subscriber is (or should be) unaware that there are other subscribers using the common control, so each computer user imagines himself in sole command of the computer.

The user terminals, the form of which vary according to the purpose to which the system is put, are each connected to an input/output buffer circuit. In most cases the maximum frequency to be transmitted is well within the audio range, and each terminal and its buffer can be connected by a private telephone circuit or through the public switched network.

USES OF TIME-SHARING SYSTEMS

Many different proposals have been made for using time-sharing techniques,[4,5,6] for all of which Fig. 3 is basically correct. A convenient, if somewhat arbitrary, distinction exists between systems in which the users merely interrogate and, possibly, update information held centrally and those in which each user can have at his disposal complete computer facilities, including feeding-in, de-bugging and running his own programs, and storing them for later use, if required.

*Common-Data-Base Systems*

In the first type of common-data-base system, all programming is carried out centrally through the local operating system, and the users are given a limited range of facilities. The simplest example, from the users' point of view, is probably that in use on the American Stock Exchange. In this system the computer is kept continually up-dated with information concerning the transactions which have taken place and the latest prices which dealers are quoting for each share. Some of this information has been available for many years over a form of teleprinter network (using ticker-tape machines); the use of a computer enables this information to be readily processed and the results made available, quickly, to a larger number of inquiry points.

Several types of user terminal are available, of which the most interesting is the "audio-response" type. About 1,000 dial telephones, mostly situated in brokers' offices, are attached to the system over private circuits. Each security quoted on the Exchange is allotted a 4-digit number and, when this is dialled, it is detected and decoded in the buffer circuit, and a request for the latest information is sent to the computer at the next commutation time.

The coded output passes at high speed from the computer to the buffer circuit, is stored there and then used to select groups of words from an audio drum so that an audible response is returned to the inquirer. This is in a standardized form and gives the following information:

(*a*) Code of the security.

(*b*) Latest bid price.

(*c*) Latest offer price.

(*d*) Price at which last transaction was made, and the difference from the previous day's closing price.

(*e*) Volume of current day's trading to date.

(*f*) Current day's opening price.

(*g*) Current day's highest price.

(*h*) Current day's lowest price.

The message is repeated until the user clears down. This part of the system is capable of handling 1,200 inquiries per minute, and, again, the similarity to a telephone exchange will be noted.

A more advanced use of a common-data-base system is for air-line reservations. Several air lines now operate computer-controlled systems by means of which their agents—sometimes in many different parts of the world—can make inquiries about flight times and available space on aircraft. A much wider range of questions can be put to the computer in this instance, and the replies are consequently of more complex form. The user terminals are, therefore, of teleprinter form and printed records are kept of each transaction.

One essential difference from the Stock Exchange scheme is that, once an inquiry has taken place and the customer has decided to make a booking, the relevant information in the computer store is up-dated by sending a further message from the user terminal. Thus, there is an element of interaction between the computer and the many users connected to it: the computer is continually being kept up to date with bookings and cancellations, and can produce, locally, accurate management reports on demand.

The SABRE system, used by American Airlines, Inc., deals with bookings up to a year ahead and includes information on special meal requirements, car reservations, inter-connexion needs, etc.

*Full Computer Service Systems*

More interesting, perhaps, are the systems which offer —or appear to offer—the complete power of a computer, simultaneously, to a number of users.

Mention was made earlier of the processes involved in writing and de-bugging a program. This can still be a tedious process, especially in research, design and development organizations where new problems are often being attacked and where, by their very nature, innumerable false starts are likely to be made during the preparation of programs. In these circumstances the use of a mode of operation is desirable in which the computer can assist the programmer by "commenting" on parts of a program as it is being prepared so that the programmer is in less danger of basing a long and complex program on a false foundation.

A computer which is dealing with a number of isolated users must have an extremely large storage capacity. This is generally made up of a large and fast "working" store backed up by magnetic-drum or magnetic-disk stores. Each user is allocated a segment of disk or drum on which his programs, data, intermediate results, etc., can be stored in between periods of active use. The programmer can call for these by name whenever he needs them, and he need have no knowledge of where they have been put. The allocation of storage, and the complex indexing which is needed to keep track of it, is controlled by the master program.

The user terminals may be electric typewriters or teleprinters connected over private circuits or via the switched public telephone network, and can, therefore, be at any distance from the computer centre. Usually, only a limited number of users are "licensed" to operate the computer, but any one of them can use any terminal. Before giving service, therefore, the computer asks the user to type in his password (which, for obvious reasons, is not printed by the typewriter). The computer thus knows the identity of the user who is operating each terminal at any time and can correctly interpret any special commands he may give.

An ideal system would contain, as a common service, a comprehensive set of compilers, so that each user can select the language which suits him best. For some special purposes it may be necessary for a user to write his own compiler; this can then be stored inside the machine for his future use. Naturally, the user must tell the computer, at the start of each session, which language he is going to use.

Each time the commutator finds a buffer circuit holding a meaningful message it stops, and the master program allocates a quantum of computer time to that user. This will probably be in the range of a few hundred milliseconds up to a few seconds, depending, for example, on the priority allotted to that particular user and the number of other users waiting in the queue. Considerable ingenuity can go into determining the optimum quantum of time to be allocated, and there are many conflicting views as to the best method.

During the allotted quantum the full power of the computer is available to the individual user and, possibly, several thousand machine instructions will be obeyed on his behalf. If it is necessary to return a message to the user this is passed to the buffer circuit, the complete contents of the working store are transferred to the user's own segment of the backing store, and the commutator steps on. Otherwise, this process takes place at the end of the quantum of time, and the user must then wait until all other demands have been satisfied before being allocated another quantum. Once the computer has given a user a comment requiring his attention, it is quite irrelevant to the system how long he waits before he re-applies for service.

It will now be seen why the backing store of a time-sharing system must be on magnetic disks or drums; these are the only devices at present capable of holding the many millions of words of information that are required and yet have access times of a few tens of milliseconds. In addition to providing a segment of storage for every potential user of the system and for holding compilers for all possible languages, the backing store is used as a common library of information, available on demand to all users. This part of the backing store is considered as a reserved area, and its contents can only be modified through the local operating system, since it would obviously be undesirable for casual users to be able to make changes without at least some central check.

The best-known system of this type is Project MAC,[7] being carried out at the Massachusetts Institute of Technology (M.I.T.). The acronym MAC stands equally for Multi-Access Computing and Machine-Aided Cognition; the latter title is preferred by its proponents, who point out that the aim of the system is to provide an extension to the power of the human mind analogous to the various mechanical aids which extend his physical capability. About 150 user consoles are fitted in the existing Project MAC system, of which any 30 can be in use at one time.

A more advanced system is being jointly designed by M.I.T. and the Bell Telephone Company. Several other experimental systems are in various stages of development in America.[5,6]

FUTURE OF TIME-SHARING

The above description has merely indicated the broad lines on which use can be made of time-sharing systems to increase the effective utilization of computers and to provide a desirable means of intimate contact between the man and the machine. It is fair to add that the need for such systems is not universally accepted and, hence, the supporters of time-sharing are occasionally inclined to overplay its potentialities. Development over the next few years must, in part, result in the isolation and definition of those fields of application where time-sharing can be efficiently exploited.

In the British Post Office it will probably be necessary, in the near future, to extend further the computing facilities available to engineers and scientists. It could well be convenient for a computer to be installed at the new Research Station site. It is hoped to obtain, before long, information on systems available for purchase within the required time, and these will be evaluated, along with more conventional systems, bearing in mind the requirements of the potential users.

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# British Joint Computer Conference, 1966


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**The 1966 British Joint Computer Conference, held at Eastbourne on 3 May, was attended by 700 delegates from 11 countries. The papers presented were of high technical standard, covering mathematical and organizational programming, and engineering techniques and problems. Following the Conference Dinner, the Minister of Technology, Mr. Frank Cousins, M.P., addressed the delegates, knitting together a number of points brought out in earlier papers.**


THE 1966 British Joint Computer Conference, which was sponsored by seven professional bodies under the aegis of the United Kingdom Automation Council, was held at Eastbourne on 3 May 1966. Seven hundred delegates attended from 11 countries; the Post Office Engineering Department sent eight members from various Branches and three members from the Technical Support Unit. The papers were of high technical standard, covering mathematical and organizational programming, and engineering techniques and problems.

The opening address looked to the 1970s and foresaw large-scale computing caused by three complementary factors: (*i*) large users, with massive amounts of data processing, (*ii*) individual users, with difficult problems involving extensive computation, and (*iii*) several hundred thousand small users having direct access from remote low-cost consoles. These demands could only be met by large well-organized centres, possibly serving the small user by day and the others by night. Limitation on the rate of growth would not be an economic one, but lack of knowledge, skill and experience. To this end there would be a trend towards co-operation between users, a greater degree of standardization and inter-system compatibility, and a wide range of adaptable ready-made programs; though the number of programmers will expand, there will still be a shortage of systems program writers. Finally, on languages, ALGOL and FORTRAN would not easily be displaced, although new special-


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applications programs were likely; PL1* may well establish itself more strongly than COBOL.

Papers were presented which covered linear programming techniques and their practical application to the specific problems of transportation, "travelling salesmen" and time-table preparation. The techniques of integer programming included cutting plane, primal, branch and bound, and partial enumeration, each with its particular application. The emphasis of speakers was that any combinatorial problem could be tackled with these techniques, but audience reaction varied from the feeling that integer programming techniques were too unwieldy, i.e. economically unjustified for complex school time-tables, unless used with discretion, to a suggestion that heuristic‡ approaches could well provide a more economic and practical solution. Other papers were read which reported the practical and successful use of such techniques as applied to (*i*) scheduling of mail vans from the C.C.S. fleet (bulk conveyance of mails in the inner London Postal Region), and (*ii*) freight locomotive scheduling on the North London Railway.

A lucid explanation was given of short-cut techniques for the solution of certain combinatorial problems and a method, for finding the shortest route between two points in a network, was described. The discussion revealed a divergence of opinion, and it was claimed that existing methods were better.

Great interest was shown in papers which described how algorithms had been developed to assist in all stages of engineering design work. Examples were given of their use in electronic-component placing and wiring, and of electrical network design. Competitive and tedious housekeeping work, e.g. accessing and placing of information, provision of generalized design bases for improvement, and tailoring to particular design requirements, were organized by the computer program. In particular, the graphical display of information to facilitate the man-machine interaction was emphasized. A speaker described how Bell Telephone Laboratories are developing special input-output terminals based on small fast computers, on-line to a big time-sharing machine, using a 10 in.-square cathode-ray-tube display, fitted with a light-pen, and typewriters to display and modify component and wiring layouts and circuits.

The second day opened with a review of achievements in electronic data processing (e.d.p.), including a report of the trend towards the creation of a separate computing unit, within each organization, responsible directly to top management, the computer being used as a management tool with conventional information being produced as a by-product. E.D.P. users had indicated, in answer to a questionnaire, that (*i*) hardware, generally, lived up to expectation but that software had not, and (*ii*) there was a greater tendency for individual users to do their own systems analysis and programming. The speaker foresaw that the economics of real-time computing would mean the creation of more service centres, computer co-operatives and utilities, i.e. centralized large computing capacity available to many users on demand, either by direct data-link connexion or via a user's own machine. The problems of data coding, data levels and mass data storage were referred to, together with those of the economics of generalized information storage and the down-grading of data by changed level of storage, filtering and ultimate purposeful destruction.

An attempt to construct a theory of management science was described in another paper: the objective was to determine principles which enable an organization to react to its environment in a high-speed self-adaptive manner. It was suggested that analysis of the data-flow mechanism in an organization would lead to improvements in the organizational structure. The resultant integrated management-information system would use an on-line computer with specially designed display equipment. Man would be used to do only those lower-speed organizational tasks, i.e. planning and developing, which he could do better than the machine. A computer-based management-training exercise was also described, and the point made that its value was not only the training of managers in a dynamic decision-making situation but also in demonstrating the power of computers as a simulation tool of management.

Four papers illustrated the problems of producing wiring and inspection checking schedules for multi-cabling schemes. It was claimed that, even allowing for programming time, these methods showed up to a six-fold improvement in operation times. On the other hand, it was stated in discussion that the approach may be limited if the number of wiring points in an individual circuit exceeded 50. The technique showed marked advantages in detection of clerical and logical errors.

A method of control of product documentations was given. The particular problem involved several remote design and manufacturing points. The procedure provided for quick control and notification of all design changes—a time scale of 7 days being currently achieved. Storage and transmitting media used in the scheme were microfilm and magnetic tape.

Descriptions were given of (*i*) improvements to established network-based resource-allocation techniques, and (*ii*) a Central Electricity Generating Board's simulation of the national electrical power grid network by the use of optimized sub-models to form a full-sized model of the one-year requirement, aimed at the eventual reproduction of a 30-year planning model.

Three papers were read on real-time applications. (*i*) A small general-purpose computer had been used to control a special-purpose military trunk exchange; this gave experimental flexibility, and was convenient and economical. Separate levels of priority had been programmed for traffic, diagnostics, control, and maintenance. An optimum solution would require a more appropriate order-code or use of micro-programming. (*ii*) A non-mathematical approach to the problem of peak activities on a real-time system was given. Peaking degenerated the real-time system; it was suggested that 95 per cent supply of peak demand be aimed at with penalties for too frequent or long-duration demands. (*iii*) The use of data links for tele-processing financial and insurance business was discussed. It was stated that the development of tele-processing techniques was likely to be more significant, to financial institutions, than further generations of computers. General discussion on the papers indicated that one in four of new computing systems were being planned with on-line terminals. Real-time working was bringing the computer and communications industries closer together.

*PL1—Programming Language No. 1 (developed by the SHARE Committee).

‡Heuristic—an adjective used to describe an exploratory method of tackling a problem, in which the solution is discovered by evaluations of the progress made towards the final result, e.g. guided trial and error.

The third day opened with a further group of papers concerned with machine design. (*i*) The large continuously addressable stores of the mid-1970s would be of $2^{73}$ bits, one thousandth of which would be immediate access, while the rest would be backing store. In order to address bits or words, the code-word concept (i.e. a real machine-word instruction descriptive of stored significant information) coupled with floating-point (f. p.) addressing, was essential. The f. p. address would be a single word containing a positive integer (probably in the range 0–127, to line up with the I.S.O.* standard 7-bit set) and an exponent, the magnitude of which would be used to define the level of storage. The consequence would be that programmers or compilers would freely write the address required and the machine would arrange transfers as necessary. (*ii*) During the study of design criteria in fast arithmetic systems, the importance of three aspects (device, logic, wiring) varies when considering "fan in" and "fan out." Optimum performance (maximum information-flow-to-cost ratio) was achieved by using 2–4 bits/word; the case was made, therefore, for use of series-parallel circuits instead of purely parallel ones. With this method it was possible to achieve maximum productivity limited only by gain/bandwidth considerations. (*iii*) The design of order-code assignments to minimize the number of decode gates, and cost per output function, was described.

Aspects of man-to-machine communications were described. (*i*) One description was of a method of speech input to a computer (proposed but not built) which involved feed-back for checking accuracy of recognition and correct operator utterance. The system was compared with present input systems. Experiments have been carried out which simulated the operating procedure of the proposed method. (*ii*) Another description was of a graphical means of input and output communication with a machine which gave visual representation of information and allowed a high transfer rate of information without the tedious and inconvenient intermediate preparation of data on paper tape or punched cards. The hardware (cathode-ray-tube and light pen) and software (vector and character generators) existed. It was claimed that this facility would be a standard feature of all digital computers within a few years. (*iii*) The design philosophy and some features of a general-purpose document-handling mechanism were given. Various types of read stations (optical character-recognition, magnetic-ink character, mark-sensing) could be fitted to interpret documents of commercial size. Documents could be re-circulated, for either delayed reading or re-reading doubtful marks, and sorted into selected output hoppers. (*iv*) A method of computer simulation of character recognition, using a flying-spot scanner to translate written characters into digital form, was described. The spot could assume 1,024 positions in both the X and Y co-ordinate positions and could have seven levels of brightness; the reflected light from a spot was compared with threshhold levels and the information on position and brightness stored in one computer word.

A system, self-adapting to the dynamic patterns of stock level and product demand, was detailed in papers on production management. The aim was to provide an integrated system which would notify rates of consumption of materials and predict true level of demand. Details were given of a working system (installed by a chemical manufacturer) covering sales forecasting, production control and financial controls.

The final conference papers can be briefly summarized as computer "pep" talks, forecasting the future pattern of integrated management-information automatic-data-processing (a.d.p.) systems, and the social and economic implications of computers and automation.

Mr. Frank Cousins, M.P., Minister of Technology, addressed the delegates after the Conference Dinner; his speech knitted together a number of points brought out in earlier papers. He emphasized that the use of computers offered a powerful tool for increasing productivity: while they were established in handling routine tasks, their acceptance as a tool of management, and the education of management to use them for the production and appraisal of information, must be accelerated. Mathematical and economic modelling was a powerful computer technique which, while becoming increasingly important to management, could become the most significant influence of computers on national life. The use of computers for routine supervision and control could reduce manufacturing costs and release labour for more productive re-deployment, but would bring problems of re-training and re-location.

Computers would make a significant contribution to the process of engineering design, and this field would require a network of computers having either access to each others' stores or joint access to large common stores. Some preliminary thought had been given to the practicability of a country-wide computer grid for general industrial and commercial purposes; the importance of the National Computing Centre was stressed.

Adequate numbers of basic programming staff should be available, but there would be a shortage of advanced systems designers and advanced programmers; improved courses and training facilities, and the recruitment of women into this dominantly male field of employment, would help. The Government's awareness of the sociological aspects of technological change was brought out in the conclusion of the Minister's speech.

*I.S.O.—International Organization for Standardization.

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## Book Review

"A Library Guide to Engineering." K. W. Neal, B.A., B.Sc.(Econ.), Dip.Ed., A.L.A. 22 pp. 3s.

A person new to the art of study has certain problems which this book attempts to solve.

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The book would be useful only to a person who has a limited knowledge of the art of the study of engineering.

D.C.G.

# The Use of X-Ray Diffraction to Study Defects Occurring During Silicon-Device Manufacture

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U.D.C. 548.73:621.382.3

**Silicon epitaxial planar transistors are being developed for future use in submerged-repeater systems, where both high reliability and small spreads in electrical characteristics are required. An interest in the crystalline defects that occur during manufacture arises from the evidence that such defects can cause device degradation both initially and during subsequent life. A powerful non-destructive method of observation, known as X-ray projection topography, is described, together with examples of typical crystalline defects introduced during device manufacture.**

## INTRODUCTION

IN an earlier article in this Journal[1] reference was made to the use of single-crystal silicon in the manufacture of planar transistors for future submerged-cable schemes. In particular, the manufacturing sequences were described, but little mention was made of the basic single crystals from which the devices are fabricated. Any crystalline defects which exist in this material, or are subsequently introduced during the many handling and furnacing treatments, can drastically influence the final product in its initial performance and in its final life expectancy.

This article deals with some of the more simple crystalline defects, suggests ways that they may affect devices, and describes a non-destructive and powerful method of observing such defects at various stages during device manufacture.

## CRYSTALLINE DEFECTS

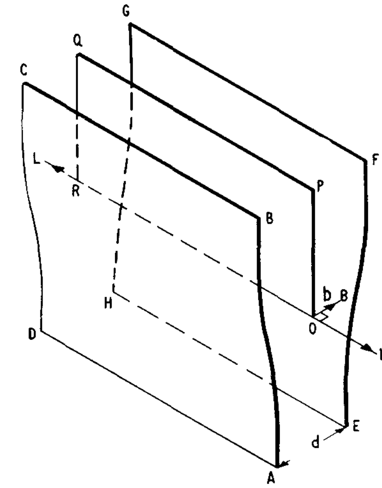
Consider a slice of single crystal silicon cut from an ingot and prepared for device fabrication; then the most likely crystalline imperfections at this stage are dislocations, i.e. defects grown-in or introduced by the cutting and mechanical polishing, precipitates, and, possibly, non-uniformity of intentional and unintentional impurity doping. All such defects will, in general, elastically strain the crystal lattice in their vicinity, and it is these strain fields which can be rendered visible by an X-ray method.

As an example, consider how a pure edge dislocation can distort the crystal lattice. Such a dislocation is shown schematically in Fig. 1. Suppose an extra half plane of atoms OPQR is inserted into the crystal lattice so that adjacent lattice planes ABCD and EFGH are displaced sideways elastically to accommodate it; then the line LL′ (the termination of this plane) is referred to as an edge dislocation.

The vector **b**, along the line OB, which is at right angles to the dislocation line, denotes in magnitude and direction the displacement of the lattice required to accommodate the extra half plane. Such a vector is referred to as the Burgers vector of the dislocation.

If, instead of inserting an extra half plane, the crystal planes are sheared with respect to each other about the line SS′, as in Fig. 2, then this line is referred to as a screw dislocation. Again **b** is the Burgers vector, but in this case it lies parallel to the dislocation line. In practice, most dislocations in crystals are neither pure edge nor pure screw, but a combination of both, changing from predominantly one type to the other throughout their length.

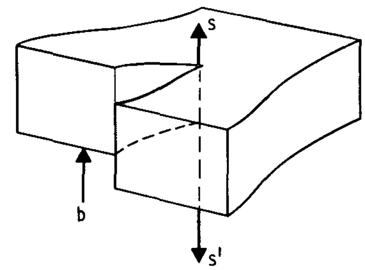
†Post Office Research Station.




LL′ is the dislocation line
**b** is the Burgers vector
d is the atomic-plane spacing

FIG. 1—SCHEMATIC DIAGRAM OF AN EDGE DISLOCATION

For topological reasons, a dislocation line must reach from surface to surface of the crystal or must form a closed loop within it. The density of dislocations is generally given in terms of the number of dislocation lines that intersect unit area of the sample. Thus, for example, densities from zero to, say, $10^4$ lines/cm$^2$ are typical for silicon single-crystals of transistor grade.



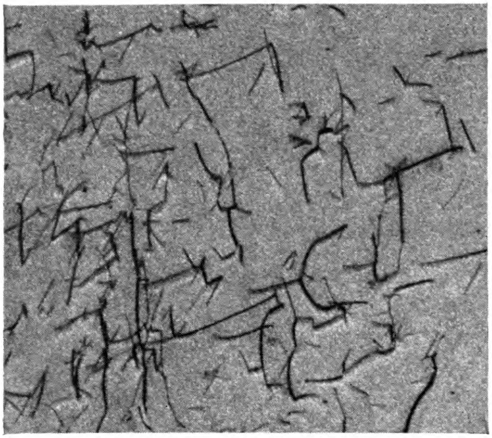

SS′ is the dislocation line
**b** is the Burgers vector

FIG. 2—SCHEMATIC DIAGRAM OF A SCREW DISLOCATION

It should be noted that, since the lattice planes are distorted in the vicinity of a dislocation, strain fields are set up which interact with impurities, vacancies and interstitial atoms in such a way that they often tend to cluster near dislocations in order to minimize the energy of the system.

## THE X-RAY METHOD OF OBSERVATION

The experimental method used to record the strain fields just mentioned is termed X-ray projection topography.[2] A typical example of such a topograph is shown in Fig. 3, which is a $\times 25$ enlargement of the original negative and shows the relatively low dislocation distribution in part of a 2 cm diameter $\times$ 0·25 mm thick



Magnification: $\times 25$

FIG. 3—TOPOGRAPH OF SILICON SLICE WITH DISLOCATION DENSITY OF A FEW HUNDRED LINES/$cm^2$

slice of silicon. For comparison Fig. 4 is a topograph of a slice with a dislocation density of $10^4$ lines/$cm^2$.

Now Bragg's Law states that, when radiation of wavelength $\lambda$ is diffracted by an array of parallel atomic planes spaced $d$ apart,

$$2d \sin \theta = n\lambda,$$

where $\theta$ is the angle between the incident radiation and the crystal plane. Intuitively, it can be seen that any

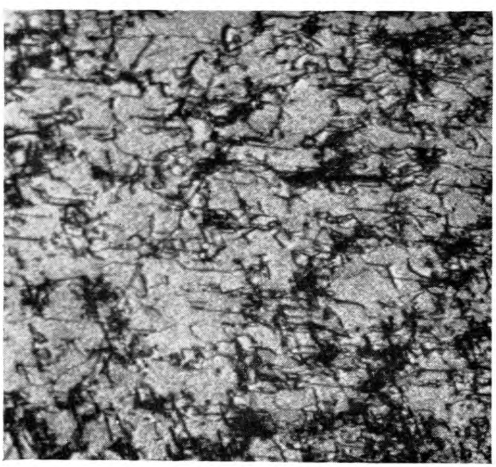


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FIG. 4—TOPOGRAPH OF SILICON SLICE WITH DISLOCATION DENSITY OF $10^4$ LINES/$cm^2$

local curvature of the crystal planes in the vicinity of a dislocation would upset the reflection condition as stated above since both $d$ and $\theta$ would vary locally. It can be shown, from the dynamic theory of X-ray diffraction, that for a crystal of thickness $t$, such that $t \leqslant 1/\mu$ (where $\mu$ is the linear absorption coefficient for the radiation of wavelength $\lambda$), a dislocated region will diffract more energy than the surrounding perfect lattice.

All topographs shown in this article are for the condition $t \leqslant 1/\mu$ and are of the same magnification.

*Experimental Method*

Fig. 5 shows, schematically, a plan view of the method of obtaining X-ray topographs. The silicon slice, first

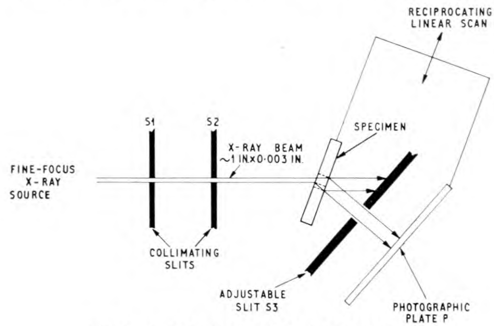



FIG. 5—SCHEMATIC DIAGRAM OF APPARATUS

etched to remove cutting and mechanical-polishing damage, is mounted centrally on a specially-constructed stage so that the selected crystal planes can be set to the Bragg reflection condition while at the same time the slice and film are scanned back and forth across the fixed X-ray beam. In order that the undeviated main beam shall not fog the film, an adjustable slit S3 is interposed so that only the diffracted beam (which may be only a few seconds of arc in width) is recorded. By repeated scanning over a period of hours a composite picture is built up.

It is also possible, by reflecting the X-rays from the opposite side of the same crystal planes, to provide a pair of topographs which can be viewed stereoscopically with a convergence angle of twice the Bragg angle. This technique can provide a most vivid 3-dimensional picture of the dislocations throughout the slice.

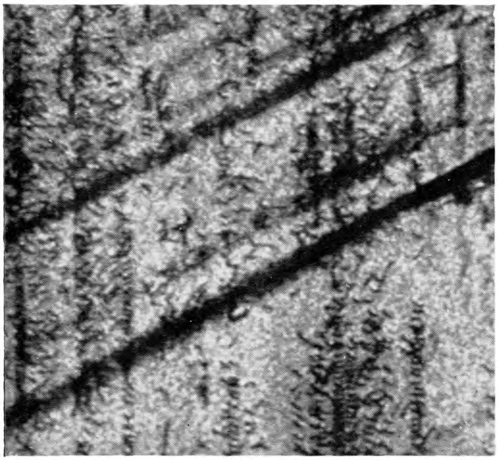
## INTERPRETATION OF TOPOGRAPHS

It should be pointed out that the visibility of any particular dislocation in a topograph is governed by the rule that the maximum contrast is obtained from dislocations whose Burgers vectors lie at 90° to the reflecting plane. Those dislocations with Burgers vectors lying in the reflecting plane will be invisible. Thus, by taking a series of topographs of reflections from different crystal planes, it is possible to find the directions of the Burgers vectors of all the dislocations in the slice and consequently the directions of the forces that have acted on the slice while it was at high temperature and in a plastic state, i. e. at temperatures above 800° C.

This general visibility rule may, however, break down if impurity precipitation has taken place along a dislocation line; the line may then be visible in all reflections and can provide a very sensitive method of trace analysis.

### USE OF THE METHOD WITH EPITAXIAL DEVICES

Consider now the use of the X-ray technique during various stages of epitaxial planar device technology. For the epitaxial transistor a topograph of the substrate crystal (typically 0·001 ohm cm resistivity) will be substantially similar to Fig. 3. When, however, a layer of 1 ohm cm silicon is deposited on to such a substrate it is possible for the defects shown in Fig. 6 to occur. This

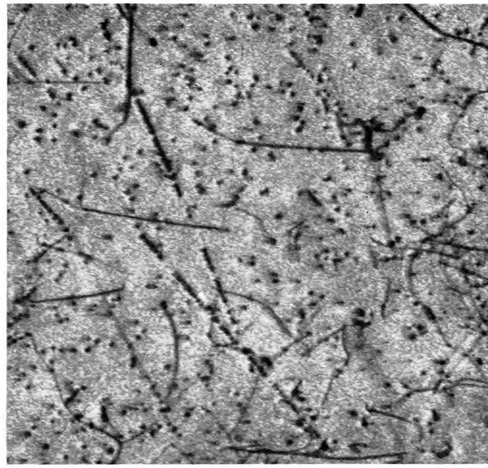


Magnification: ×25
FIG. 6—TOPOGRAPH SHOWING SLIP AFTER EPITAXIAL DEPOSITION

pattern of defects is referred to as "slip" since, by using the stereographic technique, it is possible to see that arrays of dislocations aligned on the {111} slip planes* have been produced throughout the slice thickness. These dislocations have resulted from thermal stresses set up during the high-temperature deposition of the layer and tending to bend the slice beyond the elastic limit. It is possible by careful control of heating and cooling cycles, and by the design of the reaction vessel, to minimize this effect. It is also possible to produce a similar effect by the curvature of the slice resulting from the slight differences of lattice constant (due to the different impurity doping) in the substrate and in the layer.

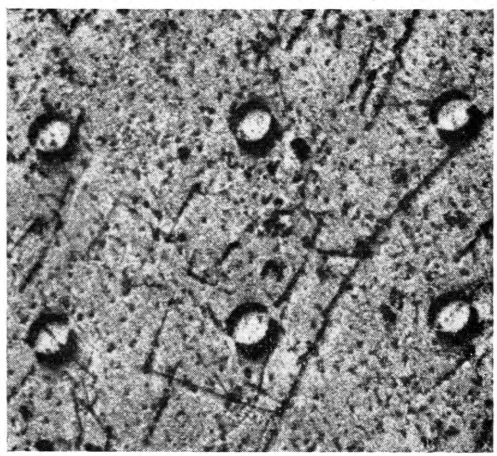
*Oxidation*

The next stage in device fabrication is the growth of a thin oxide layer over the whole of the slice by heating it in steam at about 1,000 °C. Fig. 7 shows such a slice



Magnification: ×25
FIG. 7—TOPOGRAPH OF SILICON SLICE WITH OXIDE LAYER 0.8 μm THICK ON BOTH FACES

after oxide growth. The topograph now has a generally spotty nature resulting from the precipitation of an oxygen complex both in the crystal lattice and along dislocation lines near the surfaces of the slice. Devices made on such a slice have been shown to have poor electrical reverse characteristics due, it it is thought, to high electrical-field breakdown at precipitate particles in the depletion layer. Oxides can, however, be grown which do not exhibit this effect.



Magnification: ×25
FIG. 8—TOPOGRAPH SHOWING DIFFRACTION CONTRAST FROM EDGES OF WINDOWS ETCHED IN OXIDE LAYER

As was explained in the article in this Journal, referred

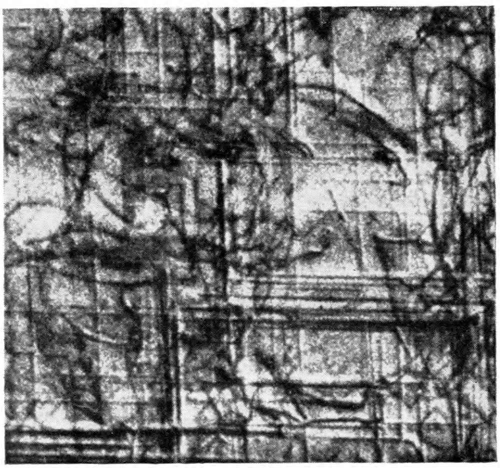
*The {111} slip planes in silicon are those crystal planes that are most closely packed with atoms and can most easily slide one upon another under the influence of a shear force. An analogy might be drawn between slip planes and the laminated structure of a pack of playing cards. A shear applied to the edge of the pack can easily slide one card over another and form a ramp.

If, as is most often the case, the crystallographic plane into which the planar transistor is fabricated is the {111} plane, then there are three other {111} planes intersecting this plane in the form of an equilateral triangle, the surface of the silicon slice being the base of the pyramid formed by these intersecting triangles.

to earlier, "windows" are now etched in the oxide so that the various p-type and n-type impurities can be diffused into the slice to produce the planar-transistor structure. Fig. 8 is a topograph taken after these windows have been cut. As can be seen, diffraction contrast is obtained from the edges of these windows as a consequence of elastic strain transmitted to the silicon underlying the window edge due, it is thought, to thermal-contraction mismatch between the oxide and the silicon.

*Diffusion*

The phenomenon of slip, as described earlier, can also play a part when, for example, the emitter–base junctions are diffused into the slice. In these circumstances there is an effect called diffusion-induced slip because an impurity such as phosphorous is introduced into the crystal lattice from a surface concentration of the order of the solubility limit, i. e. $\simeq 10^{21}$ atoms/cm$^3$. Since phosphorous is a smaller atom than silicon the crystallographic mismatch that occurs causes the silicon to slip in the layers adjacent to the surface to accommodate the foreign atoms;[3,4] Fig. 9 shows a topograph of such an effect.



Magnification: ×25

FIG. 9—TOPOGRAPH SHOWING PHOSPHOROUS DIFFUSION-INDUCED SLIP

Since this slip occurs within a few microns of the surface, the resolution of the X-ray technique is not able to show the fine detail within the slip bands. The question the device maker is most likely to ask is whether this dislocation network extends below the emitter–base p–n junction, since severe device degradation would be expected to occur if this were so. Electron-microscope evidence seems to suggest that the networks do not extend this far, although there is as yet some ambiguity between the X-ray evidence for gross slip and the micro-dislocation networks revealed by electron microscopy.

## MEASUREMENT OF SPECIMEN CURVATURE

One thing that has been implied, but not discussed in detail so far, is the extreme sensitivity of the X-ray technique to the gross lattice curvature within the crystal slice. In fact, curvature of about 1 second of arc/cm can be detected; this corresponds to a radius of curvature of about 2 km. This sensitivity has been used effectively to study the gross deformation that occurs after the mechanical polishing of one face of a slice. Here, grinding particles are forced into the crystal surface, opening up micro-cracks and causing the wafer to become convex towards the polished surface. A similar effect can be caused when metallic films are evaporated on to thin wafers (such films are invariably stressed either in extension or compression), and can cause "dishing."

Such grossly-deformed samples pose difficulties in obtaining uniformly exposed topographs; this problem can, however, be overcome by oscillating the specimen about the mean Bragg angle while scanning, by an amount equal to the dishing of the sample.

## CONCLUSIONS

By the use of X-ray technique at various stages of device manufacture it is possible to make a systematic study of the dislocation distribution before and after each heat treatment. If, in addition, a final electrical test of the completed transistors on a slice is made, a useful exercise in correlating poor-device characteristics with crystallographic defects can be attempted. This technique[5] has been in use for some time at the Post Office Research Station and is finding increasing use in industry.[6]

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# The London Radiophone Service

J. L. HYATT, A.M.I.E.E.†

U.D.C. 621.395.9:621.396.931

**The article describes the London Radiophone Service, which provides a radio connexion between mobile subscribers in the Greater London Area and the public telephone network. A description of the equipment is given, and proposals for the future expansion of radiophone services in the United Kingdom are discussed.**

## INTRODUCTION

WITH the opening of the London Radiophone Service on the 5 July 1965 the facility of being able to make and receive telephone calls in moving vehicles was made available to subscribers in the Greater London Area. This is the second land radiophone service to be introduced in the United Kingdom. A smaller scheme* was brought into operation in South Lancashire during 1959 for the benefit of mobile subscribers in the Manchester and Liverpool areas. The two schemes are somewhat similar, but the opportunity has been taken to introduce a number of refinements into the London scheme which reduce the operational demands made upon the subscriber and generally make the service more attractive.

Public radiophone services can be regarded as being complementary to private mobile-radio services. Whilst private services are widespread—there are at present some 45,000 mobile stations throughout the country—their main use lies in the direction and co-ordination of mobile staff, and messages passed are of short duration. Third-party traffic is not in fact permitted, and connexion cannot be made to the public telephone network. It is this latter need which the radiophone services meet, and, in general, they appeal to a rather different type of user who requires to carry on a rather more lengthy conversation. Since the services are adjuncts of the telephone network the Post Office has assumed responsibility for their introduction and operation. To date, however, mobile subscribers have had to provide their own mobile equipments either by renting or by outright purchase from the manufacturers. Nevertheless, to ensure satisfactory operation all equipments have to be type-approved to a Post Office performance specification before they may be used in the service.

Ideally, the standards of performance of a radiophone service should approach those of the telephone service. Although it is doubtful whether this aim will be realizable under the worst of the varying radio conditions, e.g. where the mobile station is in heavy traffic and beneath the lee of a hill, a generally high standard can be attained by ensuring that ample signal is available in the published service area.

## BASIC FACTORS AFFECTING DESIGN

In the planning of the London service certain basic factors which exerted a considerable influence upon the final system design had to be taken into consideration. These factors were as follows.

(*a*) The service had to be economically viable.

(*b*) The cost of the mobile equipment had to be kept to a minimum, consistent with reliability and the essential operational requirements.

(*c*) Operational demands made upon the mobile subscriber had to be minimal.

(*d*) Reliable service was to be provided over as much as possible of the area where demand was likely, i.e. the centre of commerce and the surrounding dormitory areas.

(*e*) The basic system design had to be capable of extension on a national basis.

## SYSTEM PARAMETERS

In the light of the foregoing basic factors, the service has evolved to provide the following system parameters.

### *Coverage*

Three base stations provide coverage over approximately the whole of the Greater London Area (see Fig. 1). For practical and economic reasons these are located at established radio stations, where suitable aerial towers are available.

### *Control*

The three stations are all controlled from a special manual position in Tate Gallery Telephone Exchange, to which they are linked by landline circuits. Each station is equipped with four radio circuits, three of them being exclusive to that station and used for connexion to telephone subscribers. The fourth—the control channel—is common to the three stations and is used for calling mobile subscribers prior to the call being completed over a connecting channel. Since the Tate Gallery exchange operator has no prior knowledge of the whereabouts of a subscriber it is essential that the call signal should be radiated throughout the whole of the serviced area.

Mobile stations are called selectively by means of an encoded 4-figure number. Receipt of the correct code by the mobile equipment operates visual and audible alarms to alert the subscriber.

Mobile subscribers call the operator by transmission of a short period of a 2,060 c/s tone modulation over any suitable connecting channel. Use of the control channel for calling the exchange is not normally permitted.

Each mobile subscriber can manually select any of the 10 channels which are available. To minimize the risk of losing calls, due to incorrect channel selection when in the stand-by condition, equipments are arranged to revert automatically to the control channel on replacement of the microphone or handset.

### *Channel Allocations*

The radio channels are 2-frequency ones, and are drawn from the two frequency blocks 163·675–164·4 Mc/s and 159·175–159·9 Mc/s, which are reserved for public land correspondence services in the v.h.f. band (see Table 1).

†Mr. Hyatt is in the Radio Services Department, Wireless Telegraph Section, but was formerly in the Inland Radio Planning and Provision Branch, E.-in-C.'s Office.

*ARMAN, L. T., and MELLER, V. C. The South Lancashire Radiophone Service. *P.O.E.E.J.*, Vol. 52, p. 253, Jan. 1960.

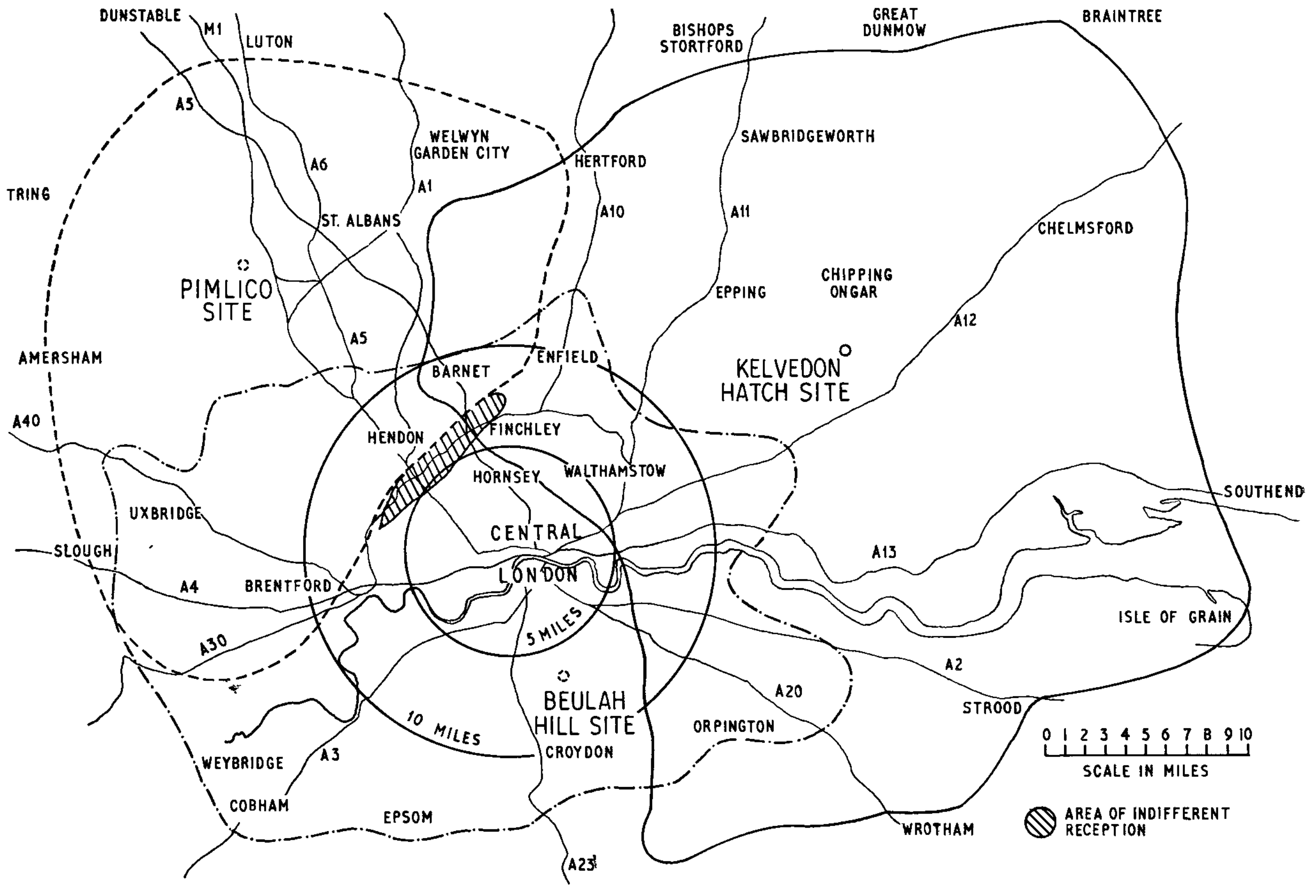



FIG. 1—SERVICE AREA OF THE LONDON RADIOPHONE SERVICE

Table 1
Channel Allocations

| Station | Channel Number | Frequencies (Mc/s) | | Channel Allocation |
|---|---|---|---|---|
| | | Transmit | Receive | |
| North East | 1 | 164·05 | 159·55 | Control Channel |
| | 5 | 164·375 | 159·875 | Traffic Channel |
| | 6 | 164·3 | 159·8 | Traffic Channel |
| | 7 | 164·25 | 159·75 | Traffic Channel |
| | 8–12 | – | – | Reserved for future expansion |
| North West | 1 | 164·05 | 159·55 | Control Channel |
| | 13 | 164·325 | 159·825 | Traffic Channel |
| | 14 | 164·2 | 159·7 | Traffic Channel |
| | 15 | 164·15 | 159·65 | Traffic Channel |
| | 16–20 | – | – | Reserved for future expansion |
| South | 1 | 164·05 | 159·55 | Control Channel |
| | 21 | 164·35 | 159·85 | Traffic Channel |
| | 22 | 164·275 | 159·775 | Traffic Channel |
| | 23 | 164·225 | 159·725 | Traffic Channel |
| | 24–28 | – | – | Reserved for future expansion |

Channels No. 2–4 are reserved for additional control channels

The frequency allocations to the base stations have been determined by the need to avoid the possibility of inter-modulation interference either with other radiophone channels or with private mobile services, operating in adjacent frequency bands. In common with private services, an overall channel spacing of 25 kc/s has been adopted. However, by limiting the minimum channel spacing at any one station to 50 kc/s, suitable channel allocation has made it possible to permit a higher peak-modulation deviation. Phase modulation is employed, resulting in a maximum deviation of $\pm$ 10 kc/s in contrast to the $\pm$ 5 kc/s to which 25 kc/s channelling systems are normally limited. In this way a signal-to-noise advantage of some 3 db is obtained.

Channels have been arbitrarily numbered for identification purposes on the assumption that all the available channels may eventually be taken up, providing up to eight connecting channels at each station and two control channels in the Greater London Area. Separate channels would then be available for use as control channels in any adjacent radiophone service that may be established.

## CIRCUIT ARRANGEMENTS

The circuit arrangements of all channels are basically similar and are shown in Fig. 2. The 2-wire audio pair from the switchboard is connected, via a terminating set, over a 4-wire circuit to the radio equipment. Outgoing signals pass via a constant-volume amplifier (c.v.a.), which compensates for variations in speech level over a range of 28 db and ensures a high average depth of modulation of the radiated signal. The transmitters are switched on by a d.c. signal controlled by the switchboard sleeve circuit and extended via the phantom of the 4-wire circuit.

In the absence of signals the receive path is normally

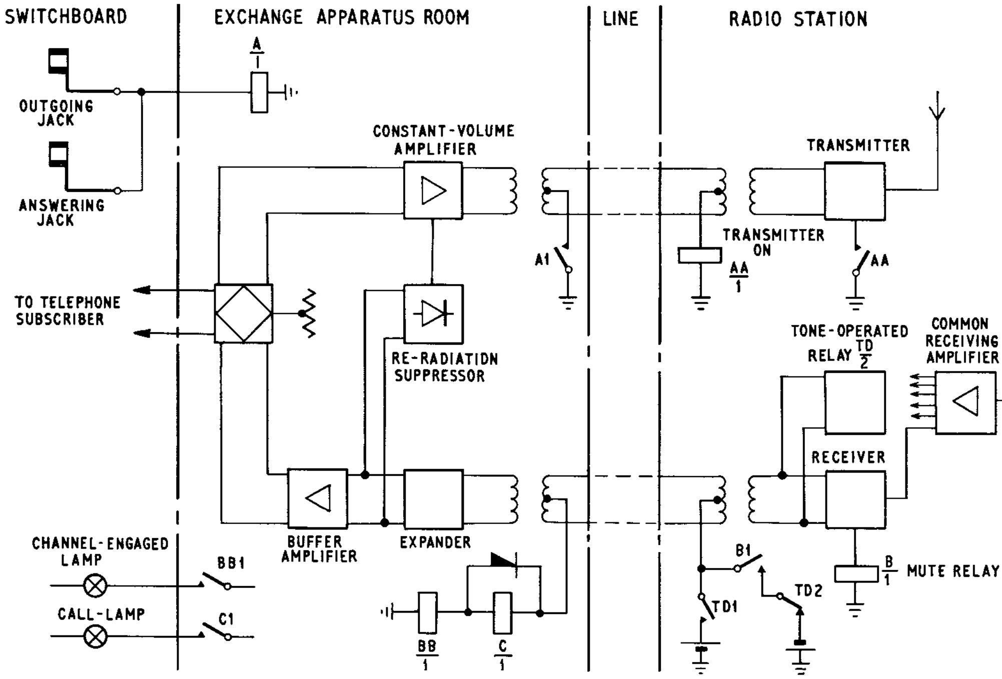



FIG 2—GENERAL ARRANGEMENTS OF TRAFFIC CHANNELS

blocked. Receipt from a mobile subscriber of signals of sufficiently high level to provide a signal-to-noise ratio of 26 db at the output terminals of the receiver opens the receiver-muting circuit and completes the receive path. Possible re-radiation of the received signal due to high-level leakage across the terminating set is avoided by deriving a control voltage from the received signal to reduce the gain of the transmit c.v.a. Under marginal reception conditions, when the re-radiation suppressor is not fully effective, re-radiation of noise during pauses in received speech is minimized by the noise reducer or expander unit. The effect of this device has previously been discussed in some detail.*

Two supervisory conditions are signalled from the receiver by means of polarized relays. Operation of the mute switch gives a "channel-engaged" lamp indication. Receipt of the mobile-subscriber's calling tone operates the tone-detector circuit connected across the receiver output terminals to signal the calling condition at the switch-board.

The control channels have additional facilities for calling purposes (see Fig. 3). Insertion of the operator's plug into the outgoing jack, which is common to the three control channels, prepares the encoder for use, connects the encoding equipment to the three transmit paths, and switches on the three transmitters. On receipt of the ready-to-start signal, which is indicated by the dimming of the supervisory lamp, the operator dials the required number, which is transmitted simultaneously from the three stations.

DESCRIPTION OF EQUIPMENT

*Radio-Station Equipment*

The three radio stations are situated at Kelvedon Hatch, near Brentwood (North-East Station), Pimlico, near Kings Langley, (North-West Station), and Beulah Hill, near Crystal Palace, (South Station).

Kelvedon Hatch and Pimlico are Post Office radio stations, and the radiophone aerials are accommodated on 300 ft towers provided for other purposes. At the South Station the aerials are installed on the Independent Television Authority's (I.T.A.) tower at Beulah Hill, but in this instance the equipment is accommodated in Livingstone Telephone Exchange, which is adjacent to the I.T.A. site.

The installations at the three stations are to all intent identical. Two 3–6 db omnidirectional receiving aerial arrays are provided, each of which is connected to a common receiving amplifier capable of supplying up to nine receivers. The gain of the amplifier is adjusted so that the overall sensitivity of amplifier and receiver is similar to that of the receiver alone.

When the service was planned it was not practicable to use common transmitting aerials, and each of the transmitters is connected to a separate zero-gain omnidirectional aerial. To minimize the generation of intermodulation products, aerials are spaced vertically down the side of the aerial tower some 12 ft apart; Fig. 4 shows the arrangement at the Pimlico station.

Connexion between aerials and equipment is by means of a low-loss (0·66 db/100 ft) coaxial feeder, the average loss being 3 db.

The equipment at each station is accommodated on three racks (see Fig. 5). The transmitter rack is equipped with six transmitters (three connecting channels, control channels, main and reserve, and one spare) and an aerial-connexion panel. The rack is of the enclosed type and is fan-cooled. The transmitters are of conventional design, and are capable of delivering 60 watts output power. The temperature-controlled crystal oscillator operates at 1/24 of the radiated carrier frequency and has a nominal stability of 0·001 per cent. It is followed by a chain of multiplier stages to drive the power output amplifier. A

*Arman, L. T., and Meller, V. C. The South Lancashire Radiophone Service. *P.O.E.E.J.*, Vol. 52, p. 253, Jan. 1960.

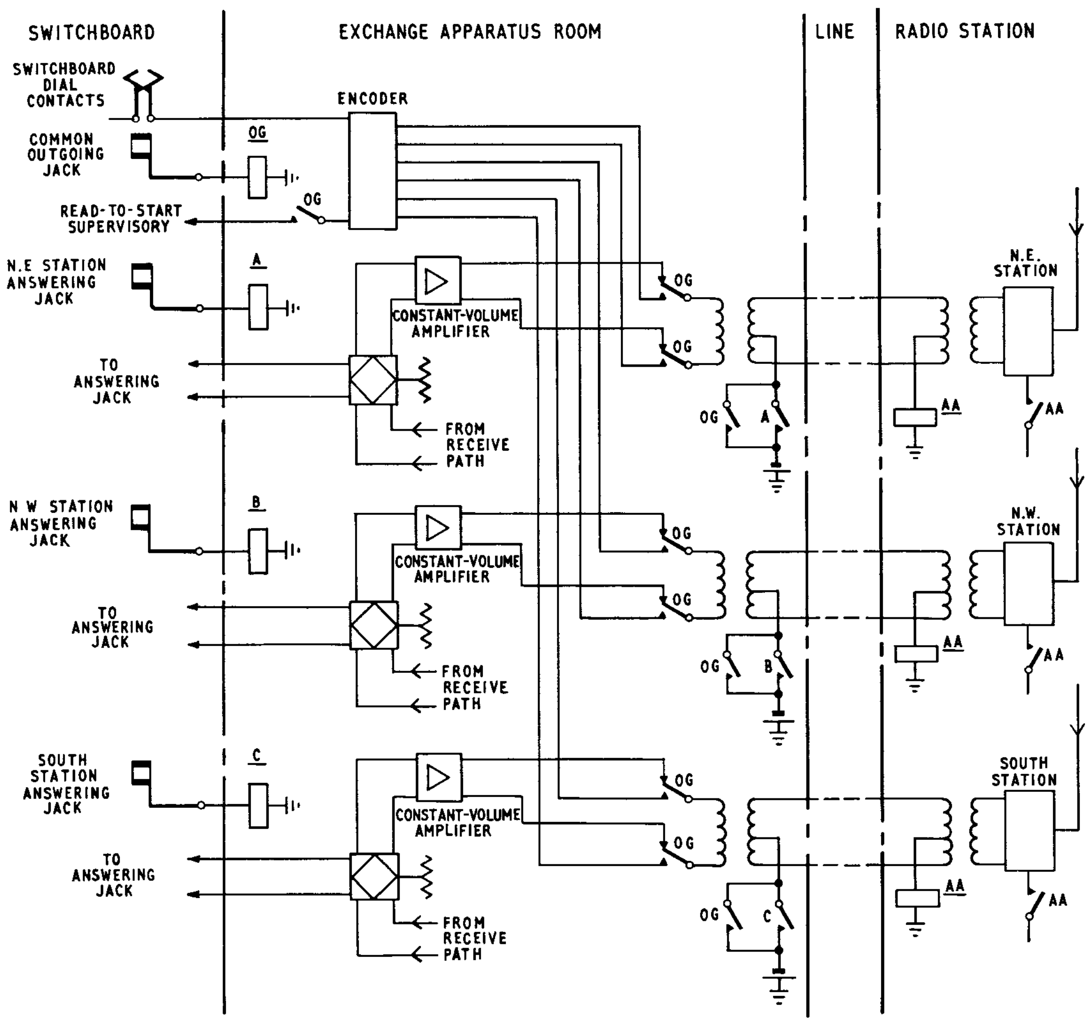



FIG 3—CALLING ARRANGEMENTS OF CONTROL CHANNEL

low-pass filter in the output lead reduces the radiation of harmonics.

The phase modulator operates at crystal frequency, and the resultant deviation is proportional to frequency over the audio range 300–3,000 c/s. An audio limiter at the input of the modulator restricts the peak deviation to $\pm$ 10 kc/s, and the following low-pass filter removes harmonic products generated by the limiter and limits the audio band to the required range. In practice, the equipment is set up to give some 2 db of clipping of speech peaks, thus enabling a reasonably high average depth of modulation to be achieved with little noticeable distortion.

The receiver rack accommodates the six receivers, the two common receiving amplifiers, and two cavity band-pass filters, which are connected in the input lead of the amplifiers and reduce possible adverse effects cf high-level out-of-band signals, such as intermodulation, cross-modulation blocking, etc.

Both receivers and common amplifiers are of solid-state design and reflect current practice in this field. The receiver uses a double superheterodyne circuit with crystal-controlled first and second local oscillators. Adjacent-channel selectivity is provided by a block filter operating at the second i.f. frequency of 455 kc/s. The audio signal is recovered by means of a Foster-Seeley type discriminator, and is passed to line via an adjustable-gain amplifier. The muting circuit is operated on the receipt of a signal of sufficient level to produce the required signal-to-noise ratio. An output from the second i.f. stage is amplified and rectified to provide a control voltage for operating the mute relay.

The third apparatus rack accommodates line transformers, relay-sets, and the calling-tone detectors associated with each receiver.

*Radio-Terminal Equipment*

The radio-terminal equipment at Tate Gallery Telephone Exchange is installed on four 10 ft high racks in the apparatus room. The constant-volume amplifier and re-radiation suppressor circuit associated with each channel constitute one unit, which has been built to a Post Office specification. The unit is of solid-state design, and module construction has been used, five of the units occupying one 10 in. high housing. The noise-reducer unit is of similar construction. Both units are designed to operate from a 24-volt d.c. supply obtained from stabilized power units.

The encoding equipment converts dial impulses into corresponding transitions between tones of 600 c/s and 1,500 c/s. This is achieved electromechanically by a

FIG. 4—AERIAL SYSTEM AT PIMLICO

series of inter-connected relays. A single "start" transition at the beginning of a code, which resets the decoders to the zero condition, and a second "finish" transition at the end, are added automatically. To prevent premature dialling, a supervisory ready-to-start condition is signalled to the operator to indicate when dialling may commence.

*Mobile Equipment*

Although the Post Office provides and operates the fixed stations in radiophone services, it is in no way responsible for the supply of mobile equipment. Nevertheless, fairly close control over its performance is essential in the interests of compatibility, and, as already mentioned, all equipment produced has to be type-approved to a Post Office specification before it can be marketed. Code numbers are issued under the authority of the Post Office, although, in the interests of production efficiency, manufacturers have been allotted blocks of the 4-digit numbers so that they may set the decoders during manufacture.

As far as possible the radio performance required of mobile equipments is similar to that laid down in the current private mobile-equipment specifications. In this way the use of off-the-shelf equipment, with little modification, has been possible.

FIG. 5—INTERNAL EQUIPMENT AT PIMLICO

Designs generally follow those of the base-station equipments but on a smaller scale. Transmitter output powers are typically 12–15 watts. Each equipment has to be capable of switching to any of the 10 channels available. So far, channel-selector mechanisms have evolved around push-button-controlled electromechanical switching devices, although solid-state switching is now a practical possibility.

Typical equipments are shown in Fig. 6. The radio and decoder unit would normally be mounted in the vehicle boot and the control unit beneath the dashboard. The control unit contains the channel-selector and call buttons, and is provided with calling and channel-engaged indicator lights.

Two types of decoder unit have been used so far: one of electromechanical design, and one of solid-state design. Both are of proprietary United States manufacture. In the first, the code signal generates pulses that operate a ratchet relay having peripheral holding contacts which are set-up in accordance with the particular code number. In the other, the received code is translated into binary code and compared with the required code which is set-up in a series of binary counters.

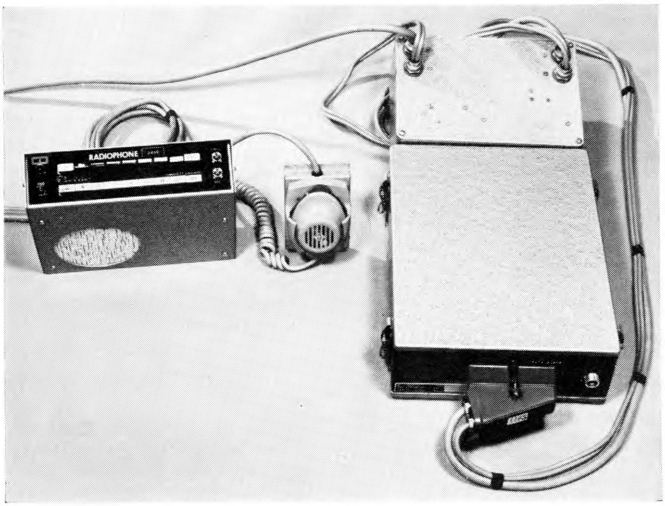
Both designs are well tried and are comparable in operational performance.

## OPERATIONAL EXPERIENCE

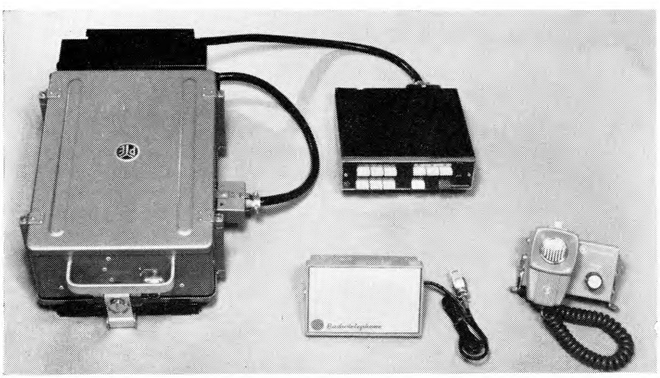
The service has now been in operation for some 6 months, and the number of subscribers is approaching 300. In fact, in view of the lack of experience of radiophone services a temporary halt has been called on the acceptance of new subscribers until more information about calling habits has been obtained. It would appear that the South Station carries the majority of traffic.

From the technical aspect the service has settled down extremely well. Doubts were at one time expressed about the reliability of the simultaneous transmission of the calling signal from the three base stations in the overlapping service areas. Whilst distortion of the tones and the generation of heteroedyne beat notes occurs, both types of decoders continue to operate satisfactorily anywhere in the service area as long as the beat-note frequencies are kept below 300 c/s. The control-channel transmitter oscillators are accordingly held to this accuracy: as the short-term stability of the radiated carriers is, in fact, better than 0·0001 per cent, no problem has been experienced in achieving this. It was also considered that delay equalization of the audio-tone signals to the three stations might be required in view of the difference in distances, and, consequently, transmission times, between the three base stations and Tate Gallery Exchange. In practice, delay equalization has been found to be unnecessary.

Intermittent interference has been experienced on the receive channels at the South Station. This has been found to be due to radiation from industrial radio-frequency equipment, such as plastic welders, wood gluers, etc. The bursts of interference are of short duration, and, as the range can be up to five or so miles, the sources are extremely difficult to trace in the densely populated areas around the station. Fortunately, the effect upon the service has been negligible to date.




(a)



(b)

FIG. 6—TYPICAL MOBILE EQUIPMENTS

## CONCLUSIONS

The system parameters of the London Radiophone Service were chosen to permit an extension to the service by the addition of further connecting and control channels as and when the number of subscribers required it. It would also be quite practicable to introduce the service into any other area, including adjacent areas, by the judicious allocation of control channels. However, the service is rather restricted by the use of a separate calling-out channel, and any means by which this could be eliminated would greatly simplify operation and prepare the way for eventual automatic operation. Recently, mobile equipments with automatic channel-searching facilities have become commercially practicable, and it is felt that the introduction of this development is significant enough to warrant some re-appraisal of the present radiophone planning. With the new facilities that now appear possible, the radiophone service would become even more comparable with the telephone in operational simplicity.

# Laying Plastic Ducts by Moleplough

S. L. F. FAGG and W. T. WILSON†

U.D.C. 621.315.235

**With ever-rising labour costs, more attention is being turned to methods by which duct and cable can be placed underground by mechanical means. This article describes the modification of a moleplough for laying duct speedily and cheaply.**

INTRODUCTION

IN suitable conditions a moleplough may be used to place plant in the ground with the minimum excavation of soil and manual digging, and with increased laying speeds compared with the alternative methods.

During trials carried out in different parts of the country, 1½ in. bore flexible polythene duct in continuous lengths up to 500 ft, and 10 ft sections of 2 in. and 3¼ in. internal-diameter rigid PVC duct jointed to form continuous lengths, were successfully placed directly in the ground.

DUCT LAYING BY MOLEPLOUGH

*Flexible Polythene Duct*

Flexible polythene duct of 1½ in. nominal bore and with a wall thickness of 0·140 in. was purchased for the trial at a cost of 3s. 10d. per yard.

A winch tractor was used to pull a Ransome moleplough, which has a 3 in. diameter mole. The cable-feeding tubes of the moleplough were of an insufficient diameter to accommodate the duct, and an extension guide was bolted on to the rear of the plough blade (see Fig. 1). This increased the dimensions of the cable space

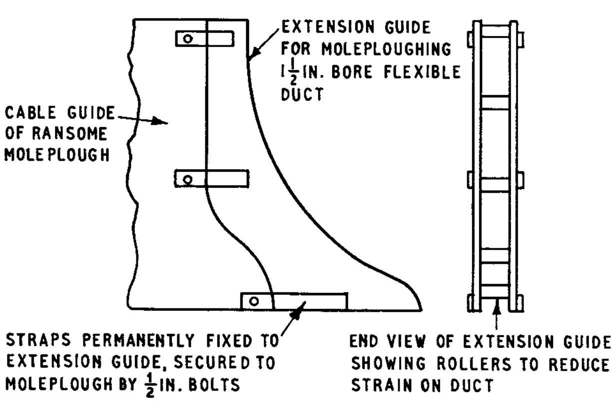



FIG. 1—EXTENSION GUIDE FIXED TO PLOUGH BLADE

to approximately 2¼ in. square, and gave a bending radius in the duct guide of 16 in.

A continuous length of duct was laid out parallel to the proposed route, and a starting pit for the plough, 5 ft 6 in. long, 6 in. wide and 16 in. deep, was excavated. The plough blade was lowered into the pit, and the mole was pulled into the end wall of the pit for about 1 ft. The end of the duct was passed down the extension guide and into the pit, where it was securely fastened to a bar driven in the ground. The moleplough was then drawn forward by the winch tractor, and the duct fed into the guide as in normal cable-laying by moleplough. The pull required from the tractor, which varied between 4,000 and 6,000 lb, and the speed of laying the duct, which varied between 10 and 20 ft/min., both depended on the nature of the soil.

Two men were used to feed the duct into the guide, one feeding the duct in and the other holding the loop of duct as it rose over and into the guide; the loop was approximately 7 ft in diameter. Water was occasionally poured into the guide, lubricating the duct and allowing it to feed into the guide freely.

Just before the duct reached a point where it was to be terminated, it was cut above the guide, sealed with a plug, and the moleplough drawn forward until the end of the duct was below the ground.

Consecutive lengths of duct were jointed by butting the ends of the duct together in the centre of the starting pit for a succeeding length, wrapping plastic adhesive tape around the duct where the ends met, and securing a short sleeve, cut from 2 in. bore polythene duct, over the joint by the use of metal clips.

*PVC Duct (G.P.O. Duct No.* 56)

Rigid PVC duct, with a nominal 2 in. bore and a wall thickness of 0·062 in., is supplied in 10 ft lengths each weighing 2·61 lb. One end of each 10 ft length is expanded to form a socket, and when two such lengths are jointed by forcing a spigot into a socket a tensile force of about 1,600 lb is required to part the joint. It was found that lubricating the spigot and socket with water enabled the joint to be made easily, the spigot going fully home into the socket.

Because of the rigidity of the duct it was found necessary to draw it into the ground behind the mole of the Ransome moleplough, which was again pulled by a winch tractor. The individual ducts were jointed together to form a continuous length, with the spigot of the length of duct nearer the moleplough. Since the duct was drawn in behind the moleplough the continuous length of duct was limited by the space available for laying out the duct and by the friction on the duct. When possible this length was 250 ft, but in restricted circumstances the length was reduced, additional lengths of duct being added up to a total of 250 ft after the initial length had been drawn into the ground.

To fix the duct to the moleplough special attachments were required, and these are shown in Fig. 2. In order to fit attachment A (Fig. 2(*a*)) to the moleplough it was necessary to cut away the bottom end of one of the cable tubes where it projected into the mole channel (Fig. 3).

The first length of duct was laid out, a 7-strand 14 s.w.g. steel wire was passed through the duct, and a small eye made in the end of this wire nearest the moleplough. This eye was secured inside the cap (Fig. 2(*c*)) by a steel pin after the metal sleeve (Fig. 2(*d*)) had been slipped over the spigot end of the duct: the sleeve was then screwed into the cap (Fig. 4). The steel wire was connected to a tensioning device, which was then pushed over the socket of the last duct and the wire

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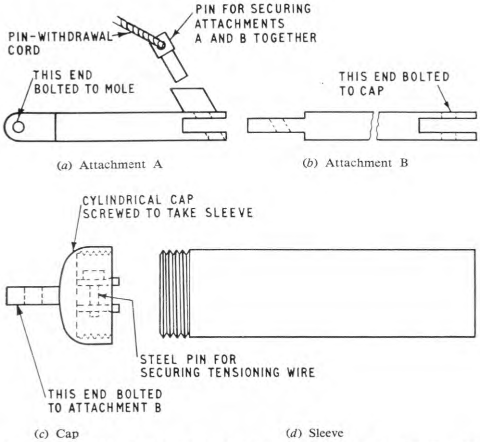


FIG. 2—SPECIAL ATTACHMENTS REQUIRED TO FIX DUCT TO MOLEPLOUGH

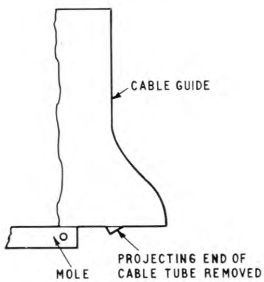


FIG. 3—CABLE TUBE CUT AWAY TO ACCOMMODATE ATTACHMENT A

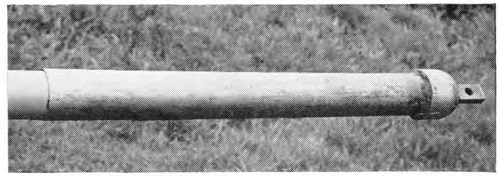

FIG. 4—DUCT, SLEEVE AND CAP READY FOR ATTACHING TO MOLEPLOUGH

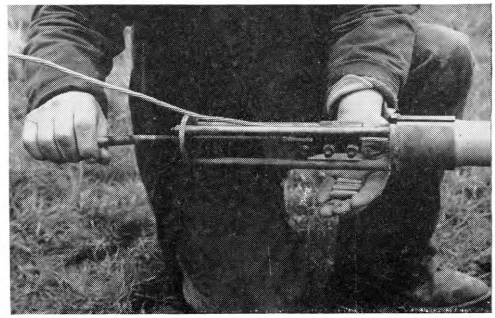

FIG. 5—TENSIONING THE WIRE

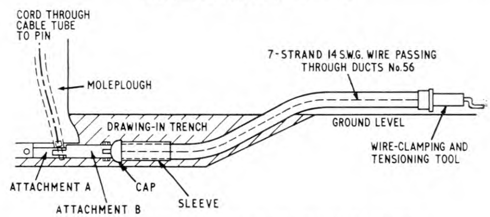


FIG. 6—EQUIPMENT READY TO DRAW IN DUCT

tensioned (Fig. 5). An indication of sufficient tension was given by a slight bowing of the duct when the wire became taut, care being taken not to over-tension the wire.

A starting pit, 9 ft long, 6 in. wide and 16 in. deep, was dug, and the moleplough blade together with attachments A and B were lowered into the pit, the attachments being supported so that they were not damaged when the moleplough blade was lowered. The mole was then pulled into the end wall of the pit for approximately 1 ft and attachment B was connected to the cap. Fig. 6 shows in schematic form the equipment ready to be drawn in. Drawing-in of the duct by the winch tractor then proceeded, the pull varying between 4,000 and 6,000 lb. A man was employed at the starting pit to control the angle at which the duct was fed into the pit (Fig. 7). The speed of drawing-in the

FIG. 7—CONTROLLING ANGLE OF DUCT ENTERING PIT

duct varied between 10 and 20 ft/min, i.e. a speed similar to that for the $1\frac{1}{2}$ in. flexible polythene duct.

At the point where the duct was to be terminated the steel pin securing attachment A to attachment B was withdrawn by pulling on a cord which had previously been attached to the pin and passed up through one of the cable guides and made fast; the withdrawal of the pin enabled the winch to pull the moleplough clear of the duct. Soil was excavated to clear the leading end of the duct, the sleeve and cap were removed, and a draw rope was pulled into the duct by the tensioning wire as this wire was removed from the duct.

When succeeding continuous lengths were to be jointed, the leading end of each continuous length was drawn into a pit similar to the starting pit. This pit served as a starting pit for the next length, and it was arranged that two lengths should meet in the middle of the length of a pit with an overlap of approximately 2 in. It was then possible to joint the lengths by raising each end in the pit, inserting the spigot into the socket, and pressing the duct down to the bottom of the pit. When drawing the duct into a pit, the duct was released from the plough by releasing attachment B from the cap.

The pin securing the connecting attachment A to attachment B was also required to release the duct from the moleplough when an obstruction was met so that the moleplough could be removed prior to excavating.

The tension in the wire passing through the duct was necessary to remove slack and prevent extension of the wire due to the friction load between the duct and the soil. The overall effect was to prevent the ducts from becoming detached from the sleeve or from each other when passing through the soil. The compressive strength of the duct (considered as a column) is approximately 3,500 lb and the earth-to-duct friction is estimated at 4 lb/ft of duct. With a safety factor of 2 it should be possible to draw-in 370 ft of duct in one length: in trials, however, a maximum length of 250 ft has been found to be more practical.

*Additional Experience*

The method just described has also been employed successfully to lay $3\frac{1}{4}$ in. bore PVC duct in continuous lengths of 200 ft at a depth of 16 in.; the pull required was 5,000 to 7,000 lb. Extended trials on actual field work with this larger duct are to take place. The $3\frac{1}{4}$ in. duct and the 2 in. PVC duct have also been drawn-in behind a new type of light moleplough that can operate in a narrow verge and which will enable duct to be drawn in by moleplough where the Ransome-type moleplough cannot operate. A recent decision has been taken to use $3\frac{1}{2}$ in. bore PVC ducts, but no difficulty is expected in drawing-in this larger duct by the same method.

CONCLUSIONS

The $1\frac{1}{2}$ in. bore flexible polythene duct may be laid at normal moleploughing depths and speeds, and in lengths limited only by the size and weight of the coils of duct. An armoured cable could also have been laid at the same time as the duct, the cable being passed down the normal cabling tube.

Up to 500 yd of the 2 in. PVC duct have been laid by a tractor and moleplough in one day. Approximately 3,500 yd of the 2 in. PVC duct were laid for a cable relief scheme in the Leicester area, and the cost per yard, including stores, was 3s. 10d. Although a greater length of the $1\frac{1}{2}$ in. flexible duct may be laid in one day this advantage is outweighed by its greater stores cost and the smaller cabling space provided: in most circumstances the 2 in. PVC duct is the more attractive proposition.

The cost of providing duct by the methods described shows that from their use considerable savings may be expected, compared with normal methods.

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# Aluminium Conductors for Telephone Cables

H. C. S. HAYES, C.G.I.A., M.I.E.E.†

U.D.C. 621.395.73 : 621.315.55 : 669.71

**In view of the high price of copper the British Post Office is examining the technical and economic factors involved in the use of aluminium conductors for telephone cables. Considerable maintenance experience has been gained with experimental cables that have been in service for periods ranging from 6 to 12 years. It is suggested that the most obvious use for aluminium-conductor cables will be between the local-network pillars and distribution points, where cables with up to 100 pairs are used.**

THE price of copper fluctuates considerably, and in May 1966 its cost per ton for use in cables rose to about £550 compared with less than half this some two years earlier. High prices portend shortage, and the British Post Office is examining the technical and economic factors involved in the use of aluminium conductors for telephone cables.

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

Copper ore in quantity occurs only in Canada, Chile, the Congo, U.S.A. and Zambia, whilst that of aluminium is to be found in many parts of the world. This, no doubt, is the basic reason why copper prices are subject to so much variation while that of aluminium remains comparatively stable at about £200 per ton.

Possibly the two most important properties of wire for cable making are electrical conductivity and weight. Other properties, notably tensile strength and ductility, are however of considerable importance. Aluminium has about $\frac{3}{5}$ the conductivity of copper and $\frac{3}{10}$ its specific gravity. It follows that for a given resistance an aluminium conductor has $\frac{4}{3}$ the diameter of a copper one; there is the compensatory feature that it has only $\frac{1}{2}$ the weight.

The relatively good conductivity-to-weight ratio of aluminium means, assuming prices per ton for copper and aluminium of £550 and £200, respectively, that the cost of the metal required to manufacture a wire of given length and resistance is favourable to aluminium in the ratio of over 5:1. This explains the wide use of bare overhead aluminium conductor (some steel cored) for the transmission and distribution of electric power.

Where cables are concerned, the comparative-cost ratio is less favourable to aluminium because the greater diameter of the aluminium wire means that the finished cable diameter and the volume of the wire insulation and sheathing are all increased roughly in like proportion. The resulting cost of manufacture can, of course, be gauged, but a true economic study of aluminium versus copper cable *in situ*, underground in a network, is really what is required and this is made difficult by the following three factors.

(*i*) The variable price of copper: a comparison made when a development scheme is being planned is unlikely to hold when the cable comes to be purchased.

(*ii*) Manufacturing costs of cables made of small-gauge aluminium wire are high because so little conductor of small gauge is, in fact, made. Costs would undoubtedly fall as production increased, but the extent is difficult to predict.

(*iii*) Aluminium cable, being ⅓ larger in diameter, makes a greater demand on duct space. In some parts of a network this is an important factor, whilst in others it is of little moment. In the estimating stage it is often difficult to assign the value of lost duct space in a realistic way.

However, despite the difficulties inherent in making a firm comparison it is safe to say that, with copper prices of the order now ruling, aluminium is making a strong economic challenge to copper in the telephone-cable field.

For many years it has been the practice to joint small-gauge copper conductors in local cables by twisting without soldering. This practice cannot be followed for aluminium because the metal, even if well cleaned just before twisting, becomes so quickly oxidized on exposure to the air that this prevents satisfactory electrical contact being made. It is found necessary at present either to weld the tips of the twisted joints or to solder them. Quicker methods of jointing are, however, in course of development, and it is justifiable to predict that shortly it will be possible to joint aluminium to aluminium, copper to copper, or aluminium to copper with equal facility.

Anticipation is a responsibility of engineering management, and it was foreseen that on economic or other grounds the need for using aluminium in place of copper might at some time arise. A few years ago it was, therefore, decided to invite a number of cable contractors to make some experimental aluminium-conductor cable for installation by Post Office labour. To make the trial as informative as possible a number of different cable sizes in the range 1 to 400 pairs were chosen, the conductor diameters ranging from 0·020 in. to 0·044 in., roughly equivalent in terms of resistance to 4 lb/mile to 20 lb/mile copper conductors. Rather over 26 sheath-miles of cable were manufactured, embracing 1,300 loop miles of conductor. Most of the cable was paper-insulated and polythene-sheathed, but about 10 per cent, on a loop-mile basis, had polythene both for the conductor insulation and the sheath.

Regions and Telephone Areas undertook the laying of the cables, which were provided as parts of normal working networks; during their installation some 30,000 wire joints were made. Each cable was given an Experimental Cable Schedule (E.C.S.) number to facilitate the recording of information about installation experience, the results of tests during construction, tests made prior to the acceptance of the cable for service, subsequent periodic routine tests, and also details of general maintenance experience. These cables were all of local type, with the exception of the Dover–Deal cable, described elsewhere,[1,2,3] which carried junctions and had a number of novel features in addition to aluminium conductors.

Although the experimental cables are not a very large sample they have been in service for periods of from 6 to 12 years and, thus, the maintenance experience gained has been considerable. The conclusion has been drawn that their maintenance performance has been substantially the same as that which would have been expected from copper-conductor cables operating under the same conditions.

The most obvious use of aluminium-conductor cable in the field would be its installation in the distribution part of the local network between pillars and distribution points, where cables with up to 100 pairs are used. There is usually ample space in the ducts and the slightly larger cable is unlikely to be an embarrassment. Also, in this part of the network a good deal of cable is laid directly in the ground where the larger size is then of no consequence. Conductor diameters will be about 0·025 in. and 0·032 in., the near equivalents in terms of resistance to 6½ lb/mile and 10 lb/mile copper conductors, the conductors being polythene-insulated within a polythene sheath.

Tensile strength and ductility (the percentage elongation a wire, usually 10 in. long, will undergo before fracture when slowly and steadily stretched) are properties of a cable conductor which should receive further mention. The former is dominant in so far as the manufacturer is concerned because high output calls for fast working machinery which, in turn, requires a conductor capable of standing up to high pulling stresses. On the other hand, although both properties are of concern to the installation engineer, it is of prime importance to him that the ductility should be sufficient, both to give an even distribution of the pulling-in tension among the conductors so that none is subjected to breaking stress and, also, to allow twisting of the wire in the jointing operation without risk of fracture. Naturally, these manufacturing and installation desiderata conflict to some extent, and recent work has been directed towards the selection of a "temper" for the aluminium which will meet all the requirements sufficiently. Some experience is being obtained in the use of an aluminium alloy which has tensile and ductility characteristics very similar to those of copper; this has a slightly lower conductivity than pure aluminium.

*References*

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[2]HAYES, H. C. S., and GLOVER, D. W. Developments in the Application of Polythene to Telecommunication Cables. *I.P.O.E.E. Printed Paper No.* 220, 1963.

[3]HAYES, H. C. S. The Dover to Deal Experiment. *Post Office Telecommunications Journal*, Vol. 15, p. 34, Winter 1963.

# A Modem for the Datel 600 Service—Datel Modem No. 1A

L. W. ROBERTS and N. G. SMITH†

U.D.C. 621.376.3 : 621.394.4 : 681.142

**The Datel 600 Service, which provides for the transmission of binary data signals over telephone circuits, requires a unit to convert the binary d.c. signals to a form that will pass through voice-frequency amplifiers and similar equipment. The facilities provided by this unit, which is known as the Datel Modem No. 1A, are described together with details of the design adopted and the factors influencing the design.**

## INTRODUCTION

THE Datel 600 Service,[1] which was briefly described in an earlier issue of this Journal, provides for the transmission of binary d.c. data signals between widely-separated locations by making use of the public switched telephone network or of private circuits. The d.c. signals must be converted to a form that will readily pass through voice-frequency (v.f.) amplifiers and similar equipment so that they can be transmitted over telephone-type circuits. The unit which carries out this function is referred to as a modem, since it will, generally, contain a modulator to convert the d.c. data signals to v.f. signals for transmission and a demodulator to convert received v.f. signals to d.c. signals. Such equipment has been developed for the Datel 600 Service and is known as the Datel Modem No. 1A. The facilities that this unit provides are given below.

A modem for general purpose use must be able to work over the many types of telephone connexion which may be encountered. It must, therefore, be relatively insensitive to the signal impairment that may be caused by variation of line characteristics, including circuit transmission loss, loss/frequency distortion and group-delay/frequency distortion. In addition, it should be able to accept data for transmission at any rate up to its design maximum, and not impose any restriction on the character code and, hence, on the number of consecutive 0's and 1's that may be used. This latter requirement necessitates the choice of a form of modulation which ensures that the line signal received by the demodulator is unambiguous.

## LIMITATIONS IMPOSED ON MODEM DESIGN BY CHARACTERISTICS OF THE TELEPHONE NETWORK

A modem for general purposes must be suitable for use on connexions established over the public switched telephone network, as well as on private circuits. The characteristics of the latter circuits can be controlled to a large degree, and may generally be made equal to the best found in the public telephone network. Thus, they need not be specially considered in modem design, as the more stringent requirements are those imposed by the public switched telephone network.

A summary of the characteristics of the public switched telephone circuits which affect data transmission are as follows.

(*a*) *Overall Transmission Loss.* Overall loss varies from connexion to connexion and may be as much as 30 db at the reference frequency (800 c/s) on extreme connexions.

(*b*) *Variation of Transmission Loss with Frequency.* The loss/frequency characteristic of an extreme connexion, routed over long trunk and junction circuits which include old-type line plant such as heavily-loaded cables, is shown

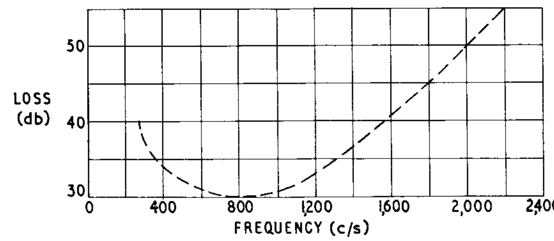



FIG. 1—LOSS/FREQUENCY CHARACTERISTIC OF NOMINAL EXTREME CONNEXION

in Fig. 1. This figure shows that the difference between the loss at 800 c/s and that at 2,000 c/s may be as much as 20 db. When the basic loss of about 30 db at 800 c/s is added, the loss at 2,000 c/s reaches 50 db; this is about the limit for practical purposes and it would not be reasonable on a connexion of this type to extend the usable frequency range any higher. Many connexions will be much better than this, and have a reasonable loss up to 3,000 or 3,400 c/s.

(*c*) *Variation of Group Delay with Frequency.* The variation of group delay with frequency is usually referred to as the group-delay/frequency characteristic and is measured in milliseconds. The group-delay/frequency characteristic of the connexion illustrated in Fig. 1 is shown in Fig. 2. The group delay shown here would not

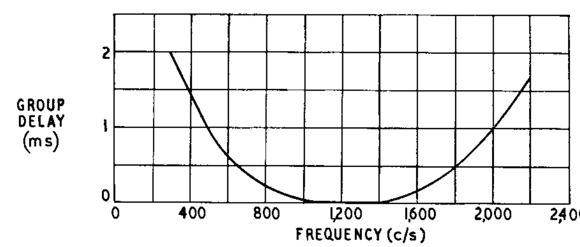



FIG 2—GROUP-DELAY/FREQUENCY CHARACTERISTIC OF NOMINAL EXTREME CONNEXION

be detectable in speech, but it does have a serious adverse affect on data-transmission line signals. For a practical system working on this type of connexion a change of 1 ms between 1,200 and 2,000 c/s would be the maximum tolerable.

(*d*) *Noise.* The noise on telephone connexions is of two types; background mush, roughly approximating to white noise, which, except on long intercontinental connexions, is of a low order and may be ignored, and impulsive noise due to dial pulses and to switching in exchanges. Impulsive noise tends to vary widely, depending on the age of an exchange and its location. The effects of such noise depend on the power level of the signal transmitted from a modem, and, whilst it is desirable to make the signal-to-noise ratio as great as possible by using a high signal level, the send level must be limited to avoid overloading the telephone line equipment, particularly telephone carrier channels.

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

[1]SMITH, N. G. An Introduction to the Post Office Datel Services. *P.O.E.E.J.*, Vol. 59, p. 1, Apr. 1966.

(*e*) *Echoes*. The use of modern telephone transmission techniques, e.g. carrier systems, results in inland circuits in the United Kingdom having short propagation times. Any echoes that may occur on lines used for speech purposes appear as sidetone in the talkers' telephone receiver and, thus, are relatively unimportant. The main affect of echoes on the data-transmission line signals is to produce an interfering signal equivalent to listener echo* at the demodulator, and this tends to reduce the total number of trunk links that can be included in a data call.

(*f*) *In-Band Telephone-Signalling Equipment*. Although it cannot properly be called a line characteristic, the presence of v.f. signalling equipment in trunk lines does impose a limitation on the exploitation of the telephone network. Pure tones within the band to which the signalling receivers are sensitive cannot be tolerated, as their false operation will interfere with the connexion, and, in the extreme case, cause it to be disconnected. Arrangements are included in signalling receivers to prevent false operation due to speech, but due to variations in equipment design it is not possible to make use of this facility except in modern signalling receivers, e.g. those of Signalling System A.C. No. 9. Frequencies from data-transmission modems must not fall within the band 450–900 c/s because adequate guarding against false operation of the trunk-signalling equipment (early type Signalling System A.C. No. 1 and Signalling System A.C. No. 3) is difficult to guarantee without placing further restrictions on the form of line signals from the modems.

From the above it will be seen that data-transmission signals must be confined to those parts of the frequency spectrum below 450 c/s and above 900 c/s, with a minimum upper limit of about 2,000 c/s for some connexions.

## GENERAL-PURPOSE MODEM DESIGN

In considering the desirable design parameters for a general-purpose modem it is clear that, due to the likely variations of level of a received signal, amplitude modulation is unattractive and that frequency or phase modulation would be preferable. There has been considerable discussion of the relative merits of these latter two methods of modulation for this particular application, and arguments can be produced in favour of both. However, for a modem to provide the characteristics suggested earlier, i.e. for it to be a robust, general-purpose equipment capable of transmitting data at any modulation rate up to the design maximum, without restrictions on the code used or the number of consecutive 0 or 1 signals, frequency modulation has been chosen internationally.

The International Telegraph and Telephone Consultative Committee (C.C.I.T.T.) at its Plenary Meeting in June 1964 approved a Recommendation for a general-purpose modem for use on the public switched telephone network; the characteristics for this modem take into account the limitations of telephone lines mentioned above. The C.C.I.T.T. Recommendation is No. V23, and it recommends that a modem for use on the public switched telephone network should include two modes of operation allowing the transmission of data at rates up to 600 or up to 1,200 binary digits/second (bits/second), using frequency modulation. The transmission may be synchronous or asynchronous, and an optional return channel for use at modulation rates up to 75 bits/second is included. The modulation rates and characteristics of the forward data channel are shown in Table 1.

*Listener echo—interfering reflected signals heard by the listener, not the talker.

TABLE 1
Characteristic Frequencies Recommended by C.C.I.T.T. for 600/1,200 bits/second Modem

| Mode | Nominal Mean Frequency ($F_0$ c/s) | Binary Symbol 1 ($F_Z$ c/s) | Binary Symbol 0 ($F_A$ c/s) |
|---|---|---|---|
| A1 (up to 600 bits/second) | 1,500 | 1,300 | 1,700 |
| A2 (up to 1,200 bits/second) | 1,700 | 1,300 | 2,100 |

Mode A1 is for use when line conditions prevent the use of Mode A2. The return-channel maximum modulation rate is 75 bits/second, and the characteristic frequencies recommended are: mean, or carrier frequency, $F_0 = 420$ c/s; binary 1, $F_Z = 390$ c/s; binary 0, $F_A = 450$ c/s.

The Recommendation also covers frequency tolerances, power levels and time constants of the carrier detectors.

## CONNEXION OF MODEM TO DATA-TERMINAL EQUIPMENT

The C.C.I.T.T. has drawn up Recommendation No. V24 for the standards of the type and form of signals to be exchanged at an interface between data-processing terminal equipment and data-communications equipment.

This recommendation lists 28 interchange circuits between the data-processing terminal equipment and data-communication equipment. Each circuit is identified by a number and a descriptive name, and it is intended that equipment designers shall select those circuits applicable to the particular system being considered from those listed in the Recommendation.

Also included in the Recommendation are the electrical-signal characteristics in terms of d.c. voltage, and the significance of positive and negative signals.

Those circuits chosen by the British Post Office for use with their Datel Modem No. 1A and the signal characteristics are given in detail in a British Post Office Specification entitled "Specification for Customer's Data Input and Output Devices for use with the Post Office Datel Modem No. 1A".[2]

## CONSTRUCTION OF DATEL MODEM No. 1A AND ASSOCIATED ITEMS

The Datel Modem No. 1A has been developed for use over either the public switched telephone network or private circuits with 2-wire or 4-wire local ends. It operates in conjunction with customers' privately-owned data terminal equipment, and the modems and data terminal equipments together form a data-transmission system between the premises of two customers.

The Datel Modem No. 1A comprises the following units.

(*i*) Data Main Unit No. 1A.
(*ii*) Data Modulator No. 1A.
(*iii*) Data Modulator No. 2A.
(*iv*) Data Demodulator No. 1A.
(*v*) Data Demodulator No. 2A.

The Data Main Unit No. 1A is the basic unit, and is

[2]Specification for Customer's Data Input and Output Devices for use with Post Office Datel Modem No. 1A. Post Office Engineering Department Specification TG2269A.

constructed in the form of a free-standing metal cabinet, $17\frac{3}{8}$ in. × $6\frac{7}{8}$ in. × $12\frac{1}{8}$ in. Fig. 3 shows this unit with an associated 700-type telephone. The finish is in two-tone grey to match that of the telephone. Access for installation and maintenance purposes is achieved by removing the front and back panels. The body of the unit is covered by a wrap-round cover, which can also be removed when desired, the cover being secured by screws underneath the cabinet which are not normally visible. The Data Main Unit No. 1A consists of the power unit, 2-wire/4-wire termination, line transformers, line-holding coil, Data Modulator No. 1A transmit-filter delay equalizer, relays, and printed-circuit boards for common circuits. Terminal blocks are provided for the termination of the standard telephone and power cords.

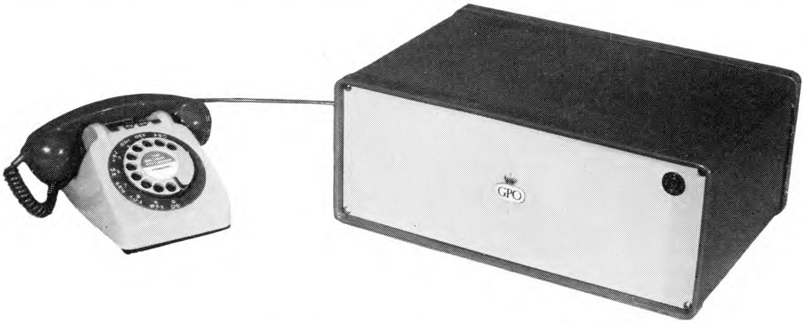



FIG. 3 —DATEL MODEM No. 1A WITH 700-TYPE TELEPHONE

The data modulators and demodulators are constructed in the form of plug-in modules, and provision is made in the Data Main Unit No. 1A for insertion of these as required. The modules use one or more printed-circuit boards for mounting the circuit components, and the edges of these boards are located in the main unit by metal guides which ensure correct location with the edge connectors appropriate to each board. The units are protected by transparent plastic covers supported by stand-off pillars attached at the corners of the printed-circuit boards. Correct positioning of the modules is ensured by polarization of the edge connectors and by varying the widths of the plastic covers on the modules. In addition, each module has a handle with the title of the unit inscribed. The modules are held in position by a retaining bar located by screws after the modules have been fitted. Fig. 4 shows a Datel Modem No. 1A with the covers removed and a modulator and demodulator partially inserted in the main unit; the transparent plastic covers have been removed to give a clear photograph, but the pillars for supporting these covers can readily be seen.

Connexion to the modem from the customers' equipment is made via a 25-way plug and socket; the latter can also be seen in Fig. 4. A non-locking press-button key is fitted below this socket to enable the equipment to be tested remotely.

The Datel Modem No. 1A has been designed to comply with C.C.I.T.T. Recommendations V23 and V24, and this is achieved in the following manner.

The Data Modulator No. 1A and Data Demodulator No. 1A form a data, or forward, channel capable of operation at data-signalling rates of up to 1,200 bits/second covered in two ranges: (*a*) up to 600 bits/second, or (*b*) up to 1,200 bits/second. Selection of the range is carried out by a control signal from the customer's equipment, but the actual data-signalling rate will be determined by (*i*) speed of operation of the customer's equipment, and (*ii*) the line characteristics.

The Data Modulator No. 2A and Data Demodulator No. 2A form the supervisory or return channel, operating at data-signalling rates of up to 75 bits/second.

The provision of plug-in modules at any one installation is determined by the

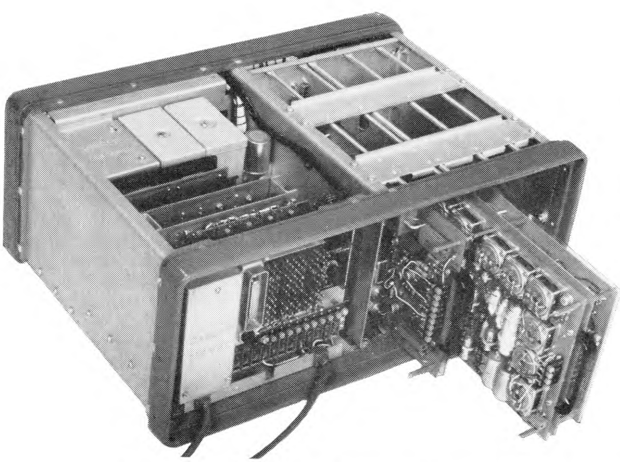


FIG. 4 —DATEL MODEM No. 1A WITH COVERS REMOVED

customer's requirements, and in order to provide flexibility in the facilities offered, five models of the equipment are available, providing the facilities given in Table 2, and are made up by inserting into a Data Main Unit No. 1A the following units.

(*i*) Model 1: Data Modulator No. 1A.
(*ii*) Model 2: Data Demodulator No. 1A.
(*iii*) Model 3: Data Modulator No. 1A and a Data Demodulator No. 2A.
(*iv*) Model 4: Data Modulator No. 2A and a Data Demodulator No. 1A.
(*v*) Model 5: Data Modulator No. 1A and a Data Demodulator No. 1A.

TABLE 2
Facilities Provided by the Five Models of the Equipment

| Facility | Models Required | |
|---|---|---|
| | A End | B End |
| 1: Data in direction A–B only. Note: This facility will not normally be available for use on the public telephone network. | Model 1 | Model 2 |
| 2: Data in direction A–B and simultaneously on return channel B–A | Model 3 | Model 4 |
| 3: Data in direction A–B or alternative direction B–A, but not both ways simultaneously | Model 5 | Model 5 |
| 4: As in 3 but with return channels | Model 3 with Model 4 | Model 3 with Model 4 |
| 5: Data in both directions simultaneously (4-wire private circuits only) | Model 5 | Model 5 |
| 6: As in 5 but with return channels | Model 3 with Model 4 | Model 3 with Model 4 |

The different models and facilities are obtained by inserting wire straps on a tag block at the rear of the case and by fitting the appropriate modulators and demodulators. The tag block also provides facilities for adjusting the transmitted signal level of the modem, for controlling the demodulator, and for changing the equipment impedance presented to the line. The wire straps and cord connexions that are available to produce the various facilities are indicated on the rear cover of the Data Main Unit No. 1A.

## CONTROL OF THE EQUIPMENT BY THE CUSTOMER

The Datel Modem No. 1A is controlled by d.c. signals from the customer's data terminal equipment over interchange circuits. D.C. signals are also sent from the Datel Modem No. 1A to the customer's data terminal equipment over other interchange circuits to indicate the operational state of the modem, data modulators and data demodulators.

The interchange circuits between the Datel Modem No. 1A and the customer's equipment are connected together via a 25-way plug and socket at the rear of the modem. This connexion is known as the interface, and the individual functions of the interchange circuits are listed below.

(*a*) *Transmitted Data.* Connects data input to the Datel Modem No. 1A from the customer's data terminal equipment (used on Models 1, 3 and 5).

(*b*) *Transmitted Supervisory-Channel Data.* Connects supervisory data to the Datel Modem No. 1A from the customer's data terminal equipment (used on a Model 4).

(*c*) *Received Data.* Connects data-channel output to the customer's data terminal equipment (used on Models 2, 4 and 5).

(*d*) *Received Supervisory-Channel Data.* Connects supervisory-channel output to the customer's data terminal equipment (used on Model 3).

(*e*) *Request to Send.* This circuit suppresses the output from the Data Modulator No. 1A until the customer is ready to transmit binary data signals (used on Models 1, 3 and 5).

(*f*) *Transmit Supervisory-Channel Carrier.* This circuit performs a similar function on the Data Modulator No. 2A to that of circuit (*e*) on Data Modulator No. 1A (used on Model 4).

(*g*) *Ready for Sending.* Connects an output signal to the customer's data terminal equipment to indicate the condition of circuit (*e*) in the Datel Modem No. 1A. Facilities are available in the equipment to delay this signal by either 20 ms or 200 ms after the application of the appropriate signal on circuit (*e*) (used on Models 1, 3 and 5).

(*h*) *Supervisory-Channel Ready.* Performs the same function for circuit (*f*) as circuit (*g*) does for circuit (*e*) (used on Model 4).

(*j*) *Data-Set Ready.* Connects an output signal to the customer's data terminal equipment to indicate whether the Datel Modem No. 1A is switched to line or not (used on all Models).

(*k*) *Data-Carrier Detector.* Connects an output signal to the customer's data terminal equipment indicating the presence of a signal at the input of the Data Demodulator No. 1A (used on Model 2, 4 and 5).

(*l*) *Supervisory-Channel-Carrier Detector.* Performs the same function on the Data-Demodulator No. 2A as circuit (*k*) does on Data Demodulator No. 1A (used on Model 3).

(*m*) *Data Signalling-Rate Selector.* Sets the data-modulation-rate range of the forward channel (used on all Models).

(*n*) *Connect Data-Set to Line.* Controls the switching of the Datel Modem No. 1A to and from the line. Alternatively, this control can be carried out by a push-button key on the associated telephone.

The interchange circuits used for control purposes are operated by a nominal ±6 volts, the −6 volts indicating the "OFF" condition and the +6 volts the "ON" condition. Those interchange circuits used for data signalling use +6 volts for binary 0 and −6 volts for binary 1. With −6 volts applied to the data signalling-rate selector circuit, the equipment is in the 600 bits/second mode, and is operated to the 1,200 bits/second mode when +6 volts is applied. These are nominal voltages, but the circuits are so designed that they will operate satisfactorily over the range −3 to −9 volts and +3 to +9 volts.

## CIRCUIT DESCRIPTION OF THE 600/1,200-BAUD MODEM

The equipment employs a frequency-modulation transmission system using the characteristic frequencies detailed in Table 1.

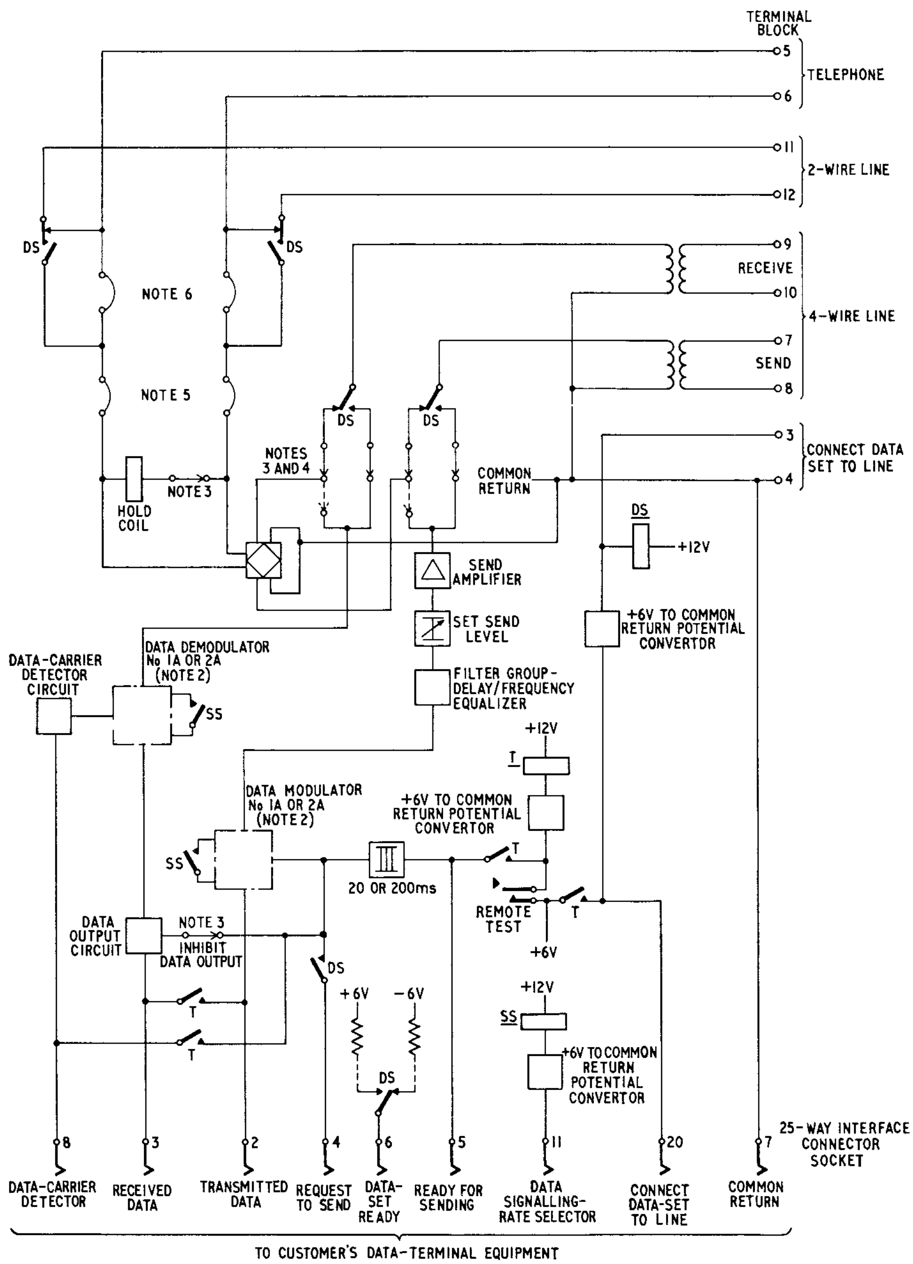
The equipment is operated from an a.c. mains supply, and the mains power unit within the main unit is adjustable in 10-volt steps to enable the equipment to work over the range 190–260 volts. The power unit provides six d.c. supplies: five are used to operate the circuits within the equipment, and the sixth provides 4·5 volts d.c. for use with an associated local-battery-type telephone, required on certain types of private circuits.

A simplified schematic diagram of the equipment is shown in Fig. 5. The following description assumes that the equipment has been wired for 4-wire working, and that a Data Modulator No. 1A and a Data Demodulator No. 1A have been inserted in the case, i.e. the modem is a Model 5.

In the idle condition the telephone will be connected to the 4-wire line via test links on the 2-wire side of the 2-wire/4-wire termination, with the send and receive lines extended to the termination via the line transformers, DS relay contacts normal and the 4-wire telephone straps. The d.c. signalling path is taken from the centre points of the line transformers to the termination in the conventional manner.

In the idle condition the d.c. signals listed in Table 3 will be present at the 25-way interface connector.

When the customer is ready to transmit data, voice communication is established between the two terminals, and then the modem is switched to line by applying a +6-volt signal from the customer's data-terminal equipment to the connect-data-set-to-line circuit in the modem, so operating relay DS. This extends the transmit and receive lines through to the modulator and demodulator, respectively, via the DS relay contacts, disconnecting the telephone from the line in the process.




Notes:
1. All circuit units are connected by unbalanced pairs on the equipment side of the 2-wire/4-wire termination and the line transformers. In the diagram only the non-earthy lead is shown.
2. Interchangeable plug-in modules.
3. Wire straps.
4. Straps shown thus —› are inserted for a 4-wire line, and are shown thus - - -› for a 2-wire line.
5. These links are removed for a local-loop test (with Model 5 only).
6. These links are inserted for a local-loop test and for a 4-wire line. The links are removed for a 2-wire line.

FIG. 5—SIMPLIFIED BLOCK SCHEMATIC DIAGRAM OF DATEL MODEM No. 1A

*Transmission of Data*

When data is ready to be sent a +6-volt signal is applied to the request-to-send circuit (see Note 1 of Table 3) from the customer's data-terminal equipment, causing (*a*) the ready-for-sending circuit to change the signal sent back to the customer's data-terminal equipment from −6 volts to +6 volts after a delay of 20 or 200 ms, which is predetermined on setting up the equipment by a wire strap on the tag block, and (*b*) the removal of an inhibit condition on the modulator output allowing carrier frequency to be transmitted to line through the group-delay/frequency equalizer, the attenuator and send amplifier. The attenuator is adjustable in 2 db steps by wire straps on the rear tag block. The frequency of the carrier will be dependent on the signals on the transmitted-data circuit and the data signalling-rate selector circuit, as indicated in Table 4.

With an OFF signal applied to the data signalling-rate selector circuit,

TABLE 3

Idle-Condition D.C. Signals at the 25-Way Interface Socket

| Interchange Circuit | Signal at Interface Socket | Signal Source |
|---|---|---|
| Request to send | − 6 volts | Customer's equipment (see Note 1) |
| Ready for sending | − 6 volts | Modem |
| Data-set ready | − 6 volts | Modem |
| Data-carrier detector | − 6 volts | Modem |
| Data Signalling-rate selector | ± 6 volts | Customer's equipment (see Note 2) |
| Connect data-set to line | − 6 volts | Customer's equipment (see Note 3) |

*Note* 1. The operation of the request-to-send circuit has been designed to respond either to −6 volts or to a disconnexion for the OFF condition, and to +6 volts for the ON condition. Since, in the idle condition, the input to the request-to-send circuit is disconnected at a DS contact, in practice the input voltage could be either +6 or −6 volts.

*Note* 2. This signal depends on the customer's requirements, i.e. whether he wishes to operate the equipment in its 600 bits/second or 1,200 bits/second mode, line conditions permitting.

*Note* 3. As previously mentioned this interchange circuit can be operated in one of two ways:

(*i*) by ±6 volts on the interchange circuit, or

(*ii*) by push-button key on the customer's telephone.

TABLE 4

Equivalence of Transmitted-Data Potential and Frequency Transmitted

| Potential on Transmitted-Data Circuit (volts) | Data Signalling-Rate Selector Circuit (volts) | Output Frequency (c/s) |
|---|---|---|
| −6 | −6 | 1,300 |
| +6 | −6 | 1,700 |
| −6 | +6 | 1,300 |
| +6 | +6 | 2,100 |

relay SS is unoperated and holds both modulator and demodulator in the 600 bits/second mode. With a +6-volt ON condition applied, the equipment is switched to the 1,200 bits/second mode.

*Reception of Data*

With no line signal incoming to the Datel Modem No. 1A the d.c. output signal on the received-data circuit is predetermined, when setting up the equipment, to binary 1 or 0 by a wire strap on the tag block. With the carrier-detector circuit in its idle state, an OFF signal will be returned to the customer's terminal-equipment via the data-carrier-detector interchange circuit. When a line signal is received, it will be applied to the Data Demodulator No. 1A and the signal on the received-data circuit for a given frequency will correspond to that shown in Table 3 for the transmitted-data circuit.

The carrier-detector circuit is operated by the received line signal and an ON signal is returned to the customer's equipment on the interchange circuit. There is also an additional output from the demodulator which is applied to pins 24 and 25 of the interface socket. The customer can connect these pins to an external loud-speaker-amplifier to monitor incoming data signals; this is known as the audio-monitor output.

When the modem is connected to a 2-wire telephone circuit, the 2-wire straps are inserted on installation, thereby connecting the carrier signals from the send amplifier to the 2-wire line via a 2-wire/4-wire termination, and incoming line signals are fed via the termination to the input of the demodulator. When the modem is in the speech mode, the telephone is connected to line via DS relay contacts, the appropriate test link being removed at the installation stage.

With the straps set for 2-wire operation, an a.c. path is formed between the modulator and demodulator across the 2-wire/4-wire termination. The attenuation of this path will depend on the impedance of the 2-wire line. Consequently, if Model 5 is used, the signals from the Data Modulator No. 1A will be fed to the Data Demodulator No. 1A and the transmitted-data signals will appear on the received-data circuit. This is overcome by using the request-to-send ON signal to clamp the received-data circuit to a predetermined 1 or 0 condition. This is carried out at the installation stage by wire straps on the tag block. If the modem is connected to a telephone line on the public switched telephone network or to a P.B.X. extension, the holding coil shown in Fig. 5 is wired in to provide a d.c. holding loop when the modem is connected to line.

The operation for Models 1 and 2 is the same as for a Model 5, except that transmission of data is possible in one direction only.

Models 3 and 4 operate as for a Model 5, except that the Data Demodulator No. 2A and Data Modulator No. 2A are fitted in each model, respectively, and consequently the line frequencies for the return direction will be 390 c/s for binary 1 and 450 c/s for binary 0. The request-to-send inhibit facility is not required on these models because the receive filters in both demodulators will reject the line signals from the modulators within the same main unit.

When facility 6 of Table 2 is provided it is necessary to connect two Datel Modems No. 1A together in parallel, and, to overcome impedance-matching problems, each equipment may be arranged to have an output impedance of 1,200 ohms instead of its normal 600-ohm impedance. This change is effected by wire straps on the tag block at the time of installation.

## TESTING FACILITIES

Installation and maintenance test facilities are provided in the modem in the following manner.

*Remote-Test Facility*

A remote-test facility is available with the equipment wired as a Model 3 or Model 4. This facility is used by a Datel Test Centre, to ascertain which end of a data transmission link is faulty, before calling out the local maintenance engineer. The procedure is described below.

The Datel Test Centre establishes a connexion over the public switched telephone network to the installation to be tested. This connexion is terminated at the Datel Test Centre on a compatible modem, and the customer is asked to remove the interface plug and operate the non-locking REMOTE TEST switch as soon as tone is heard in the telephone receiver. The tone will be either 1,300 c/s or 1,700 c/s for testing a Model 4, or 390 c/s or 450 c/s for testing a Model 3.

Operation of the REMOTE TEST switch operates relay T, one contact of which operates relay DS, and the modem under test is now connected to the line. The incoming line signal operates the data-carrier-detector circuit, which changes to the ON condition and a potential of +6 volts is connected to the request-to-send circuit via another T-relay contact, so causing the modulator to transmit to line.

The receive-data circuit is connected to the transmitted-data circuit by a third T-relay contact so that the frequency transmitted by the modulator is dependent on the received line frequency, i.e. if a frequency of 1,300 c/s is applied to the Data Demodulator No. 1A a binary 1 condition will be applied to the Data Modulator No. 2A and consequently 390 c/s will be transmitted to line. Relay T is held operated by +6 volts from the ready-for-sending circuit via one of its own contacts, thus allowing test signals to be passed through the demodulator and transmitted back to the test centre by the modulator. This method of testing imposes two restrictions:

(*i*) it is only possible to test at the 600 bits/second setting of the equipment as no control signal is applied to the data signalling-rate selector circuit. and

(*ii*) the equipment can only be tested at a data signalling rate of up to 75 bits/second, as there will always be a return-channel unit in the main unit.

To restore the modem to normal, the line signal is removed, causing the carrier-detector circuit to restore to the OFF condition, thus releasing relay T and reconnecting the telephone to the line.

The remote-test facility cannot be used with a Model 5 equipment at the present time, but a method of enabling this to be done is being developed and will be available on later equipment.

*Test Transmission of Binary* 1 *or Binary* 0 *Signals*

Test switches mounted at the rear of the case connect the appropriate d.c. signals on the various interchange circuits to allow binary 1 or binary 0 signals to be transmitted to line.

*Back-to-Back Test*

The modem can be connected back-to-back, if wired for 2-wire operation, by suitably positioning the appropriate test links (see Fig. 5, Notes 5 and 6). This open-circuits the 2-wire side of the 2-wire/4-wire termination so causing minimum loss between the send and receive sides of the termination and thereby allowing signals from the modulator to appear at the input of the demodulator. This test is only suitable for use at a Model 5 installation; the modulator and demodulator are then operated at the same modulation rates and characteristic frequencies. The facility for inhibiting the received-data circuit by the request-to-send circuit must be disconnected during testing.

The telephone is connected to line and is unaffected by the operation of relay DS, so that incoming telephone calls can be acknowledged.

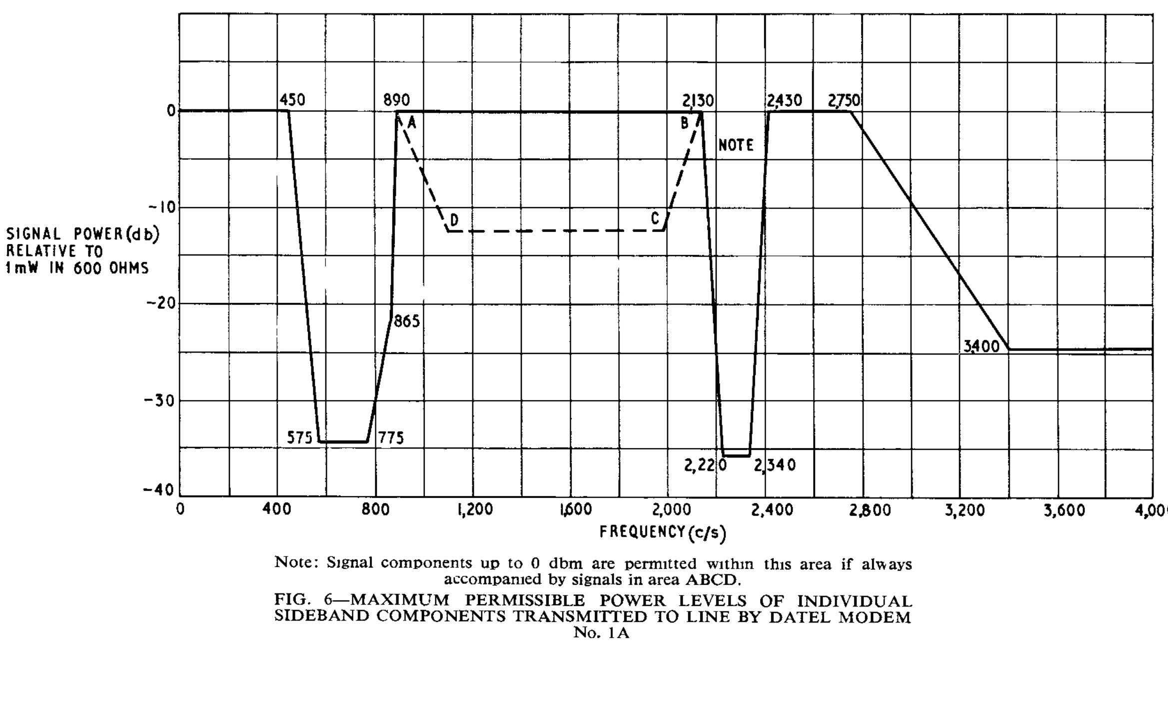
## MODULATORS AND DEMODULATORS

*Data Modulator No. 1A*

The Data Modulator No. 1A used in the Datel Modem No. 1A is an astable multivibrator whose frequency can be changed by voltage switching. The circuit is arranged so that with any voltage between −3 and −9 volts on the transmitted-data interchange circuit, 1,300 c/s is generated. With a signal in the range +3 to +9 volts on the input either 1,700 or 2,100 c/s is generated, depending on the mode of operation to which the equipment is switched under the control of a data signalling-rate selector interchange circuit.

The multivibrator output is controlled by the request-to-send circuit so that, with an OFF signal applied, the level of the line signals is reduced to below −50 dbm, and in the ON condition signals are transmitted without attenuation.

The output of the modulator is filtered by a band-pass filter to ensure a sinusoidal line signal and to restrict the level of those component frequencies sent to line that




Note: Signal components up to 0 dbm are permitted within this area if always accompanied by signals in area ABCD.

FIG. 6—MAXIMUM PERMISSIBLE POWER LEVELS OF INDIVIDUAL SIDEBAND COMPONENTS TRANSMITTED TO LINE BY DATEL MODEM No. 1A

would otherwise interfere with trunk-signalling equipment. The maximum level of any side frequencies to avoid false operation of trunk-signalling equipment is shown in Fig. 6. The level of the 750 c/s signal transmitted to line must not exceed −34 dbm, and to achieve this the transmit filter must have an insertion loss at 750 c/s of at least 20 db more than for a frequency in its pass band, otherwise the level of the second side frequency when transmitting at 950 bits/second in the A2 mode (1,200 bits/second) will be of sufficient level to cause false operation of early-type 2 v.f. trunk-signalling equipment.

The output from the filter is passed via a group-delay/frequency equalizer, housed within the Datel Modem No. 1A, before being connected to the modem output circuit. The equalizer has been designed to equalize the group-delay/frequency characteristic of the transmit filter to within ±0·1 ms over the frequency range 1,100–2,300 c/s so that the line signal is reasonably free from distortion.

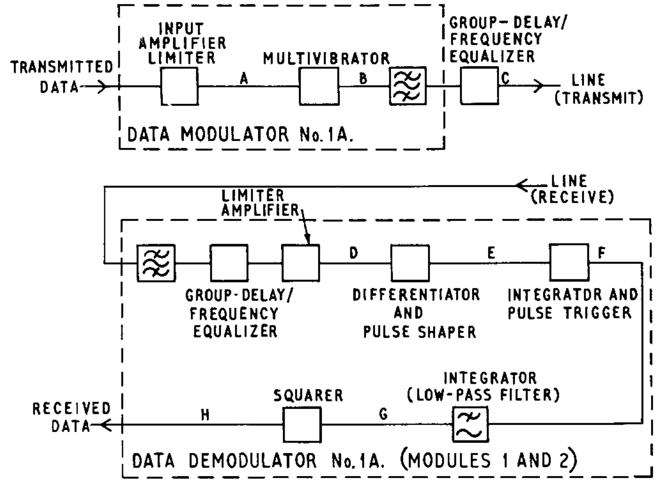
*Data Modulator No. 2A*

The operation of the Data Modulator No. 2A is similar to that of the Data Modulator No. 1A, the only difference being that the characteristic frequencies generated are 390 c/s for binary 1 and 450 c/s for binary 0. The binary 0 frequency remains at 450 c/s irrespective of the setting of the data signalling-rate selector circuit.

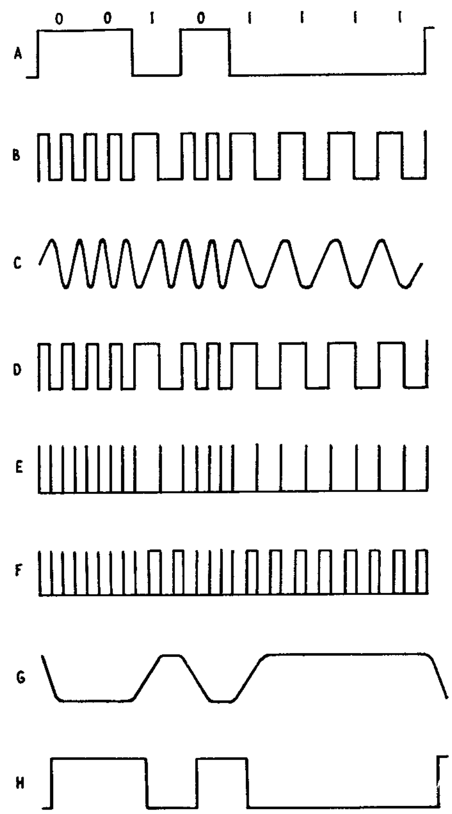
The transmit filter has a low-pass loss/frequency characteristic and has been designed to restrict the level of component frequencies sent to line that might interfere with telephone-signalling equipment and the forward data channel. A group-delay/frequency equalizer is not required for this channel.

*Data Demodulator No. 1A*

In the demodulator a problem occurs in that at 1,200 bits/second a single element will only have a duration of about 833 μs. One cycle at 1,300 c/s has a duration of about 769 μs, thus a single digit of binary 1 would be represented on the line by $1\frac{1}{12}$ cycles of 1,300 c/s signal. Furthermore, it is difficult to design a linear discriminator using conventional tuned-circuit techniques to cover the band of 1,200 c/s or more where the ratio of the bandwidth of the discriminator to carrier-frequency is small. One way of dealing with this problem is to use what is known as a zero-crossing detector, and this is the solution adopted for the forward data channel in the Datel Modem No. 1A. Fig. 7(*a*) is an explanatory diagram of a frequency-modulation modem using this method of demodulation. The waveforms shown in Fig. 7(*b*) are those obtained at the various points indicated by the respective letters in Fig. 7(*a*). Considering the operation of the demodulator, the signal from line (waveform C) is amplified, after passing through the receive filter, by a limiter-amplifier, and the waveform as shown at D is obtained. This waveform is differentiated, and the negative-going spikes are inverted to give a series of narrow positive-going pulses, the interval between the pulses being determined by the frequency of the received signal. This pulse-train, which is shown at E, is fed to an integrating circuit so that each pulse, corresponding to the zero crossing of the line signal, resets the integrating circuit. The output of the integrating circuit will be a series of pulses whose width is a function of the line frequency: this is shown at F. The train of varying-width




(*a*) Block Schematic Diagram of Modem




(*b*) Waveforms at Points A–H

FIG 7—EXPLANATORY DIAGRAM OF MODEM WITH DEMODULATOR USING ZERO-CROSSING DETECTOR

pulses is then integrated in a low-pass filter to produce an output signal, G, whose d.c. amplitude is proportional to the width of the pulses fed to the filter. The output signal from the low-pass filter is then squared to form the received-data signal, as shown at H.

The band-pass receive filter is provided to reduce the unwanted-signal power to a minimum. This unwanted signal will include the return-channel signal. As has been mentioned, losses of up to about 50 db can be expected on extreme connexions at 2,000 c/s (Fig. 1). The loss at

1,700 c/s on such a circuit would be about 42 db; thus, the level of the received line signal on the data channel could be −42 dbm at the line terminals of the modem. The receive filter must accept this while at the same time rejecting the return channel, which could be at a level of 0 dbm at the line terminals. The discrimination must be sufficient to prevent the return-channel signal affecting the performance of the data-channel demodulator. The effect of the requirements of the send and receive filters, i.e. the send filter to pass 900 c/s but reject 750 c/s by at least 20 db and the receive filter to reject the return channel when there is a difference in level between forward and return channel signals of the order of 45 db, is to cause the filters to have a group-delay/frequency response at the lower end of their pass range which adversely affects the performance of the equipment. The Data Demodulator No. 1A is made up of two units known as Modules 1 and 2. Module 1 is the demodulator section and Module 2 is a group-delay/frequency equalizer to compensate for the filter characteristics. The characteristics of the equalizer are similar to those of the equalizer provided for the Data Modulator No. 1A.

*Data Demodulator No. 2A*

The return-channel Data Demodulator No. 2A, while including a receive filter and limiter-amplifier in the same way as the forward channel, employs a conventional tuned-circuit discriminator. The receive filter has a band-pass loss/frequency characteristic with 3 db points at 350 c/s and 490 c/s.

PERFORMANCE

The Datel Modem No. 1A has been subjected to controlled tests in the laboratory and to tests on practical connexions as found in the public switched telephone network. The equipment has been available to customers since January 1965, and is being used mainly on connexions via the public switched telephone network and also for data transmission from the United Kingdom to the United States, the method of access in this country to the international trunk being via normal exchange lines.

Initially, comprehensive tests were made from each installation. Space does not permit the tests and results to be described in detail but they showed that satisfactory transmission at 600 bits/second is possible, and in many instances 1,200 bits/second can be achieved on connexions established via the public switched telephone network without the need for any special measures. For private circuits 1,200 bits/second is possible provided the characteristics of the circuit do not exceed those of three carrier links and/or 100 miles of 20 lb/mile cable loaded with 88 mH at intervals of 1·136 miles.

CONCLUSIONS

The Datel Modem No. 1A is relatively complex equipment to be installed in customer's premises where maintenance facilities are generally severely limited. In addition, when the equipment was developed, little experience was available in the United Kingdom of the performance of the modulation and demodulation techniques adopted for the modem when used in association with circuits having characteristics found on the public telephone switched network. Subsequent experience has shown that the design parameters chosen and the circuit design are capable of giving satisfactory service at 600 bits/second and, under favourable conditions, at 1,200 bits/second, with a low equipment fault-rate.

ACKNOWLEDGEMENT

The Datel Modem No. 1A described in this article was developed to a British Post Office specification by the Plessey Company, Ltd.

# The Commonwealth Telecommunications Conference 1965–1966

H. WILLIAMS, A.C.G.I., M.I.E.E.†

U.D.C. 061.3 : 654.1

**A recent conference held in London has made most important recommendations affecting Commonwealth telecommunications. The reasons for the conference and the background to the problems with which it was concerned are outlined. The conference's recommendations are briefly described.**

THIS important Conference, which was held in Marlborough House in March this year, marks a further milestone in the development of Commonwealth telecommunications relations. It was actually the conclusion of a conference which commenced in April 1965 but found it could not finish its work without further study. The reasons for, and the most important outcomes of, the Conference cannot be fully appreciated without an understanding of the Commonwealth Telecommunications Board and the background to the problems facing it. The present dilemma is in fact a recurrence of a similar situation which occurred about 40 years ago.

Until about 1927, Commonwealth communications were conducted on an extensive network of submarine telegraph cables, operated by various companies. In 1927, the United Kingdom started opening direct short-wave "beam" radio-telegraph circuits, first to Australia, and then in rapid succession to Canada, South Africa and India. These systems were operated by the British Post Office at the United Kingdom end, and at the other ends by private companies. The opening of these short-wave circuits introduced the possibility of unrestricted competition between the operators of radio and cable systems which, if allowed to develop, might have led to the liquidation of the cable companies. The strategic value to the Commonwealth of the telegraph

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cable network was considerable, and no doubt was also taken into account, for the governments of Great Britain, Canada, Australia, New Zealand, South Africa, the Irish Free State and India called an Imperial Wireless and Cable Conference in 1928. The repercussions of this conference were many, but it may be recorded that, as a result, an operating company was formed, known as Imperial and International Communications, Ltd. (later Cable and Wireless, Ltd.), to which the British Post Office leased its beam radio stations, and which also took over the necessary telegraph cables. The 1928 Conference also recommended the creation of an Imperial Communications Advisory Committee consisting of one representative of each of the governments concerned and one representative of the Colonies and Protectorates. This Committee controlled the tariffs of the operating company, which took account of both cable and radio circuits. Thus, the attempt was made to operate both networks side by side in a viable economic environment.

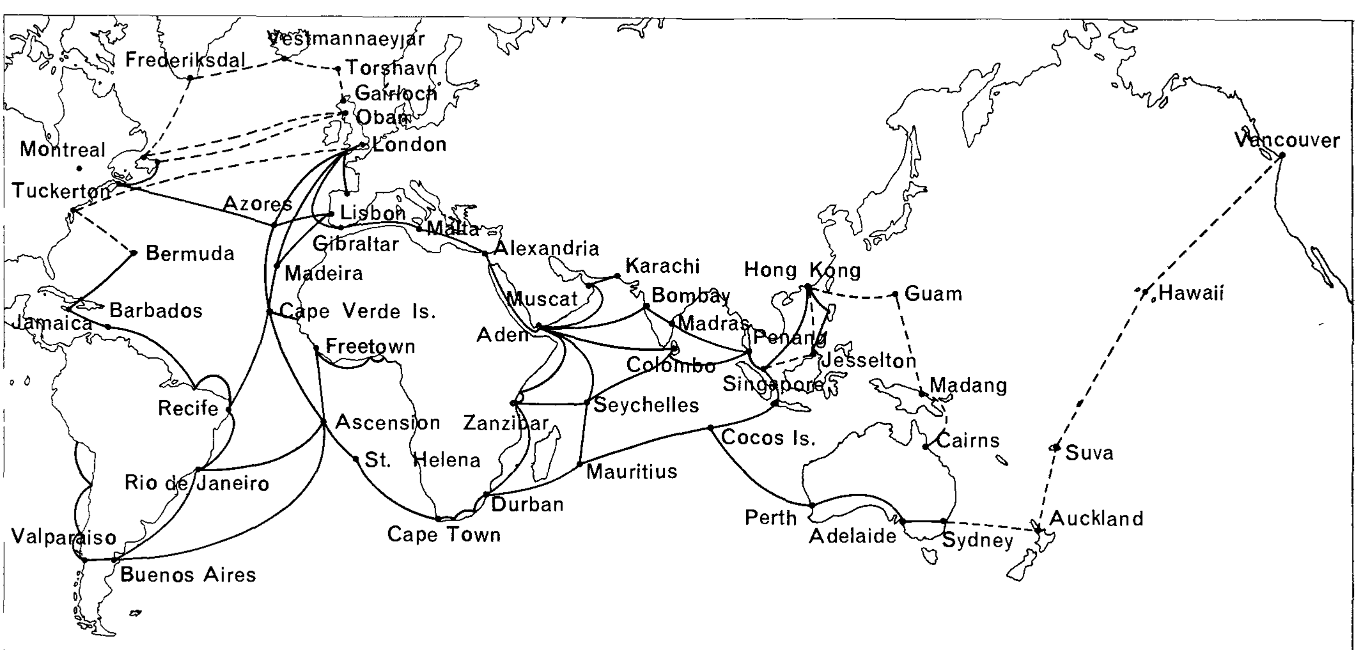
The next major step in the development took place in 1944. In 1942, the name of the controlling committee had been changed to the Commonwealth Communications Council. This Council in 1944 reviewed the communications system of the "British Commonwealth and Empire" and the problem of the future of the various direct radio-telegraph circuits that had been established during the war. As a result of this review, the Council recommended that a Government-owned Public Utility Corporation should take over Cable and Wireless, Ltd., followed by similar corporations in Commonwealth countries, to take over the administration of the external communications of these countries. The Corporations were all to be interlocked by an exchange of stock. The Board of Directors of the United Kingdom Corporation would be appointed from the United Kingdom, Canada, Australia, New Zealand, South Africa and India. Under this scheme, all the partner governments were to bear their full share of the responsibility for the maintenance of the cables by the United Kingdom Corporation.

These recommendations, after much negotiation and a further conference in 1945, led to the Commonwealth Telegraphs Agreement (1948) by which the governments of the United Kingdom of Great Britain and Northern Ireland, Canada, the Commonwealth of Australia, the Dominion of New Zealand, the Union of South Africa, India and Southern Rhodesia agreed to establish the Commonwealth Telecommunications Board (C.T.B.). The C.T.B. was incorporated in the United Kingdom in May 1949, by the Commonwealth Telegraph Acts 1949.

Its functions include recommendations on the formulation of joint telecommunications policy, co-ordination of the development of cable and radio systems, co-ordination of research, the fixing of tariffs, etc. A further function was to administer a Wayleave Scheme. In essence, the Scheme provides for all the member countries—known as Partners—to share the costs of running their external telecommunications services.

The C.T.B. has thus been functioning in its present form since 1949. During that time a number of Commonwealth countries have become independent—Ceylon, Cyprus, Nigeria, Ghana, Malaysia, Tanzania, Jamaica, Kenya, Sierra Leone, Malawi, Zambia, Singapore. All of these countries have acceded to the Commonwealth Telegraphs Agreement (1948), which thereby entitles them to participate directly in the work of the Board and to appoint members.

However, a further change commenced in 1956 when the first repeatered submarine telephone cables were laid across the Atlantic (TAT-1), to be followed shortly afterwards by CANTAT, COMPAC and now SEACOM. First-quality telegraph and telephone circuits can be derived in large numbers from these cables, and these developments reduced still further the utility of the old telegraph cables with their limited capacity and slow




——— Principal telegraph-cable routes
- - - - - Submarine telephone cables

PRINCIPAL TELEGRAPH AND SUBMARINE TELEPHONE CABLES speed of operation. The illustration shows the principal telegraph cables and submarine telephone cables at the present time.

For a considerable time, therefore, there have been difficulties in agreeing the financial pooling arrangements inherent in the Wayleave Scheme. Firstly, there have been complaints about the cost of the very large network of Commonwealth telegraph cables owned by Cable and Wireless, Ltd. These cables were very useful in their day, and still are useful to some extent, but with h.f. radio links and new telephone cables they are becoming less and less of an asset. As the cables are owned by Britain, and as a very considerable part of their capital value still has to be written off, the Wayleave arrangements mean that other Commonwealth countries pay quite large sums every year to Britain towards writing them off.

It is now possible to examine the reasons for the recent conferences. The first item needing discussion was the Wayleave Scheme. At the Conference, agreement was reached on this problem. Britain's offer to write down to one-half the remaining value of the cables was accepted, and the other Partners agreed that this remaining value should be written off over 12 years. If this recommendation is implemented, this particular problem will have been solved.

The second big financial problem was how to apportion the revenues on traffic from a foreign country which transits a Commonwealth country on its way to another Commonwealth country. Britain and Canada argued that the transit country should retain the Commonwealth earnings on this traffic; other Commonwealth countries thought that the terminal Commonwealth country should get all or most of the earnings. No agreement was reached on the principle, but a compromise was reached by which the earnings on this traffic would be split 50:50 between the transit and terminal Commonwealth countries.

The net result of these agreements is that the First Wayleave Scheme arrangements can now be regarded as settled, to the reasonable satisfaction of all parties, for a good way ahead.

The second item was concerned with organization. The Commonwealth Telecommunications Board is permanently located in London, and all Partners are supposed to nominate Members. In practice, some of the newer Commonwealth countries, in particular, find it difficult to spare a senior man full-time in London, so this arrangement is not very convenient to them. Furthermore, the Board is mainly concerned with the First Wayleave Scheme, which does not include the modern long-distance telephone cables like CANTAT, COMPAC, etc. The Commonwealth Telecommunications Conference (1965) therefore recommended that ways of improving the organization of Commonwealth co-operation in telecommunications should be studied.

A meeting of Commonwealth countries was held in Nairobi in November 1965 to examine possibilities and to report back. The 1966 Conference recommended that a new Organization should be set up, broadly on the lines recommended by the Nairobi meeting, as follows.

(*i*) Commonwealth Telecommunications Conferences should be held regularly (normally every 3 years) in Commonwealth countries in rotation (instead of in Britain, as the practice had been).

(*ii*) A Commonwealth Telecommunications Council should be set up, on which all countries that are Partners in any Commonwealth telecommunications financial arrangement should be represented; the representatives would be senior external telecommunications officials. The Council would meet at least once a year, in Commonwealth countries in rotation, and would make arrangements for proper consultation between Commonwealth countries to be carried on between its formal meetings.

(*iii*) A permanent Commonwealth Telecommunications Bureau should be set up in London to serve the new Organization. The name was chosen so that it could perpetuate the initials (C.T.B.) of the Commonwealth Telecommunications Board.

(*iv*) The cost of the new Organization would be shared (Britain to bear 64·5 per cent of the costs, and no country to bear less than 0·5 per cent); as the costs of Council meetings and Conferences would be shared, instead of borne by the host country, it would be financially feasible for even the smallest Commonwealth country to take its turn to act as host.

As a result of these recommendations, the Commonwealth Telecommunications Board would be wound up. The first Council meeting is expected to be in April 1967. The Board would overlap with the Council for a while, as it will take some time to make proper arrangements for the Board's dissolution. The Commonwealth Cable Management Committee, which manages the long-distance telephone cables, will remain in being, but will maintain close liaison with the Organization.

Thirdly, the Conference devoted as much time as it could to looking at future circuit needs, particularly the incorporation of satellite communications in the Commonwealth networks. It was obvious from the discussions that further major changes will result from this new method of communication. These changes cannot yet be assessed, and the Conference remitted questions on these topics to the new Organization for further study. Obvious items for discussion will be network planning and the financial arrangements to be adopted for satellite communications.

The Conference also discussed aid for developing Commonwealth countries in the form of technical advice and training (the Conference was not concerned with capital aid). Malaysia put forward a proposal that there should be a Commonwealth Training Fellowship Scheme, by which the costs of sending students to another Commonwealth country for training could be shared, and the Council will be looking at this idea.

All the Conference's recommendations are, of course, only recommendations at this stage: it cannot be assumed that the British Government, let alone the Governments of other Commonwealth countries, will necessarily accept them.

# Incoming Core-Type Register-Translator for Director Areas

## Part 1—Principles of Design

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U.D.C. 621.395.341.72:621.395.345

**This article, which is in two parts, describes an electronic, time-shared, register-translator system which incorporates magnetic-core information stores, and magnetic-core and semiconductor circuit elements. The register-translator is used in director areas to distribute incoming traffic to each exchange in the area. Part 1 deals with the principles of design; Part 2 will describe the logic design of the incoming register-translator.**

### INTRODUCTION

THE register-translator described in this article provides the same facilities as those incorporated in an electromechanical incoming register-translator designed some years ago and described earlier in this Journal,[1] but it also contains features not catered for by the original incoming register-translator. Its function is to receive traffic from sources outside the director area and distribute it, in accordance with the code digits received, to the appropriate exchange within the area.

The circuit and physical construction techniques on which the design of this incoming register-translator is based are radically different from those of the original electromechanical version and were developed by Ericsson Telephones, Ltd. The system technique was first explored jointly by the manufacturer and the British Post Office in a field trial of a 3-digit director model at Balham telephone exchange in the South West Telephone Area of the London Telecommunications Region.[2]

The circuit design is based on the use of magnetic cores in information-processing and storage circuits, the principles of which were described in an earlier volume of this Journal.[3] The technique used in this register-translator system is one in which a single common processing equipment is time-shared between a relatively large number of individual registers. In such a technique, the information-storage part and processing part of the registers are divorced so that the processing facilities, alike in all registers, can be carried out by a single high-speed processing unit. As will be shown, the time-sharing technique requires a greater information-storage capability per register than a space-divided equivalent (a discretely operative equipment providing all required register facilities), and, in addition, each register requires signal-conversion equipment to make the electronic system compatible with the electromechanical register-access apparatus.

The physical design is based on a system in which all components, including relays, are mounted on slim, slide-in, plug-and-socket connected, units.

Each register-translator unit consists essentially of two associated equipment cabinets known as a cabinet-pair. One cabinet of the pair contains, primarily, the electronic common-equipment plug-in units and is known as the E.C.E. cabinet. The second cabinet of the pair contains, primarily, the registers' electronic–electromechanical interface equipment called, in this system, register signal-conversion units and is thus referred to as the S.C.U. cabinet. A register-translator installation comprises several cabinet-pairs, and requires a —30-volt "silent" power supply in addition to the normal exchange —50-volt supply. The maintenance aids provided for each installation include a data-logging printer mounted, with its control equipment, on a separate Post Office standard-type 2 ft 9 in. rack. A general view of the E.C.E. cabinets installed at Maxwell (London) trunk exchange is shown in Fig. 1.

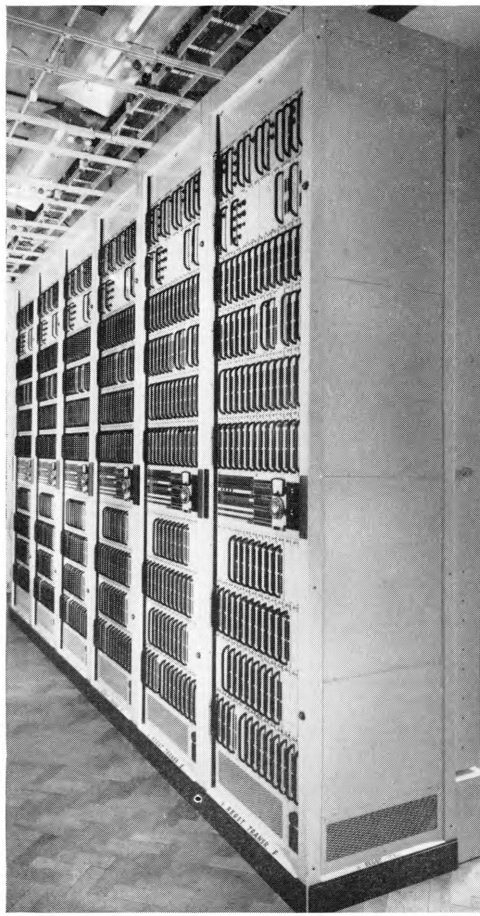
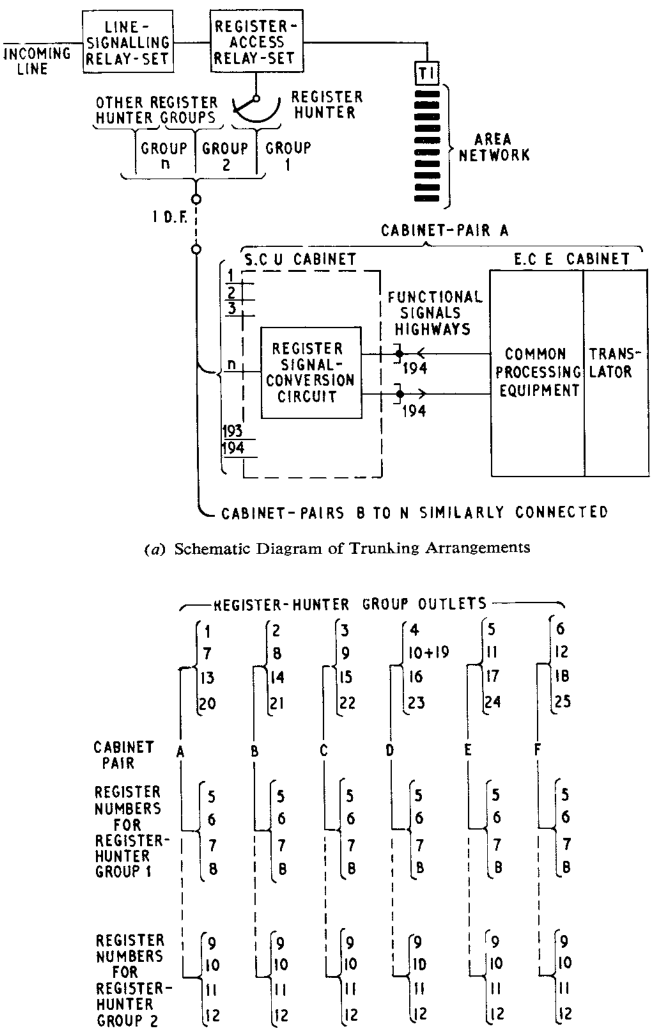


FIG. 1—GENERAL VIEW OF ELECTRONIC COMMON-EQUIPMENT CABINETS AT MAXWELL (LONDON) TRUNK EXCHANGE

†Telephone Exchange Systems Development Branch, E.-in-C.'s Office.

Fig. 2 shows the trunking of a typical incoming register-translator installation. Traffic from the register-access relay-sets is offered to all registers in all cabinet pairs via register-hunters in such a way that, with the withdrawal from service of any cabinet pair, the traffic is spread uniformly over the registers in those cabinet pairs remaining in service. It is important that high-capacity common equipment, such as this type of register-translator, shall be very reliable; nevertheless, occasionally a cabinet pair will have to be withdrawn from service on




(a) Schematic Diagram of Trunking Arrangements



Notes: 1. Registers 1–4 are used for maintenance test purposes only.
2. Register-hunter Group 3 et seq. continue the sequence.

(b) Typical Allocation of Register-Hunter Outlets for a Hunter Group in a 6-Cabinet-Pair Scheme

FIG. 2—TRUNKING ARRANGEMENTS OF THE INCOMING REGISTER-TRANSLATOR

account of a fault condition. By careful attention to detail the circuit and equipment designers have endeavoured to optimize cost, the failure rate, and the out-of-service time when faults do occur. Much thought has been given to the needs of the maintenance staff in the interests of minimizing equipment out-of-service time, and the equipment incorporates features which, it is hoped, will minimize fault-diagnosis time and routine maintenance attention.

FACILITIES

The following is not an exhaustive list of facilities but it does illustrate the salient features of the equipment. Each register:

(*i*) receives and stores up to eight digits,

(*ii*) is capable of sending digits by loop-disconnect pulses at 10 pulses/second, with a break:make ratio of 2:1, and with 800 ms inter-digital pauses (i.d.p.), the i.d.p. being subject to curtailment by the detection of selector switching,

(*iii*) re-transmits all "numerical" digits in their received order after the routing digits have been sent, the penultimate and last digits being re-transmitted with a 500 ms i.d.p.,

(*iv*) causes the seizing register-access relay-set line to be switched through, and the dissociation of register-access relay-set and register signal-conversion circuit (s.c.c.) when sending is complete,

(*v*) causes the seizing register-access relay-set to return number-unobtainable tone (n.u.t.), and the dissociation of the register-access relay-set and register s.c.c. under forced-release conditions, when, for example, no digits are received for 20 seconds or a "spare" code is received, and

(*vi*) anticipates the future addition of incoming and/or outgoing multi-frequency (m.f.) signalling.

Each unit of common processing-equipment can deal with 194 traffic-carrying registers on a Strowger pulsing basis, and control of m.f. signalling has been anticipated in its design, the control being brought into use when required by the addition of a few appropriate standard plug-in units. The common equipment incorporates a translation field which can produce up to eight routing digits for each of 1,000 3-digit code combinations, the design anticipating automatic alternative-routing requirements.

The common-processing equipment incorporates a "logic-check" system which continuously monitors the performance of the register-translator. Also incorporated are a number of individual element check-circuits and an associated fault analyser and alarm system.

Instead of the conventional style of register routiner, each cabinet-pair is provided with a live traffic monitor or call comparator. The comparator is associated with any register just seized, receives the incoming digits and repeats the digits to a register set aside for the purpose in another cabinet-pair; this register is referred to as the comparison register. The comparator receives outgoing information from the observed register and the comparison register, and compares these two sets of data. At the conclusion of operations by the register-translator, the comparator is released and is then available for association with another register. If, however, parity between the two data sets does not occur, all information pertaining to the call, staticized in the comparator, is transferred to the data-logging printer before another call can be monitored. Each comparison is counted by the total-calls-observed meter, and the occasions that the comparator records disparities are totalled by the disparity-printer-demand meter.

The comparison method of checking the performance of equipment has the following advantages over the conventional routiner.

(*i*) It does not generate traffic that imposes additional use of the signal-conversion equipment, and, therefore, can be continuously operating.

(*ii*) By monitoring the performance of the equipment under public traffic conditions it is not necessary to determine arbitrary (and often stringent) test limits and, then, to maintain the apparatus to these limits.

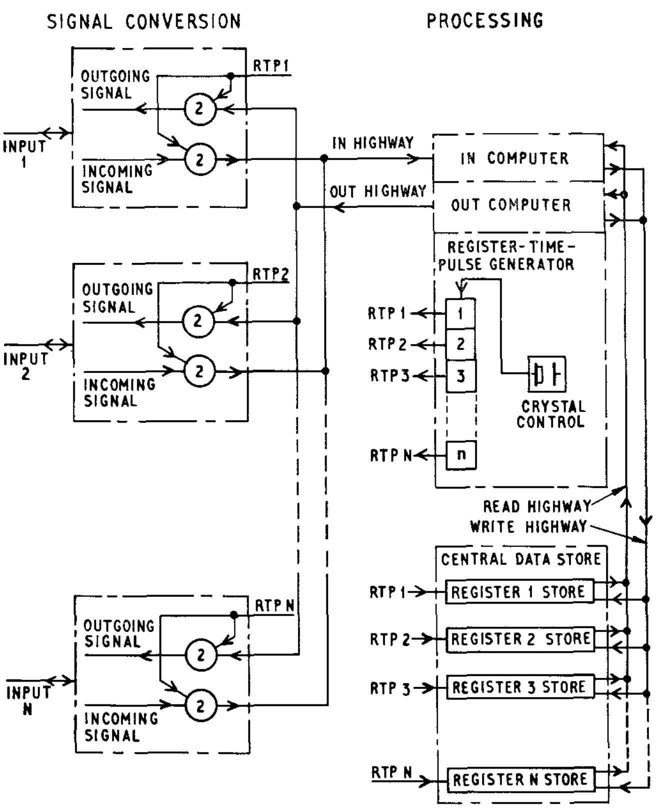
(*iii*) All digit combinations and translations are checked at a rate determined by their use, and this is achieved without any additional man-hour expenditure.

(*iv*) It provides a measure of the quality of service given by the equipment concerned.

## PRINCIPLES OF OPERATION

In the decription that follows, loop-disconnect pulse-signalling methods are assumed throughout, and, in describing the operation of ferrite cores used as two-state devices, the terms "set" and "reset" refer to the two states. It must, however, be emphasized that such two-state devices produce only transient outputs, corresponding with and occurring at one or other of the two possible changes of state. In functional diagrams used in this article the general symbol for a toggle has been used with the letters S and R inserted to indicate the set and reset states, respectively.

Fig. 3 illustrates the fundamentals of this time-shared electronic register-translator system. In each register-translator unit individual inputs 1–$N$ are served by a single high-speed common-processing unit via time-division multiplex (t.d.m.) highways. A re-cycling pulse generator provides a sequence of discrete time periods (register time pulses) during which each input in turn is associated with the common-processing equipment. During the period of association, known as a time slot, information passes each way between an input and the common-processing equipment, using the "in" and "out" highways, respectively, and between the central data store and the common-processing equipment, using the "read" and "write" highways. In the core-type incoming register-translator being described, the pulse generator provides a maximum of 210 time slots during a period of $16\frac{2}{3}$ ms. Each time slot is approximately $80\,\mu s$ in duration and is subdivided into three discrete phases: read, decide and write.




RTP—Register time pulse

FIG. 3—SCHEMATIC DIAGRAM OF A TIME-SHARED COMMON-PROCESSING EQUIPMENT SERVING $N$ INPUTS VIA T.D.M. HIGHWAYS

The common-processing equipment comprises two sections: one deals with the processes concerned with incoming information and is called the "in" computer; the other deals with those processes concerned with outgoing information and is called the "out" computer.

Each input is equipped with an information store (a register) physically associated with all other registers in a common assembly, and collectively known as the central data store. In any system in which the common-processing equipment is time-shared between a number of inputs, the total information-storage capacity must be very much greater than that required in a space-divided equivalent because the time-sharing technique requires that each input must maintain a record of the "stage-of-processing" of the call. Thus, the register information store accommodates not only the incoming-digits storage, but also in-computer and out-computer storage sections.

The various basic elements used in the director-area core-type incoming register-translator will now be considered in more detail.

## REGISTER-TIME-PULSE GENERATOR

The re-cycling pulse generator mentioned above consists essentially of two shift-registers—one, shift-register A, is of 15 stages, and the other, shift-register B, is of 14 stages—and a matrix of gates which combine the shift-register outputs to produce 15 × 14, i.e. 210, final outputs (see Fig. 4). The shift-registers are driven by a 12·6 kc/s crystal-controlled oscillator, the periodicity of which is the basic time-slot duration of $79{\cdot}365\,\mu s$. Time-slot read-phase pulses are derived directly from the oscillator output, but the decide-phase and write-phase pulses are

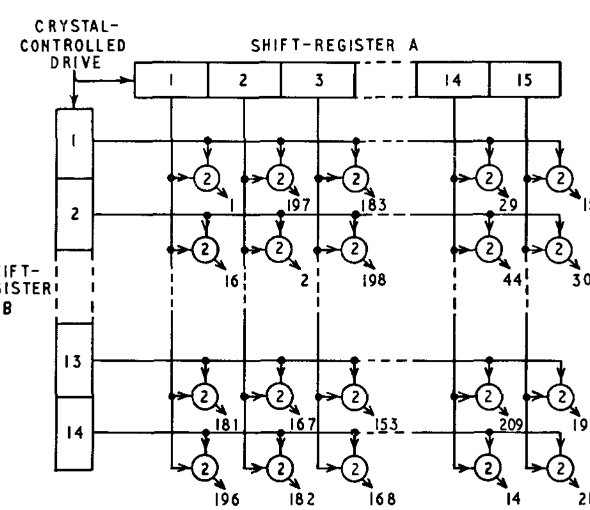



FIG. 4—FUNCTIONAL DIAGRAM OF MAIN SEQUENCING MATRIX

extracted from points on a magnetostrictive delay line which is excited by the oscillator output; the phases are referred to as Ro time, R2 time and Rw time, respectively. Both shift-registers are driven at the rate of one stage per 79·365 μs, but each shift-register-stage period is subdivided into Ro and Rw times so that each of the 210 outputs is marked by twin pulse conditions; Fig. 5 shows the circuit principles of the gating function.

each of the 28 pairs of diodes served by lead A1. Also at Ro time a positive-going pulse is applied, via both B1(Ro) leads, to the 15 diodes connected to each lead. At only one matrix intersection in each drive-transformer group are conditions such that a diode is forward biassed, i.e. at intersection A1/B1(Ro), all other diodes being reverse biassed and thus in a state of high resistance. Current flows in the 43-turn winding of register 1 drive trans-

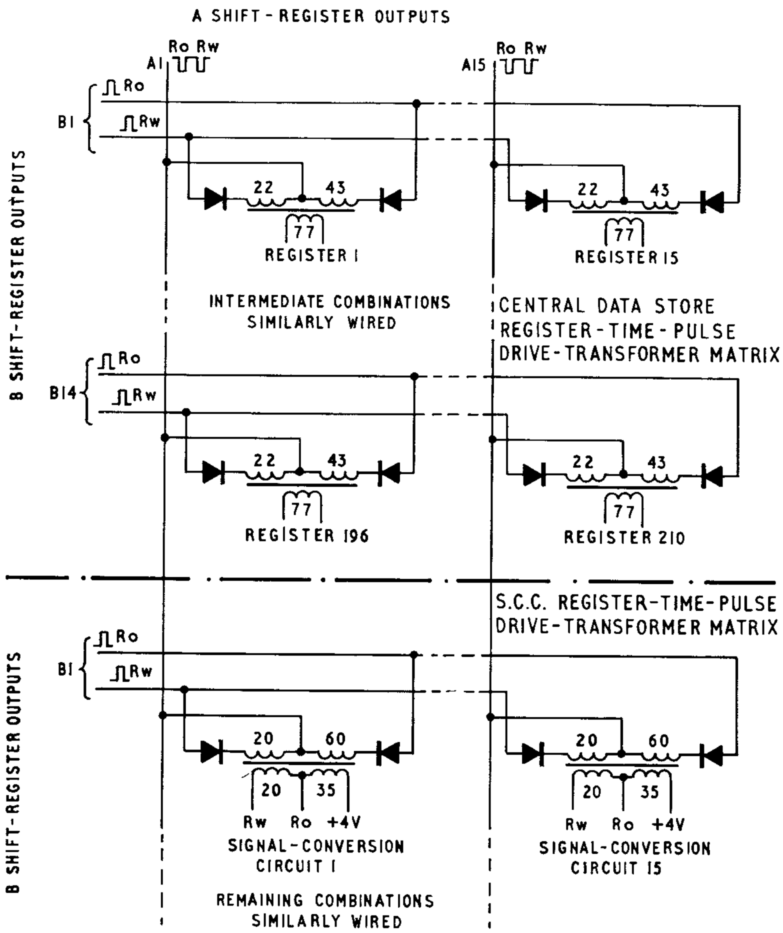



FIG. 5—CIRCUIT ARRANGEMENTS OF MAIN SEQUENCING MATRIX

Each of the 15 A-shift-register outputs feeds the centre tap of a winding on each of 28 transformers, 14 of which serve the data store while the other 14 serve the register signal-conversion circuits. Each lead carries the corresponding Ro plus Rw pair of pulses. Two groups of B-shift-register outputs are provided: one group feeds the central data store drive transformers while the other feeds the registers s.c.c. drive transformers. The two leads of each of the 14 twin B-shift-register output leads feed opposite ends of the above-mentioned centre-tapped transformer windings via semiconductor diodes, one carrying a pulse at Ro time and the other a pulse at Rw time.

For the purpose of this explanation, consider the time when the A and B shift registers are both at stage 1. At Ro time a negative-going pulse is applied, via lead A1, to

former and in the 60-turn winding of s.c.c. 1 drive transformer, inducing corresponding currents into the respective secondary windings. Similarly at Rw time, a negative-going pulse is applied to the A1 lead and a positive-going pulse is applied to both of the B1(Rw) leads, resulting in current flowing in the 22-turn winding of register 1 drive transformer and in the 20-turn winding of s.c.c. 1 drive transformer, inducing corresponding currents into the respective secondary windings.

The store drive current is thus in the form of a "forward" current at Ro time and a "reverse" current, of approximately half the value of the forward current, at Rw time. The significance of this will be seen later when considering the operation of the core-type central data store.

## E.C.E. TO S.C.C. HIGHWAY SYSTEM

Fig. 6 illustrates typical highways between the E.C.E. and S.C.U. cabinet pairs. Each register s.c.c. is supplied with its own pair of register time pulses (Ro and Rw) via discrete leads from the s.c.c. register-time-pulse drive-transformer matrix. In addition, each s.c.c. is connected to common functional signal highways via decoupling diodes; two typical highways are shown as CD and Z in Fig 5. These highways convey information signals from the common equipment to the signal-conversion circuits. Within each s.c.c. the highway connexion terminates on one end of winding 1 of a 9 mm ferrite core carrying three windings. The other end of winding 1 is returned, with other similar windings in the s.c.c., to the Ro lead. Winding 2 of each core in the s.c.c. is series connected and supplied with a drive current during Rw time.

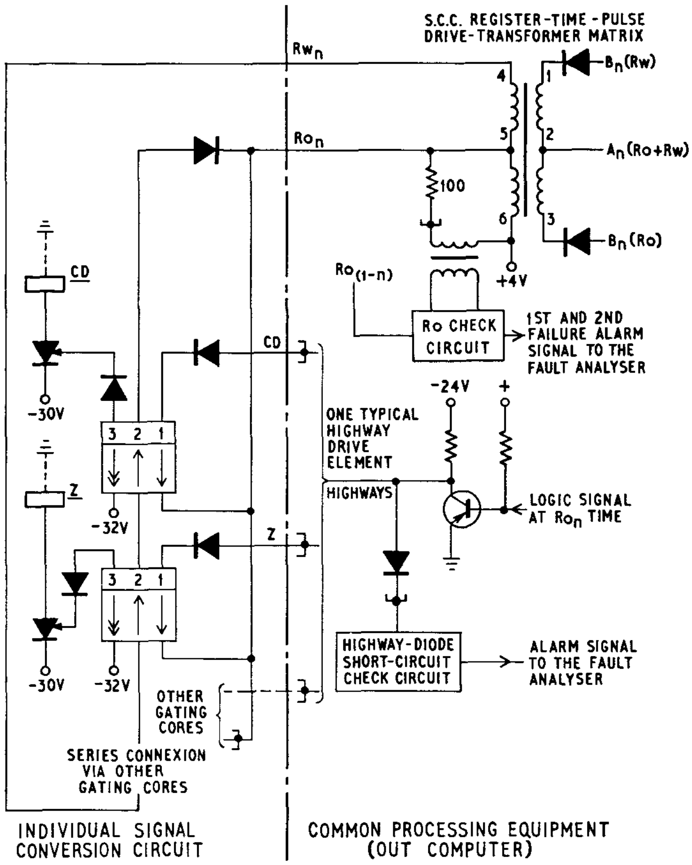



FIG. 6—E.C.E. TO S.C.C. HIGHWAYS SYSTEM

Thus, once each scan time (a $16\frac{2}{3}$ ms period) and at the end of the time slot, i.e. at Rw time, each core is supplied with a resetting current. At the beginning of each time slot, therefore, i.e. at Ro time, each core is ready to be switched by a signal via the highway concerned. For example, if relay CD of register s.c.c. 27 is to be operated, the common equipment transmits a pulse to the CD highway at $Ro_{27}$ time. The current in winding 1 of the CD-highway core sets that core, and a corresponding output is taken from winding 3 to trigger the associated controlled rectifier and, hence, operate relay CD. At the end of the time slot, i.e. at Rw time, a current in winding 2 resets the core, the reverse output voltage in winding 3 being ineffective due to the presence of the rectifier in the output circuit, so that relay CD remains operated until the circuit is disconnected by later operations within the s.c.c.

Considering the drive transformer (Fig. 6), it will be seen that, during the Ro time period, winding 2–3 is stimulated and produces a current in the secondary winding 4–5–6 such that terminal 4 is negative with respect to terminal 5, which in turn is negative with respect to terminal 6, the latter terminal being connected to +4 volts. Furthermore, during the Ro time period, a negative signal is applied to the base of the transistor to turn the transistor on and raise the potential of the highway from −24 volts to earth potential. In only one register s.c.c. will there be a complementary condition on the Ro time pulse lead; hence, in that s.c.c. the decoupling diode will conduct and the corresponding core will switch.

Fig. 7 shows an analysis of Fig. 6 during the $Ro_{27}$ time period. Notice that the diode in the Rw series connexion is reverse biassed during the Ro period because terminal

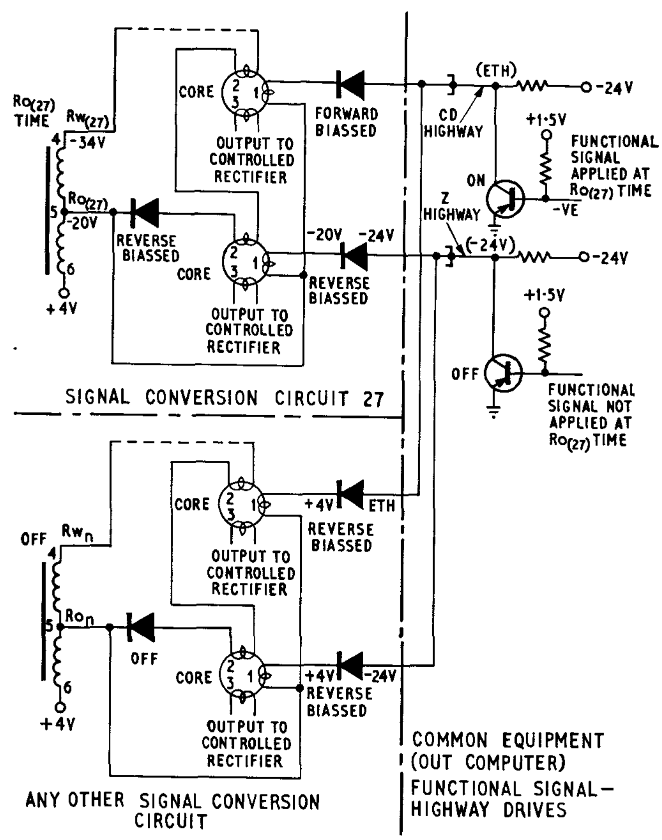



FIG. 7—ANALYSIS OF CONDITIONS DURING $Ro_{27}$ TIME FOR CIRCUIT OF FIG. 6

4 of s.c.c. 27 drive transformer is negative with respect to terminal 5, and that the quiescent-highways decoupling diodes in the same s.c.c. are reverse biassed at this stage because the Ro drive is less negative than −24 volts while all other s.c.c. highway decoupling diodes are reverse biassed by virtue of the +4-volt potential on the quiescent $Ro_n$ leads.

A check circuit-element monitors the highways via commoned decoupling diodes (see Fig. 6). Normally, the highways do not rise above earth potential, but any short-circuited s.c.c. highway decoupling diode will cause the connexion of a permanent +4-volt condition to the highway concerned, which will be detected by the check circuit and result in an alarm signal.

Another check circuit is connected across winding 5–6 of all the s.c.c. drive transformers via individual 100-ohm decoupling resistors, the circuit monitoring the presence of each Ro pulse supplied; in partially-equipped installations the checking circuit is operative only at those Ro times for which corresponding Ro register time pulses are produced.

### SIGNALLING FROM S.C.C. TO E.C.E.

A typical example of a highway carrying information from the s.c.c. is that used to convey pulsing-in signals. Fig. 8 shows this arrangement, in which a contact of the line relay makes and breaks a connexion of the $Ro_n$ lead to the pulsing-in highway, highway SN.

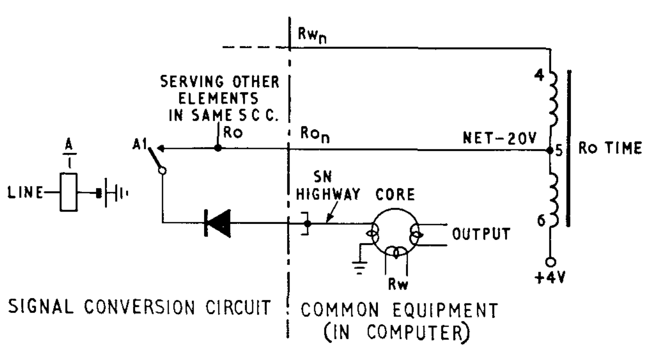


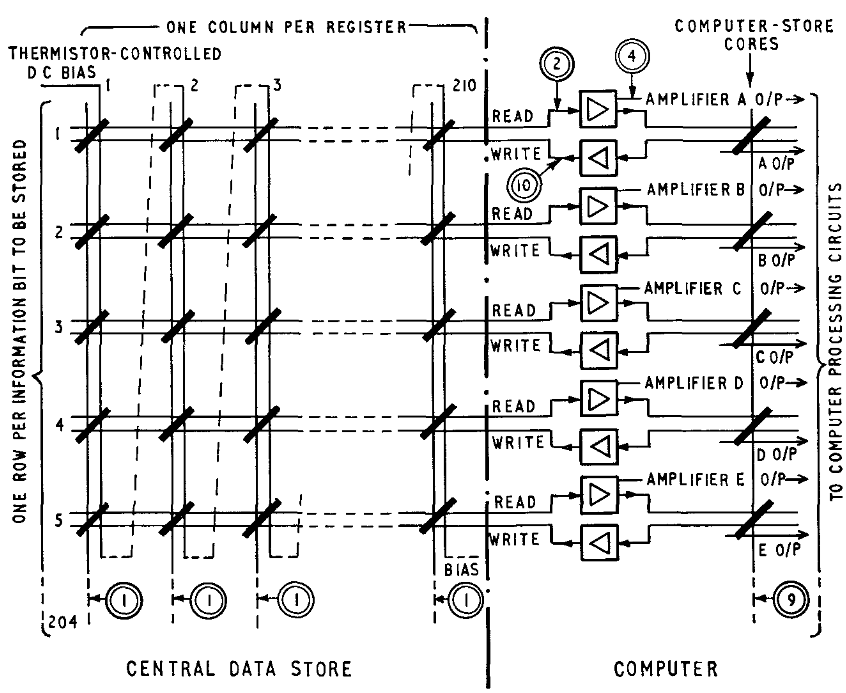

FIG. 8—TYPICAL S.C.C. TO E.C.E. IN-COMPUTER HIGHWAY

At $Ro_n$ time, with the relevant contact A1 closed, current flows via the SN highway decoupling diode and a core in the electronic common equipment. The core is set until the corresponding Rw time, when it is reset and produces an output which is stored in the relevant register data store as indicative of a make condition. At this time all other s.c.c. highway decoupling diodes that are connected to the SN highway by their A1 contacts are reverse biassed by virtue of the +4 volts applied via their respective drive transformers. At any $Ro_n$ time and with the relevant contact A1 open, the electronic common equipment core is not set and, hence, no output appears at the ensuing Rw time, this being indicative of a break condition.

### CENTRAL DATA STORE

In the director-area core-type incoming register-translator the total storage required to accommodate dialled-in digits and stage-of-processing amounts, with a spares allowance, to 204 bits/register. For 210 registers, therefore, the central data store requires a total of 210 register columns each of 204 bits, giving a total of 42,840 bits. The central data store uses 2 mm cores (one per bit) arranged in the Cambridge "direct-selection" configuration,[3] and for convenience this configuration is shown, in a simplified form, in Fig. 9.

Consider any one register and the information that may be stored in it. At the commencement of the time slot concerned (at Ro time) a current pulse is passed along the central-data-store register-column wire such that cores in the set state are switched to the reset state. A corresponding pattern of signals appears on the central-




O/P—Output.
Note: A number inside two concentric circles and associated with a lead indicates the relevant waveform illustrated in Fig. 11

FIG. 9—SCHEMATIC DIAGRAM OF CENTRAL DATA STORE AND COMPUTER-FUNCTION STORE

data-store read-out wires which, after amplification, switch corresponding store cores in the computer from the reset to the set state. The amplifier output signals, and output signals produced by the computer-store cores when switched, may be utilized by the computer processing circuits. At the conclusion of the time-slot period, i.e. at Rw time, a current pulse is passed through the computer-store cores so that those in the set state are switched to the reset state. The resulting pattern of signals is amplified and applied, via the write wires, to corresponding rows in the central data store, but the write currents are arranged to be less in amplitude than that necessary to switch any core in the store. However, coincidentally, the relevant register column is marked by a current of similar value, the resulting flux augmenting that due to row stimulation, so that at the row and column intersections marked by the row and column currents, and at those only, the cores concerned will be switched by the resulting magnetizing forces. Thus, information is returned to a particular register in the central data store at the end of the time slot.

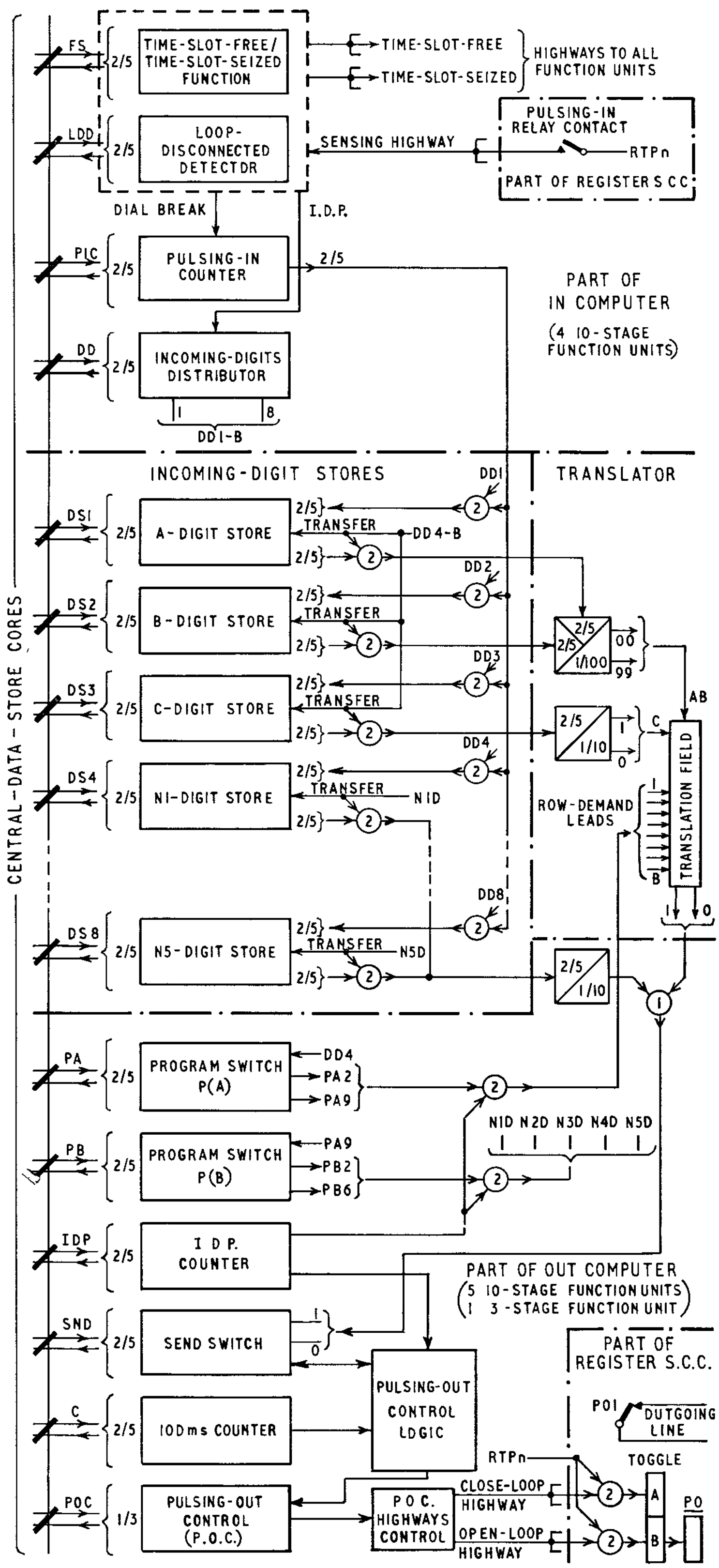
The cycle of events, read, hold and write, is now repeated with the next register column during the next time slot, information signals passing from the central-data-store column concerned into the computer store and then, at the end of the time slot, back to that central-data-store column. The following time slot embraces the processing of the information held in the next column, and then the sequence continues, column by column, the whole sequence occupying $16\frac{2}{3}$ ms. Considering any one time slot, therefore, it will be seen that information, once inserted into the central data store, may be regenerated at $16\frac{2}{3}$ ms intervals. This dynamic mode of operation facilitates the inspection of information held in a register by observation of signals at the output terminals of the read-out amplifiers, using an oscilloscope triggered at the time slot concerned.

*Insertion of Information*

Information may be inserted into any central-data-store register column by external stimulation of the write amplifiers at the appropriate time-slot Rw time, independently of anything previously read-out and held by the computer-store cores. Alternatively, the pattern of information held by the computer store can be operated on and modified during the hold period, which is arranged to coincide with the decide phase (R2 time), so that a new pattern is passed to the central-data-store column at the associated Rw time. A third and important method is the use of a "function-control" element to cause the digit value held in the computer store to be increased by 1. Thus, for example, if the value 3 is read-out of the register store at Ro time, the value returned to the store at the associated Rw time may be unchanged, i.e. as 3, or, increased by 1, as 4; this is determined by a control signal applied at R2 time by a function-control element which is itself controlled by other logical circuits.

### SUB-DIVISION OF THE COMPUTER STORE

Each facility or function requires its own section of common-processing equipment and a certain number of cores on each central-data-store register column. Fig. 10 shows a block schematic diagram of the register-translator in and out computers showing how the various functions are assigned to portions of the register columns and to




1/3—One-out-of-three code.
1/10—One-out-of-ten code.
1/100—One-out-of-a-hundred code.
2/5—Two-out-of-five code.

FIG. 10—BLOCK SCHEMATIC DIAGRAM OF REGISTER-TRANSLATOR ILLUSTRATING USE OF VARIOUS FUNCTION UNITS

standard common function units, of which there are four types: incoming-digit unit, 10-stage function unit, 3-stage function unit and 1-stage function unit.

*The Function Units*

Each dialled-in digit is retained in a two-out-of-five code form by an incoming-digit unit in the common-processing equipment. Thus, five rows in the central-data-store core matrix are allocated to each digit to be stored. The stored-digit value can be extracted from the incoming-digit unit, when required, by stimulation of the unit "transfer" terminal by a control signal during the relevant time slot.

The other computer function units, like the uniselector in electromechanical systems, are basic manipulative tools. The 10-stage function unit receives signals from, and sends signals to, the central data store in two-out-of-five code but produces logic outputs in a one-out-of-ten mode. The 3-stage function unit is a smaller version of the 10-stage unit, operating in one-out-of-three mode and thus requiring three rows in the matrix. The 1-stage function unit is a flexible auxiliary unit requiring only one row in the matrix. The processing-unit logic employs as many of these function units as the total facilities require. For example, 10-stage function units are used in the incoming register-translator to control the incoming-digits distributor, the send switch, the outgoing sequence switch, the 100 ms timer, the 4-seconds timer, and the incoming-digit counter. Control of the s.c.c. pulsing-out relays is by means of a 3-stage function unit. The 1-stage type of function unit is used with some of the larger function units as an auxiliary control aid, and sometimes, alone, to control the less complex functions.

Typical waveforms appearing in the function units are illustrated in Fig. 11.

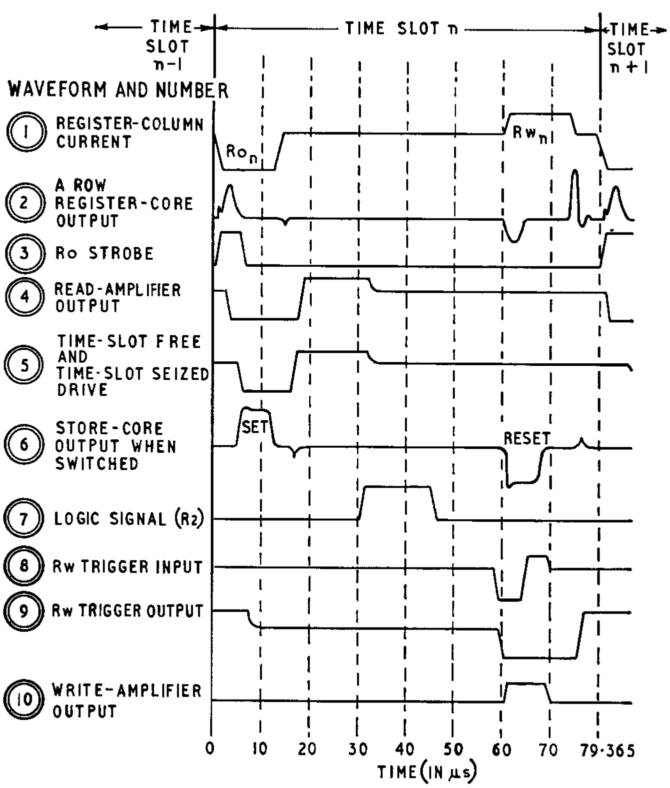



FIG. 11—CENTRAL-DATA-STORE AND FUNCTION-UNIT WAVEFORMS

*10-Stage Function Unit*

Lack of space precludes any more than a brief description of the 10-stage function unit, but a knowledge of its mode of operation is essential to the understanding of the core register-translator system. Consider, therefore, the functional diagram of this function unit, shown in Fig. 12, and its operation during any one time slot. Information is read-out of the central data store at the commencement of the time slot, i.e. at Ro time, in a two-out-of-five code form, but is re-coded into a one-out-of-ten code form to set one of the 10 unit-store cores. The set unit-store core is reset at the end of the time slot, i.e. at Rw time, and its output is arranged to stimulate the two write amplifiers corresponding with the two-out-of-five code of the unit-store core value concerned, provided that, simultaneously, the unit "repeat" core (RP), which is always set during the read phase, is reset coincidentally. The RP core is reset at Rw time if no "advance" instruction has been applied to the unit within the time slot concerned; alternatively, the write amplifiers corresponding with the unit-store core value plus 1 are stimulated if an advance instruction has been applied to the unit. The advance instruction is applied to the unit by a function control element in the computer during the time-slot decide phase, i.e. R2 time, while information from the central data store is held by the function unit. The advance instruction resets core RP ineffectually and sets the "advance" core (AD) so that at the end of the time slot, i.e. at Rw time, it is core AD and not core RP that is reset coincidentally with the unit-store core, the AD core output signal causing the new value to be written into the central data store.

In addition to the advance-by-1 method of control, the unit-store cores can be operated on directly by a function control element in the computer at R2 time so that any held value can be replaced by some other value.

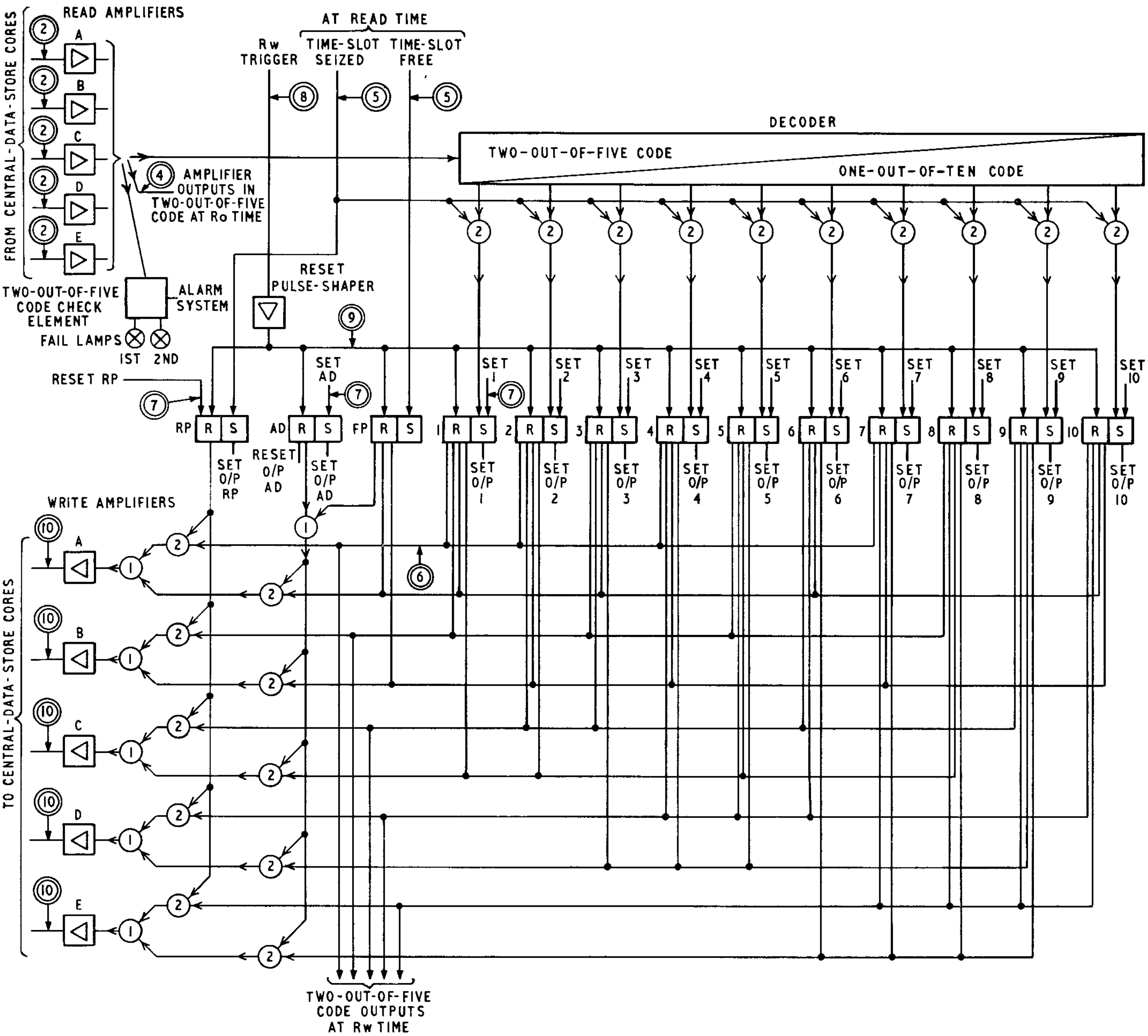
When switched by the outputs of the read-out amplifiers at Ro time, the unit-store cores produce output currents which are available to the computer processing circuits. The read-out amplifiers themselves also produce additional outputs which may be used in the computer processing circuits.

Each function unit is equipped with a check circuit, which is associated with the read-out amplifiers and verifies that the two-out-of-five code is maintained. Any detected malfunction produces an alarm. To enable the check circuit to function in time slots not carrying a call, a two-out-of-five code pattern corresponding to digit 1 is maintained in each "free" function store. Two, alternative, supervisory signals, "time-slot free" and "time-slot seized," respectively, are distributed to each function unit to define the state of the time slot. The former controls the "free pattern" core (FP) and, hence, the maintenance of digit 1 in function stores in idle time-slots, while the latter activates units in "seized" time slots.

*Read and Write Amplifiers*

Fig. 13 illustrates typical central-data-store read-amplifier and write-amplifier circuits serving each row in the central-data-store matrix. The operation is as follows.

Each read amplifier consists essentially of three basic stages: a pulse amplifier, a strobed stage, and a pulse shaper. Transformer T1 provides d.c. isolation for the core-store read-out circuit, and its ratio of 1:12 provides impedance matching and voltage amplification; the




O/P—Output

Notes: 1. S indicates core in set state, and R indicates core in reset state.

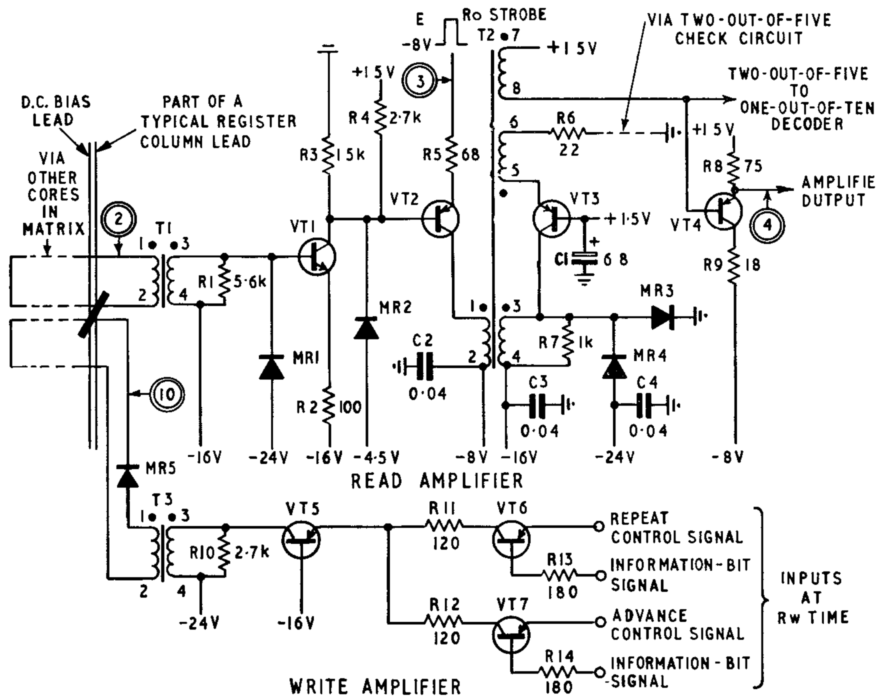
2. Unit-store codes 1–10 also carry a winding, not shown, which can be used, as required, for input or output purposes.

3. A number inside two concentric circles and associated with a lead indicates the relevant waveform illustrated in Fig. 11.

FIG. 12—FUNCTIONAL DIAGRAM OF THE 10-STAGE FUNCTION UNIT

5,600-ohm resistor R1 damps transformer T1 and prevents the generation of transient voltages. The positive-going voltage from transformer T1 is fed to n–p–n transistor VT1, which also acts as a voltage amplifier. Rectifier MR1 at the base of transistor VT1 protects the transistor against excessive emitter-to-base voltage under write conditions when a negative-going signal appears at the output of transformer T1, and also limits the collector-to-base voltage under this condition. The 100-ohm resistor R2 controls the stage gain and input impedance, and the 1,500-ohm resistor R3 is the collector-load resistor. Transistor VT2 emitter is connected to a strobe waveform such that it is at −8 volts with the strobe absent, and at earth potential with the strobe present.

In the absence of a data-store output signal, transistor VT2 will be held off by the net positive condition applied to the base by the potential divider formed by resistors R3 and R4. The strobe is used to ensure that only central-data-store outputs appearing at Ro time are effective; an unwanted output appears, for example, at the expiry of the write pulse, when the store cores traverse their reversible domains. Rectifier MR2 limits the amplitude of the store output signal appearing at the collector of transistor VT1 to −4·5 volts, a value which is positive




Note: A number inside two concentric circles and associated with a lead indicates the relevant waveform illustrated in Fig. 11

FIG. 13—CORE-TYPE CENTRAL-DATA-STORE READ-AMPLIFIER AND WRITE-AMPLIFIER CIRCUITS

with respect to the emitter with the strobe absent, thus ensuring that transistor VT2 can only be turned on while the strobe is present. Transistor VT2, when it does turn on in response to a store output at Ro strobe time, triggers the blocking oscillator of which VT3 is the active device.

The blocking-oscillator output produced across winding 7–8 of transformer T2 is of approximately 6-volt amplitude and 15 $\mu$s duration, and may, for example, drive a two-out-of-five to one-out-of-ten decoder. An emitter-follower stage may be used to drive transistors in function control elements.

The write amplifier is connected in common-base configuration to give constant-current drive in the matrix. The diode in series with the matrix drive eliminates the possibility of a reverse current flowing in the matrix write circuit when the drive current is switched off. The energy stored in the drive transformer is dissipated in the 2,700-ohm resistor R10, connected across the primary winding.

*Logic Gates*

Transistors are used for all logic AND and OR gating functions, but INHIBIT functions may be carried out by the use of a reverse-drive winding on cores included in the function control elements, as explained later. Clearly, in any arithmetic system a wide variety of gating configurations may be required, but from an equipment standards point of view it is desirable to minimize the variety of configurations. In the core-type register-translator this has been achieved by producing gating units accommodating a relatively small variety of gating configurations but with the capability of being coupled together in many ways, via unit terminals, to satisfy actual design requirements. The standard unit contains seven different gating-element configurations.

*Function Control Element*

It will be recalled that the core-type register-translator register time slot is divided into three phases, namely read, decide and write phases. It must be possible to transfer information from one phase to another: the ferrite core, which is a two-state device producing a transient output corresponding with and occurring only at a change of state, is a useful device for achieving this. Consider a core with three windings such as that shown in Fig. 14. Winding 1 may receive an information signal at time t1. If winding 2 is interrogated later at time t2, an output will be produced in winding 3. If winding 1 is not stimulated at time t1 there will be no useful output at time t2 when winding 2 is interrogated. Unwanted outputs occurring at the expiry of the time t1 input signals are of acceptable polarity but are inhibited by the strobed amplifier. The unwanted output, which appears at interrogation time t2 when no input at time t1 has occurred, is inhibited by the input threshold of the amplifier. Also shown in Fig. 14 is the equivalent functional representation.

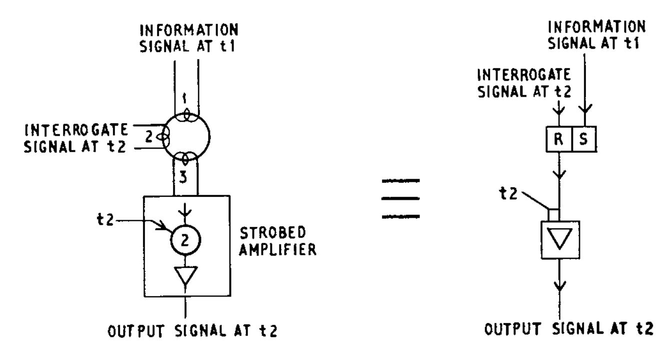
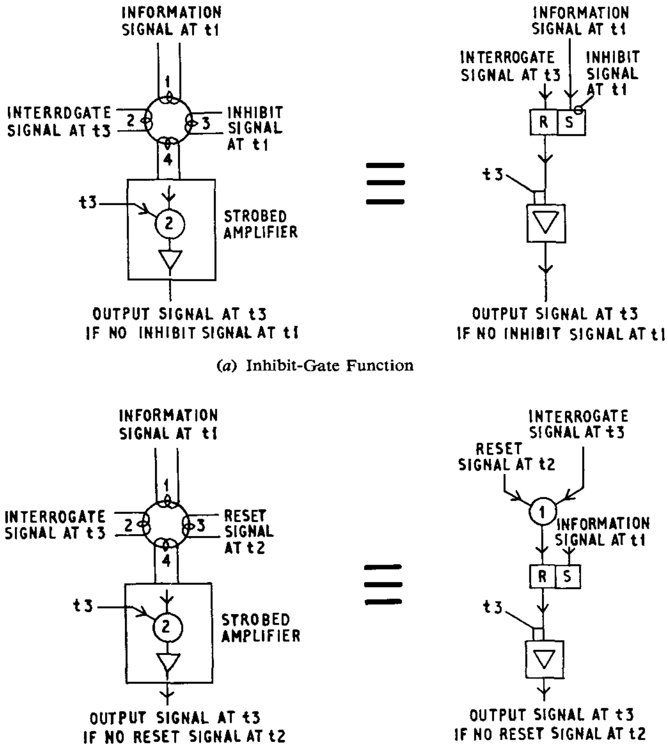



FIG. 14—THREE-WINDING-CORE FUNCTION CONTROL ELEMENT

The addition of a fourth winding makes the arrangement more flexible. It is now possible to use the additional winding either for an inhibit function or, in conjunction with the amplifier strobe, as a means of cancelling held information as shown in Fig. 15(a) and (*b*), respectively.




(*a*) Inhibit-Gate Function

(*b*) Alternative-Reset Function

FIG. 15—FOUR-WINDING-CORE FUNCTION CONTROL ELEMENT

In the equipment practice used, the core and output amplifier shown in the configurations of Fig. 14 and 15 are associated as a standard circuit element (see Fig. 16),

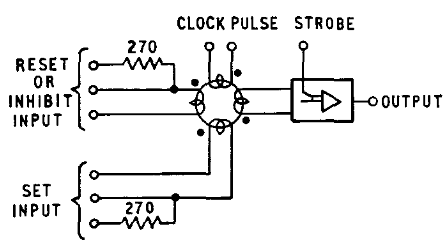



FIG. 16—STANDARD FUNCTION CONTROL ELEMENT

and, typically, nine such elements are accommodated on one plug-in unit. The various windings are brought out to terminal points and, hence, any control configuration can be achieved by suitable inter-terminal wiring.

Information signals may be derived from the transistor-type logic gates referred to earlier, and such logic gates combined with function control elements form the manipulative circuits used in the core-type register-translator. The use of cores makes it possible to use a signal combination, once gated, several times over by series connexion through the appropriate cores. Fig. 17 shows three control elements each requiring the AND function A.B.C. Function control element FC1 uses the gated signals direct, but in control element FC2 the out-

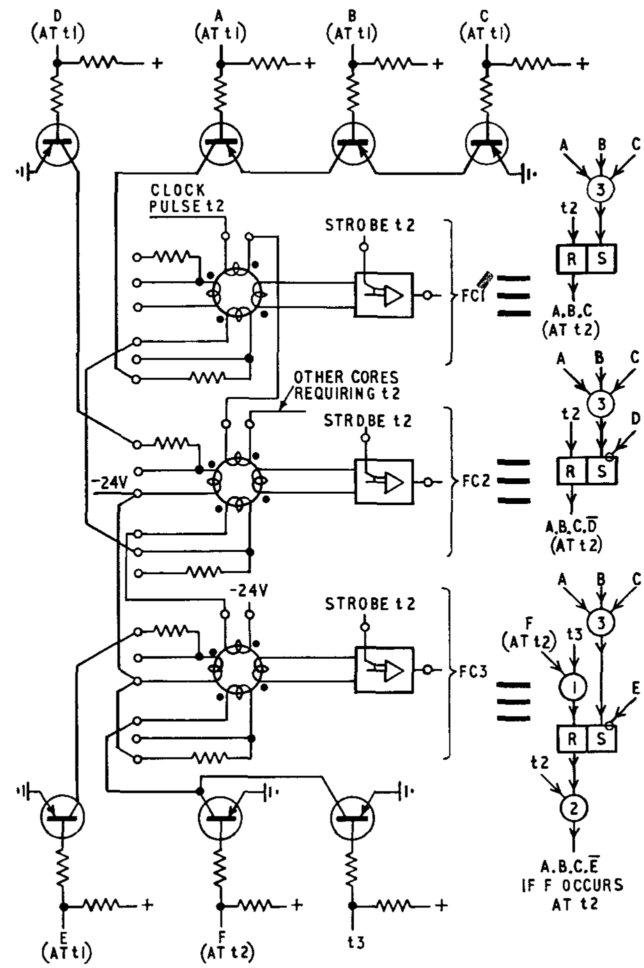



FIG. 17—TYPICAL CORE-TRANSISTOR MANIPULATIVE CIRCUIT

put is dependent upon the absence of a D signal, while in control element FC3 the output is dependent upon the absence of an E signal and the presence of an F signal at time t2; note that the core is reset ineffectually at time t3 in the absence of an F signal. These control functions are realized by the inter-terminal-point wiring shown. The equivalent functional representations for the three control elements are shown at the right-hand side of Fig. 17.

## CONCLUSION

The principles of the basic elements, i.e. the register-time-pulse generator, central data store, function control element, and highways systems joining the many inputs to a single computer, have now been described. Part 2 of this article will describe how these basic elements are used in the core-type register-translator system to perform the manipulative processes required.

(*To be continued*)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# The New Leafield Radio Station

## Part 1—General Principles

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U.D.C. 621.396.7

**After a short survey of the prospects for high-frequency long-distance radio-telegraphy in an era of rapid and profound technological change, the concepts underlying the design of the recently rebuilt radio-telegraph transmitting station at Leafield are discussed. The techniques, among the most advanced so far used in this field, which made these concepts realizable are briefly described in Part 1; Parts 2–4 will deal with the more significant of these in more detail.**

### INTRODUCTION

THE history of Leafield radio station dates back to 1912, when work was started there on the first stage of what was to be the Imperial Wireless chain, a scheme to provide radio-telegraph communication between the countries of the British Empire using spark transmitters of 300 kW power. Only the masts were, in fact, erected by 1914 when the work was interrupted by the first Great War, and it was not until 1922 that the first link between the United Kingdom and Abu Zaabel in Egypt was opened using 250 kW Elwell arc transmitters.[1]

The demonstration in 1923 by Marconi of the practicability of world-wide short-wave communications led to the abandonment of the long-wave project and the introduction in 1925 of the first long-distance short-wave commercial services at Leafield and elsewhere. By 1952 the number of short-wave transmitters had grown to nine. The original masts were, however, used to support aerials for three long-wave valve transmitters.

The first transmissions from Leafield in 1922 were press broadcasts from the original arc transmitter, since when the station has traditionally been associated with multi-destination press traffic, and remains active in that role today.

The provision during the 1950s of alternative, more economic, means of carrying medium-range press traffic reduced the demand for the long-wave services, which ceased operation in 1961. Much of the short-wave equipment, and the station buildings too, were over 30 years old and unsuited to present-day needs. All these factors led to the decision to replan the station along modern lines and enlarge the site. The first stage, the recovery of the original long-wave masts,[2] was successfully completed in 1962 and marked the end of an era in radio communications history.

### TRAFFIC REQUIREMENTS

It may be asked whether, in an age when the success of the transoceanic cable in meeting the rapidly expanding demand for intercontinental circuits is now an established fact, and when communication satellites promise even greater circuit capacities in the near future, there is any longer a place for long-distance high-frequency (h.f.) point-to-point communications. The unprecedented growth forecast for traffic between Europe and the rest of the world up to 1975 of 12 per cent per annum, and the rapidly changing technical situation, make it more than usually difficult to predict the precise roles to be played by the various communication media over the next decade. However, experience has so far shown that the stimulation of demand by new techniques creates pressure for increased h.f. facilities in other parts of the network where, for one reason or another, it is economically viable. The inherent flexibility of the h.f. medium fits it admirably for this role, and the frequency spectrum available to the fixed services in the 3–30 Mc/s band will, it seems, remain a valuable international asset indefinitely. It consequently seems unlikely that there will be any appreciable decline in h.f. facilities until well into the 1970s, if then.

The prevailing congestion in the h.f. band makes it out of the question to seek more than a marginal increase in the number of frequency allocations, but much has been, and continues to be, done to improve spectrum-utilization efficiency by reducing frequency tolerances, adopting single-sideband modulation and telegraph multiplexing techniques, and by these means to bring about major increases in the traffic-handling capacity of existing h.f. routes. This is particularly true of radio telegraphy where it is now technically possible for a single transmitter to carry, without undue sacrifice in performance, up to 96 teleprinter channels in a radio bandwidth of 12 kc/s. Whilst the deficiences in the propagation medium will always prevent a loading efficiency approaching that of a line system when using the most modern techniques, the application of TOR error-correcting equipment nowadays results in a standard of performance on circuits of up to 10,000 miles in length comparable with that over line circuits for a very high proportion of most days.

The growth of the overseas radio-telegraph circuits over recent years is shown in Fig. 1. The demand for

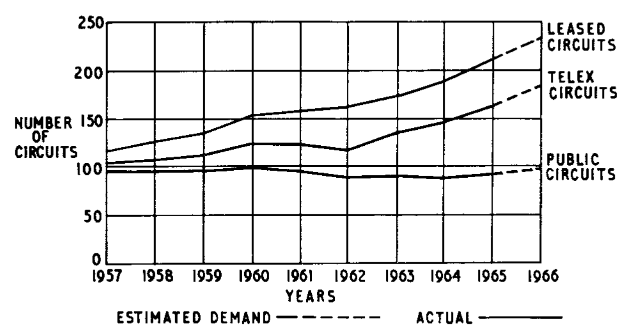


FIG. 1.—GROWTH OF OVERSEAS RADIO-TELEGRAPH CIRCUITS

Telex circuits is particularly notable, but, since transfer of the North Atlantic public circuits into the TAT cables is included in the period, the substantial growth of this service on other routes is masked. There is little doubt that expansion has been fostered here, as in other sectors, by the exploitation of modern techniques, and so long as this attitude prevails the prospects for the h.f. long-

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distance radio-telegraphy services are anything but discouraging.

Multi-destination press traffic is influenced by rather different considerations. Whilst some of the demand is syphoned off by improved public communications and cable private-circuit facilities, the rapid dissemination of news by radio to widely scattered recipients within broad zones of common ethnographical interest will continue to be an economically attractive proposition in some areas of the world such as the Middle East, East and West Africa and South East Asia. This service poses special problems of its own, in that the wide zonal coverage requirements lead to some sacrifice in gain from the aerial systems, and the indifferent reception conditions in large cities makes special demands on the power-handling capacity of the transmitters.

The new Leafield station will continue to play its part in catering for this class of service, and six transmitters of 85 kW (c.w.) capacity are provided for the purpose. At the same time, the currently expanding needs of the fixed radio-telegraph services are served by 12 transmitters of 30 kW (p.e.p.) capacity. These 18 transmitters, together with their drive and control equipments, are housed in a new building adjacent to, but operationally distinct from, the old, which is being dismantled.

### DESIGN CONCEPTS

One of the major differences between a h.f. communication system and other radio systems is the necessity to change frequency several times each day to counter changing propagation conditions. More often than not this is accompanied by aerial changes in order to maintain the effective radiated power at each frequency. On high-power equipment especially, this has always posed problems in equipment utilization, reliability and loss of circuit time, and these have become more pressing with the increases in circuit density brought about by multiplexing.

Another important difference has been the relatively high level of staffing necessary to operate, as well as maintain, the equipment. Watch-keeping duties were eliminated at most transmitting stations during the 1950s but it has, hitherto, been necessary to keep them continuously manned to carry out essential centralized-control functions and to be on hand to restore service in an emergency. The new Leafield station has been designed so that, if circumstances permit, it can be controlled remotely and the more commonly-experienced failures rectified without staff attendance being necessary.

In designing the station the aims have been, therefore,

(*i*) a high degree of equipment utilization,

(*ii*) the utmost reliability,

(*iii*) uninterrupted circuit operation on at least some routes, and

(*iv*) minimum staffing costs, with an ultimate goal of partial unattended operation.

The technical performance of h.f. radio equipment needed to meet the electrical requirements of modern communication systems has changed very little since 1955, but full advantage has been taken of technological advances to make equipment more reliable and flexible in use. These advances, which have in large measure made possible the realization of the design concepts include, to name the most significant,

(*a*) the change-over to solid-state circuits, not only in low-power radio-frequency equipment but in the h.t.d.c. power-supplies of the transmitters,

(*b*) the appearance of the frequency-following self-loading transmitter and the associated frequency-synthesizer carrier generator, and

(*c*) the development of reliable motorized switching exchanges and wideband impedance-matching devices, both capable of large radio-frequency power throughputs.

In integrating the various components into a system capable of eventual remote control, emphasis was placed on the service as the basic unit, rather than the transmitter, as hitherto. This led to the idea of allocating a number of transmitters to be shared impartially among a group of services. The size of the group is determined by the need to balance complexity against utilization efficiency. Six to eight transmitters per group is optimum; in fact, three groups of six were chosen for Leafield. The concept, not unfamiliar to telephone-switching engineers, is nevertheless a breakthrough in the radio field.

### SITE AND BUILDINGS

The old site extended to 152 acres, but even after recovery of the long-wave aerials this was insufficient to support the required h.f. aerial development. The balance between transmitter and aerial annual charges is of some importance in determining optimum station costs,[3] and it is now generally accepted for planning purposes that at least 20 acres of aerial space is necessary for each transmitter. Allowing for some economies in the press-service aerial requirements a doubling of site area was indicated. In fact, an extension of 135 acres was required, resulting in a fairly satisfactory aerial farm but with little provision for future expansion.

The building (Fig. 2) follows precedent in adopting a three-wing layout for the transmitter hall, but a two-storey design has been adopted for the first time, with the transmitter cubicles at first-floor level. This has resulted in significant building economies and a rather more attractive layout of the transmitter ancillary equipment, as well as providing a basement carrying all engineering and domestic supplies. A separate apparatus room houses the low-power drive and control equipment, as well

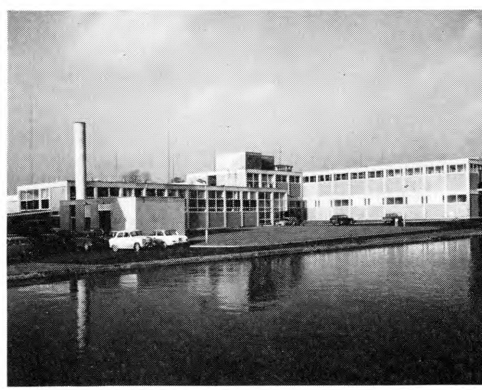

FIG. 2.—THE LEAFIELD RADIO STATION

as the central control console whilst this remains at the station. Offices, stores and welfare accommodation are grouped in what is, virtually, a fourth wing. The old accommodation, much of which is temporary or outdated, will be put to other uses.

### TRANSMITTERS

The present trend in h.f. transmitter design is towards automatic self-tuning and continuously adjustable coupling to the load so that optimum operating conditions are always secured. At Leafield the transmitters employ conventional tuned-amplifier stages, with the motorized drives for variable capacitors and inductors controlled by phase discriminators. Their technical performance is well within current C.C.I.R.* standards for this class of equipment, which has not changed materially since 1959. It is in the spheres of reliability and ease of control that the main advances are apparent.

The twelve 30 kW transmitters, for fixed-service operation, are in two self-contained groups in two of the wings (Fig. 3). The third wing contains the six 85 kW transmitters which, although intended for single-channel press-broadcast services, can also be operated as multi-channel transmitters rated at 80 kW p.e.p., or, by a reduction in h.t. voltage, at 30 kW p.e.p. The two types of transmitters are identical except for the final stages, where the larger uses two 3Z/253E valves in parallel instead of a single valve. The maintenance advantages of this arrangement are considerable.

FIG. 3.—SIX OF THE 30 kW FIXED-SERVICE TRANSMITTERS

### SIGNAL GENERATION AND CARRIER SUPPLIES

The station is able to emit practically all types of radio-telegraph signal in common use. Frequency-division multiplex systems using either two-tone or narrow-deviation frequency-shift methods[4] in conjunction with independent-sideband drive units account for the greater part of the fixed-service traffic, though single-channel or twin-channel frequency-shift keyers are also available. The press-broadcast services, for the most part, use amplitude modulation, though frequency-shift methods are likely to become more widely used.

Primary modulation, for all types of emission, takes place at 100 kc/s; further modulation is carried out at 3 Mc/s in a separate modulator associated with each transmitter. The flexibility necessary to the efficient utilization of the transmitter group is thereby introduced at a convenient frequency of 100 kc/s by means of dry-reed switching matrices. Practically all low-power equipment is of the transistor type, and the reliability thus engendered has enabled a reserve chain to be dispensed with except for manual patching facilities. A further novel feature is the duplication of outlets from drive equipment to permit two transmitters to be modulated simultaneously at different carrier frequencies during frequency-change periods, a procedure known as dualling. Complementary demodulators and switching matrices enable the baseband signal to be recovered for monitoring purposes.

Carrier generation, always a sensitive element in h.f. radio technique, assumes even greater significance in modern systems. The current Radio Regulation stipulates a frequency tolerance of 15 in $10^6$ for all h.f. radio emissions, which is readily achieved with good quality, but relatively simple, crystal oscillators. This is not, however, sufficient to enable automatic frequency control (a.f.c.) to be dispensed with in the receivers, where an all-too-frequent cause of system failure is "capture" of the a.f.c. by interfering signals. The C.C.I.R. recognizes this, and now recommends overall tolerances of about 15 c/s on systems dispensing with a.f.c. The transmitting station share of this tolerance is about 3 c/s, or 0·1 in $10^6$ at the highest emitted frequency. A performance of this standard is only attainable with relatively sophisticated and expensive oscillators, and has led to the choice of frequency-synthesizers controlled from a master-oscillator. The association of a synthesizer with each transmitter also ensures the full availability of the transmitter within its group or, if needs be, within the station as a whole.

The synthesizers are decadic and give outputs at 125 c/s intervals in the range of 4–8 Mc/s; after suitable multiplication the carriers are then available at intervals not exceeding 0·5 kc/s. Each decade is "locked" to an appropriate pulse train derived from the 100 kc/s master source, and the frequency is selected remotely, according to a prearranged program, by motorized switches. Fifty frequencies are programmed, and selection of any one initiates the automatic-tuning processes in the transmitter.

The master-oscillator system is of interest in that, for the first time at a commercial station, the crystals and their transistor-type maintaining oscillators are sunk in sealed containers down shafts 30 ft below ground as an alternative to using conventional ovens. This gives conditions which are almost ideal for precision oscillators.

### AERIALS AND AERIAL DISTRIBUTION

The enlarged site of 287 acres allows a not over-generous area of 16 acres for each transmitter. Undue congestion has been avoided, however, by using concentric tiered rhombics for the fixed services and wideband log-periodic aerials for the press services and for stand-by purposes.

It has for long been suspected, and is now conclusively proved,[5] that over long-distance point-to-point circuits dominant modes of propagation are present at angles to the horizon below 10° for a very high percentage of useable circuit time, and that considerable advantages result from the use of aerials at both ends of the circuit which are "matched" to these modes. For horizontally-polarized aerials this implies mean heights of 150 ft or

*C.C.I.R.—International Radio Consultative Committee.

more above the ground plane at frequencies of 12 Mc/s and below. It is perfectly feasible to operate two rhombic aerials, simultaneously if needs be, when they are suspended concentrically from a common set of masts provided the vertical separation is adequate. This is now common practice throughout British Post Office stations, each rhombic being designed to match reasonably well to the prevalent propagation modes over one octave of frequency. For the dualled services operating daily on more than two frequencies it is necessary to provide more than two aerials to cover the overlap periods if a reasonable match is to be secured. It is largely for this reason that triple-tiered rhombics, erected on 300 ft stayed masts, have been introduced.

The log-periodic aerial is a comparative newcomer in the h.f. field and has been used by the Post Office for the first time at Leafield. As so far developed it is some way below the rhombic in performance and is not favoured for fixed-service use, but it can be designed for operation over an arbitrarily-large frequency band and has a wide main lobe of radiation which renders it useful in certain circumstances where zonal coverage is desired. It fitted the press-broadcast-service needs rather neatly, which had been previously met by broadside dipole arrays with as many as four or five to a service. As designed, the aerial is a compromise between compactness, structural robustness and reasonable performance.

All the services operated from Leafield lie in the arc 90°–200° E, in itself an interesting commentary on the current trends in h.f. development. This makes the use of log-periodic aerials, rather than the more conventional omni-aerials, acceptable for stand-by purposes, and four of them are provided to cover break-down of the service aerials.

The now standard arrangement of radio-frequency power distribution by coaxial cable of 50 ohms characteristic impedance within the building, connected by balun matching transformers to external open-wire balanced feeders, has been adopted. The lower-power balanced feeders are, conventionally, 600-ohm twin-wire lines, but the high-power feeders are of four-wire construction to restrict line voltage and, thus, to enable the same hardware to be used. The lower characteristic impedance of 305 ohms is also more suited for direct connexion to the log-periodic aerials.

Wideband transformers of the balun type using coaxial-line techniques are now quite widely used for matching coaxial cables to 600-ohm balanced feeders at powers up to 30 kW. A high-power 300/50-ohm version, which has been developed for the press services, can carry 100 kW, the highest capacity so far achieved.

The provision of adequate flexibility between transmitters and aerials, always a difficult problem, assumes even more fundamental importance when the aim is interruption-free, unattended, operation. It is necessary for the switching arrangements to permit the day-to-day selection of aerials appropriate to the frequencies used, to allow for the speedy replacement of faulty transmitters or aerials, and to enable the longer-term changes arising from service alterations to be made. It is, at the same time, essential in the interests of reliability to avoid over-complication. The matrix-switch type of aerial exchange has been successfully used in a number of post-war schemes and has been further developed at Leafield in the directions of greater robustness and maintainability. Each 30 kW transmitter-group has its own 7 × 14 matrix exchange (Fig. 4), giving complete flexibility within the group and, by means of interconnecting trunks, limited overall flexibility. The individual switches are motorized

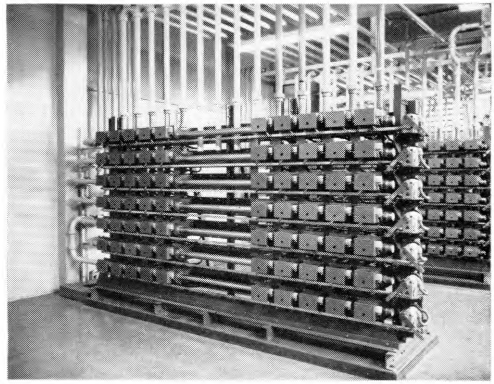

FIG. 4.—THE 7 × 14 MATRIX EXCHANGE FOR THE 30 kW TRANSMITTER GROUP

for remote operation, and can be jacked-out safely and without disturbing working services. Auxiliary switching for the dualled-service aerials is performed in separate 5-switch exchanges. It has not, so far, been found necessary to provide a matrix exchange for the high-power transmitter-group because of the simpler service requirements and the wideband aerials; all that is needed is a reserve chain with remotely-operated field-switches to select the appropriate stand-by aerial.

In designing the radio-frequency power transmission system the overall aim has been to maintain the voltage standing-wave ratio (v.s.w.r.) at the transmitter output terminals below 2, a value within the range of the transmitter automatic-matching circuits. The standing-wave-ratio indicator on the transmitter rejects anything greater than this as a fault condition and stand-by aerial selection is automatically initiated.

## CONTROL SYSTEM

The aim, in designing the control system, has been to reduce the operation of the station to its simplest terms so that continuity, or near-continuity, of service can be maintained without direct involvement of the operator in the comparatively complex operations accompanying frequency and aerial changes. The operator at the control point, and eventually at the traffic terminal, is enabled to start up and shut down services, to initiate frequency changes, and to satisfy himself by simple supervisory signals that performance is satisfactory. Provision for replacing faulty transmitters or aerials, the more vulnerable links in the chain, is an integral part of the system.

Each of the six-transmitter groups has its own control system, though that for the press-broadcast group is comparatively simple. Four or five services are assigned to each of the fixed-service groups and share the group's transmitters impartially. It is also possible for one group to "borrow" a transmitter from the other to become, in effect, a seven-transmitter group if service needs require it. Thus, a high degree of protection against transmitter breakdown as well as provision for dualling is achieved with a spare capacity of 20–25 per cent.

The control equipment has to perform five basic functions on receiving a single command:

(*i*) seize a free transmitter with its synthesizer,

(*ii*) select the required frequency,

(*iii*) select the aerial within the service group appropriate to the frequency,

(*iv*) test the circuit, and

(*v*) route the traffic signal through the selected transmitter to the aerial.

An interesting feature of the common equipment is the low-power switching matrix which serves to connect the drive equipment to the transmitters. This matrix, operating at 100 kc/s, is an analogue of the transmitter-aerial switch matrix and employs reed-contact switching elements. A similar matrix is used to complete the monitoring connexions in the reverse direction.

Monitoring is based upon the use of input and output level detectors and v.s.w.r. detectors in the transmitter output feeders. In addition, a full range of telegraph monitoring facilities are available at the station on a basis of manual selection of individual channels either at the telegraph input or at the radio-frequency output of the service.

CONCLUSIONS

The new Leafield station incorporates the most advanced examples of a number of technical developments evolved over a period of nearly 20 years and directed to solving some of the problems traditionally linked with operation of high-power h.f. transmitting stations. The aims have been to achieve maximum utilization of the large capital investment involved and, at the same time, to reduce operating and maintenance costs to a minimum. It is probable that the Leafield re-development will be the last single operation of this magnitude in the h.f. field within the United Kingdom, but plant at other Post Office stations is in need of modernization and similar projects based on the Leafield concept are planned. Such means will enable h.f. radio to play a useful and economically viable role in the fast-growing overseas communication network, at least until the late 1970s.

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# Book Reviews

"Principles of Television Engineering." Roy C. Whitehead, A.M.I.E.E. Iliffe Books, Ltd. 270 pp. 167 ill. 35s.

Published as two separate paper-backed volumes, Principles of Television Engineering has been prepared as an introduction to the study of television engineering. It is intended primarily for students intending to make a career in the television world, but it is also of interest to those studying general telecommunications subjects.

The subject treatment throughout is simple, and can readily be followed by readers with some knowledge of basic radio principles and circuits. The mathematical ability required is limited to simple algebra and elementary calculus. These volumes can be confidently recommended to anyone wishing to acquire a good general impression of the equipment used throughout the whole chain of television broadcasting.

The first volume outlines the basic principles of television in a remarkably simple and readable form, ranging as it does from the spectrum of light to the principles of scanning and synchronization. Nearly half the volume is given over to seven appendices which cover, in greater detail, subjects that are only touched upon in earlier chapters—examples are: gamma control, blanking and gating, and the timing and standard pulse systems. It is in this form that the details of scanning circuits are fully developed.

The second volume starts with a study of television studio techniques and equipment including both film and tape recording arrangements. It is followed by chapters on transmission from studio to viewer, including both cable and broadcast components. The largest part of the volume however is devoted, quite properly, to receiver design and circuits, including aerial systems. Under this heading there are chapters on Tuners and I.F. Amplifiers, Detectors and Video Amplifiers. Again there are six appendices covering in more detail such aspects as time-constant calculations, d.c. restoration and clamping, and an outline of the types and operating characteristics of camera tubes.

Although printed in paper-backed form on commercial grade paper these little volumes are very well illustrated with many diagrams and are particularly easy to read. R.A.D.

"Digital Instruments." K. J. Dean, B.Sc. Chapman & Hall, Ltd. viii + 181 pp. 94 ill. 25s.

This is the third book dealing with transistor circuits which the author has produced recently, and, in an effort to make this volume self-contained, he has attempted to compress the relevant portions of his other works into the first two chapters.

The first chapter, dealing with coding, is moderately successful, but the second chapter, which covers semiconductor theory, gating circuits, toggles, shift registers, etc., is extremely confusing to both reader and author. The "pulse plus bias" gate described on p. 26 operates in a different mode from that usually employed and is most certainly quite different from the application described on p.31. There is also confusion on positive and negative logic and the statement at the top of p. 21 is incorrect.

The third and fourth chapters deal with descriptions of input and output devices, respectively, and are in general much better written. However, there are several points which would irritate a telecommunications engineer. For example, the illustration of the obsolescent slipping-cam dial on p. 50, and the statement that information is presented to a teleprinter in binary decimal code on p. 87.

The remaining third of the book deals with actual digital instruments and effectively covers the measurement of frequency, time, voltage and resistance. Chapters 6 and 7 which deal with the differing techniques of stepping, successive approximation and ramp function digital voltmeters are well presented and can be recommended to those requiring a working knowledge of the subject.

D.J.H.

# Notes and Comments

**Birthday Honours**

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

| | | | |
|---|---|---|---|
| Belfast Telephone Area | G. F. Alton | Assistant Executive Engineer | Member of the Most Excellent Order of the British Empire |
| Belfast Telephone Area | G. H. Sheridan | Inspector | British Empire Medal |
| Engineering Department | Capt. O. R. Bates | Commander, H.M.T.S. *Monarch* | Officer of the Most Excellent Order of the British Empire |
| Lincoln Telephone Area | E. Jackson | Technical Officer | British Empire Medal |
| London Telecommunications Region | H. E. Francis | Deputy Regional Director | Officer of the Most Excellent Order of the British Empire |
| London Telecommunications Region | G. A. Thomas | Executive Engineer | Member of the Most Excellent Order of the British Empire |
| North Eastern Region | E. King | Assistant Executive Engineer | Member of the Most Excellent Order of the British Empire |
| Oxford Telephone Area | C. R. Hamley | Technical Officer | British Empire Medal |
| Post Office Research Station | P. E. White | Assistant Executive Engineer | Member of the Most Excellent Order of the British Empire |

**J. W. H. Freebody, Whit.Sch., B.Sc. (Eng.), A.C.G.I., D.I.C., M.I.E.E.**

John Freebody, recently promoted to Assistant Engineer-in-Chief, is one of several distinguished engineers whom the Post Office has drawn from H.M. Dockyards. On completing his education at the City and Guilds Engineering College (London University) he entered the Post Office in January 1933 as a Probationary Assistant Engineer (old style). After training, he joined the Telegraph Branch, Engineering Department, in which

he was promoted to Executive Engineer (old style) in March 1940 and to Assistant Staff Engineer in October 1947.

For some 25 years he was closely engaged in developing, providing and maintaining telegraph services beginning with the, then, new Telex and private teleprinter service. During the war he was concerned with teleprinter services for defence, and contributed notably to the rapid build-up of service communications. All aspects of telegraphy—machines, switching, and transmission over both cable and radio circuits—came his way, and he made his mark both at home and in international councils of the C.C.I.T.T. He contributed from time to time to the I.P.O.E.E., and rounded off this first phase of his career by becoming a household name through revising "Herbert's Telegraphy." His interest in the affairs of the I.P.O.E.E. has been a continuing one, and he has been its Treasurer since 1963.

In 1958, John Freebody was promoted to Staff Engineer and set the task of founding the Technical Support Unit —a branch of the Engineering Department formed to give advice to H. M. Treasury on the choice and installation of computers in Government Departments. That the T.S.U. quickly established a solid reputation with all who consulted it, and also with the computer manufacturers, is due in no small measure to the enthusiasm with which he threw himself into this work. In April last year responsibility for the T.S.U. was transferred from the Treasury to the Ministry of Technology, and the firm foundation which he had laid allowed it to be doubled in size in order to serve all parts of the public sector.

This computer phase of his career brought John Freebody into contact with most Government Departments; he served on computer committees of the British Standards Institution, made a major study tour in the United States of America, and attended international computer conferences in Paris and New York.

In June 1965, he returned to take charge of the Telegraph Branch, and the interest which he had developed in data transmission, plus his conviction of its rapidly growing importance, led him to rename his old home the Telegraph and Data Systems Branch. Now he has been selected to break new ground by forming the Long-Range Systems Planning Unit, in which his task will be to identify and evaluate those developments in telecommunications which will affect the future operations of the Post Office. In view of the growing convergence between digital systems for computing and for communications, his experience and understanding could hardly be more appropriate.

To his gifts as an engineer John Freebody adds a disarming friendliness of manner and generous readiness to help which have won him friends in many places. Those friends will be greatly pleased by his new appointment, and all of them will join in wishing him every success.

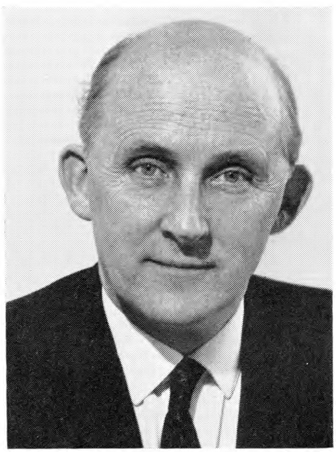
F.J.M.L.

**H. E. Francis, O.B.E., M.I.E.E.**

The appointment of Mr. Francis as Deputy Regional Director in the London Telecommunications Region has been welcomed by his many friends in the Post Office, the telecommunications industry and overseas telephone administrations.

Mr. Francis entered the Post Office in 1925, and after a short spell as a Youth-in-Training he continued training as a Probationary Inspector. This was followed by 20 years' experience of all aspects of telephone exchange planning, construction and maintenance, principally in the Telephone and Equipment Branches of the Engineer-in-Chief's Office, as it was then called, but including a short period in the Leeds Technical Section and six very enjoyable years in the Aberdeen Telephone Area. He was promoted to Assistant Engineer (old style) in 1936 and to Executive Engineer (old style) in 1942.

The end of the war brought a widening experience of telephone systems, commencing with 4 years' secondment



to the Indian Government with responsibility for planning automatic exchange areas and the trunk network. After a short time back with the Post Office this was followed by 6 months with the Anglo-Iranian Oil Company in 1950, as senior engineering member of a team advising the company on its communications network in Persia.

In 1952 Mr. Francis was appointed Assistant Staff Engineer in Telephone Branch, being mainly concerned with the design of equipment for trunk switching. There followed 7 years of intensive work in preparation for the introduction of subscriber trunk dialling, in connexion with which he made official visits to Germany, Sweden and Switzerland, and also spent a short time in Yugoslavia as a United Nations Technical Assistance Expert. His outstanding contribution during this period and his wide experience of telephone exchange design and planning were recognized in 1959 by his appointment as Staff Engineer in charge of his old Branch—the Exchange Equipment and Accommodation Branch.

During his long and varied service Mr. Francis has acquired a wide knowledge of telecommunications in general and automatic exchanges in particular, and this has been repeatedly demonstrated by his lectures and published articles and papers, two of which were awarded I.P.O.E.E. Silver Medals, and his work as an examiner in telephony for the City and Guilds of London Institute. Readers of this Journal will remember the comprehensive group of articles on subscriber trunk dialling prepared under his guidance and published in the January 1959 issue.

When in 1963 the General Directorate of the Post Office approved the setting up of the London Trunk and Junction Network Task Force to prepare a long-term plan for London's telephone system, it seemed natural that Mr. Francis should be appointed to lead the team of engineers, scientists and traffic experts that was assembled for the task. His boundless enthusiasm and inquiring mind, combined with a firm but kindly leadership, soon welded this unusual combination of talents into a hard working and effective team. After the successful completion of its study of the London network last August, the Task Force turned its attention to the United Kingdom international telephone service, and his colleagues wish Mr. Francis every success in this new sphere of responsibility. They also offer congratulations on the O.B.E. recently conferred on him in Her Majesty the Queen's Birthday Honours List.

E.D.

**F. A. Horne, M.B.E., E.R.D., B.Sc.(Eng.), A.M.I.E.E.**

Mr. Horne, who has been promoted to Staff Engineer in charge of the Organization and Efficiency—Work Study and Stores (OWS) Branch of the Engineering Department, entered the Post Office in 1936 by the Open Probationary Inspector Competition.

From 1936 he served as an Inspector in the Scotland West Area until the outbreak of war in 1939, when he began a period of $6\frac{1}{2}$ years with the Royal Corps of

Signals. During that time he rose from 2nd Lieut. to Company Commander in regimental appointments, and then to Major as Staff Officer, Lines, in L. of C. formation Headquarters in N.W. Europe. He was mentioned in despatches and awarded the M.B.E.

In 1946 he returned for a short while to Scotland West Area, before transferring to the Central Training School, Stone, where he spent 2 years as a lecturer in local-lines planning. In 1948 he was successful in the Limited Competition for Probationary Engineer, was appointed to Local Lines Branch of the Engineering Department and, there, was engaged for 2½ years in developing and promulgating methods for designing the layouts of exchange areas.

In 1951 he left the Post Office for 3½ years secondment to the East African P. & T. Administration, in charge of installation of equipment and of line planning and construction for Tanganyika.

On his return to the Post Office, in 1954, he went as Executive Engineer to the Belfast Telephone Area to take charge of external planning. Promotion to Area Engineer in 1956 was accompanied by a transfer to the Aberdeen Area where he was employed in setting up the organization and procedures for the newly-created post of Area Engineer, Inverness—the only Area Engineer in the Post Office with Headquarters remote from his Telephone Manager's Office. Mr. Horne remained at Inverness, in charge of all construction and maintenance work, until the Autumn of 1962 when he was seconded to Ghana for 18 months to advise on staff and training. During that tour abroad he was promoted to Regional Engineer, in absentia, and he resumed duty with the Post Office in that rank in 1964 with the responsibility for engineering training in the London Telecommunications Region.

Formerly a keen sportsman, he now devotes his surplus energy and his leisure time to his garden. His other relaxations are photography and wine making.

Thus, Mr. Horne brings to his new duties a very wide variety of experience and detailed practical knowledge of the organization and execution of telecommunications engineering work in the field. Knowing this background, and his calm but determined temperament, his many friends and colleagues look forward confidently to his success in the arduous task ahead, and wish him satisfaction and enjoyment from his new duties.

W.A.H.

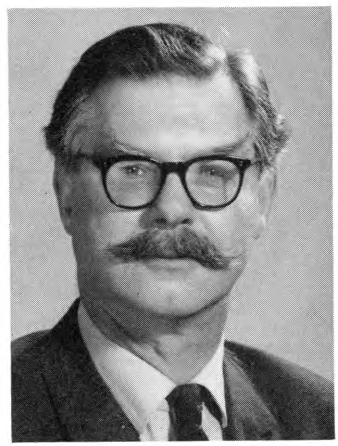
**W. E. Thomson, M.A.**

The recent appointment of Mr. Thomson to a new Senior Principal Scientific Officer post in Research Branch has been welcomed by all who know him. In RE Division, he has taken over responsibility for the expanding mathematical-research side, and this means that a peg and a hole have been matched as perfectly as could be.

After early education at Daniel Stewart's College, Edinburgh, and graduation in mathematics and physics at Edinburgh University, Mr. Thomson entered the Post Office as a Probationary Inspector (old-style) in 1938 and was soon appointed to the television group of the Radio Branch at Dollis Hill. The second world war diverted him to work for the Defence Services, mostly under the headings of navigational aids and hindrances. On his return to the television field, he assisted in the development of the original London–Birmingham coaxial-cable television link. Then, as one of the very few who, at that time, appreciated the advantages of handling television-transmission problems in the time domain rather than the conventional frequency domain, he developed the first waveform corrector for outside-broadcast links provided on telephone cable pairs.

In 1948 he was transmuted into a Senior Scientific Officer in the mathematics group of the Research Branch at Dollis Hill, and, in 5 years of varied work, firmly established his reputation as a mathematician who can communicate with scientists and engineers as well as with other mathematicians. One or two of his papers on waveform matters, published during that period, are still being cited and so qualify for the "classical" category.

Next came his appointment to a new Principal Scientific Officer post in the Telephone Switching Division of Research Branch to study problems of switching and traffic flow. Interleaved with these was the task of establishing the mathematical basis of ERNIE. It must surely be significant that Mr. Thomson has no difficulty in holding his own against those of us who become reconvinced each month that ERNIE's randomness is not above reproach.



Returning to the mathematics group in 1960, with some 5 years' experience of computer programming, he was in a good position to co-operate in the selection and initiation of the first Engineering Department electronic computer, installed at Dollis Hill. One program for which he was responsible was that used initially at Goonhilly for deriving the aerial steering data from the predicted satellite positions. Unfortunately for the Research Branch, all this experience made him the obvious choice for secondment in 1963 to the London Trunk and Junction Network Task Force, the unique team of engineers, traffic experts and scientists which has successfully completed its work under the direction of Mr. H. E. Francis. Now, after his 2 years on questions of the optimum routing of traffic in a complex system, Mr. Thomson's advice is again available to a wider clientele.

Outside his official activities, Ettrick Thomson has always managed to find some time for the social side, ranging from Treasurership of the Social Club to active membership of the Sailing Club. A one-time regular performer in the Dollis Hill Christmas Pantomime, he now displays annually another of his talents by designing the backcloths, a task that so far has resisted computerization.

N.W.L.

**Notes for Authors**

Authors are reminded that some notes are available to help them prepare the manuscripts of the Journal articles in a way that will assist in securing uniformity of presentation, simplify the work of the Journal's printer and draughtsmen, and help ensure that the authors' wishes are easily interpreted. Any author preparing an article for the Journal who is not already in possession of the notes is asked to write to the Managing Editor to obtain a copy.

It is emphasized that all contributions to the Journal, including those for Regional Notes and Associate Section Notes, must be typed, with double spacing between lines, on one side only of each sheet of paper.

Each circuit diagram or sketch should be drawn on a separate sheet of paper; neat sketches are all that are required. Photographs should be clear and sharply focused. Prints should preferably be glossy and should be unmounted, any notes or captions being written on a separate sheet of paper. Negatives or plates are not needed and should not be supplied.

**Supplement and Model Answer Books**

Students studying for City and Guilds of London Institute examinations in telecommunications are reminded that the Supplement to the Journal includes model answers to examination questions set in all the subjects of the Telecommunication Technicians' Course. Back numbers of the Journal are available in limited quantities only, and students are urged to place a regular order for the Journal to ensure that they keep informed of current developments in telecommunications and receive all copies of the Supplement.

Books of model answers are available for some telecommunication subjects, and details of these books are given at the end of each Supplement.

# Institution of Post Office Electrical Engineers

### Institution Field Medal Awards, 1964–65 Session

In addition to the Institution Senior and Junior silver and bronze medals, up to three bronze medals, the Field Medals, are awarded annually for the best papers read at meetings of the Institution on field subjects primarily of Regional interest.

Field Medals were awarded to the following authors for papers read during the 1964–65 session:

E. H. Piper, Bournemouth Telephone Manager's Office (South Western Region). "The Training of Youths."

R. C. Mansell, F. C. Salter and L. Turner, Engineering Branch, Birmingham (Midland Region). "The Birmingham Television Network Switching Centre."

J. Logan, Aberdeen Telephone Manager's Office (Scotland). "Post Office Engineering Drivers and Road Safety."

### Result of Essay Competition, 1965–66

A prize of £6 6s and an Institution Certificate have been awarded to the following competitor in respect of the essay named:

A. Richmond, Technical Officer, Oban. "Pulse-Code Modulation—With Some American Features."

Prizes of £3 3s each and Institution Certificates have been awarded to the following four competitors:

G. W. E. Gay, Technical Officer, Salisbury. "Installing a Combined 50-Point Line-Finder and Final-Selector Rack."

B. T. Boardman, Technical Officer, Liverpool. "An Outline of Computer Principles."

J. Gilliland, Technical Officer, Glasgow. "Great Oaks from Little Acorns Grow."

C. R. Hill, Technical Officer, Lancaster. "Work Controls or Work Execution."

Institution Certificates of Merit have been awarded to:

R. J. Waterhouse, Technical Officer, Central Training School. "Change into Top Gear."

A. G. Hickson, Technical Officer, Northampton. "Never a Dull Moment."

W. Findley, Technical Officer, Glasgow. "Telecommunications—Past and Futuristic."

P. J. Froude, Technical Officer, London Postal Region. "A Visit to the London Fire Brigade Headquarters."

E. Doylerush, Technical Officer, Conway. "An Introduction to Radio Astronomy."

The Council of the Institution records its appreciation to Messrs. W. A. Humphries, D. G. Jones and T. J. Rees, who kindly undertook to adjudicate upon the essays entered for the competition.

*N.B.—Particulars for the next competition, entry for which closes* 15 *January* 1967, *will be published later.*

S. Welch,
*General Secretary.*

### Additions to the Library

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

2838 *Tizard.* R. W. Clark (Brit. 1965).
The life of Sir Henry Tizard.

2839 *Automatic Transmissions.* R. F. Ansdale (Brit. 1964).
Gives an outline of the performance characteristics of the different types of automatic motor-car transmissions and their mode of operation.

2840 *Radio & TV Servicing* (63/64). J. P. Hawker and J. Reddihough (Brit. 1964).
Circuit diagrams and servicing instructions—1963–4 models.

2841 *Radio & TV Servicing* (64/65). J. P. Hawkes and J. Reddihough (Brit. 1965).
Circuit diagrams and servicing instructions—1964–65 models.

2842 *A Guide to the Engineering Properties of Iron Castings.* Joint Iron Council (Brit. 1963).
A brief reference book for engineers, designers, etc., providing summarized information on the properties of grey, malleable, nodular and other cast irons.

2843 *Audio-Visual Handbook.* R. Cable (Brit. 1965).
Describes what the various tools are, how they can be most effectively used and how the more expensive and complicated aural and visual aid equipment can be properly maintained.

2844 *Questions and Answers on Automobile Engines.* P. J. Unstead (Brit. 1965).
Deals with the principles, operation and servicing of automobile petrol engines.

2845 *Worked Examples in Electronics and Telecommunications. Vol.* 2. B. Holdsworth and Z. E. Jaworski (Brit. 1965).
Covers the syllabus of the London University part II degree course in electronics, part of part II in electrical theory and measurement, and a part of part III in electronics and telecommunications.

2846 *The Slide Rule.* R. Saffold and A. Smalley (Brit. 1962).
A programmed textbook covering the basic principles of the slide rule and showing how those principles are applied to practical problems in science, engineering, business and technology.

2847 *Newnes Complete Guide to the Miniature Camera.* T. L. J. Bentley (Brit. 1964).
An up-to-date and comprehensive guide.

2848 *Computers and Their Uses.* W. H. Desmonde (Amer. 1964).
Gives a glimpse into the essential characteristics of digital data processing machines and their uses—a general introduction for the intelligent layman or student.

2849 *Semiconductor Circuit Analysis.* P. Cutler (Amer. 1964).
Intended to develop the reader's ability to analyse and design transistor circuits; at a level appropriate to the training of engineering technicians or engineers whose primary concern is with practical applications.

2850 *Small-bore Heating and Hot-water Supply for Small Dwellings.* J. J. Barton (Brit. 1964).
Primarily a practical manual for those concerned with domestic central heating and hot-water supply.

2851 *Digital Computers in Action.* A. D. Booth (Brit. 1965).
An introduction to the digital computer and its programming for students who wish to acquire a knowledge of how computers can help in their own disciplines.

2852 *Reports and How to Write Them.* H. A. Shearing and B. C. Christian (Brit. 1965).
Aims at helping readers and writers to overcome the emotional and intellectual barriers that divide them.

2853 *Pick-ups; the Key to Hi-fi.* J. Walton (Brit. 1965).
Intended to help the non-technical enthusiast to choose a pick-up without relying on a manufacturer's competence or honesty—or even his own ears.

2854 *Understanding Lasers and Masers.* S. Leinwoll (Amer. 1965).
Describes, as simply as possible, what they are, how they work, what they do, and what they can be made to do.

2855 *Design and Construction of Transistor Superhets.* R. H. Warring (Brit. 1965).
Mainly from the practical angle.

2856 *The Electron in Electronics.* M. G. Scroggie (Brit. 1965).
Relates modern concepts to the things a student of electronics is likely to know already, and expresses them in familiar terms and symbols.

2857 *The Transistor.* J. Dosse (German 1964).
A clear and precise presentation; includes recent types of transistors.

2858 *Introduction to Congestion Theory in Telephone Systems.* R. Syski (Brit. 1960).
Presents the study of stochastic processes describing the passage of telephone traffic through a switching system, and introduces recent mathematical developments in the general congestion theory applicable to telephone traffic.

2859 *Fundamentals of Electricity.* J. B. Owens and P. Sanborn (Brit. 1965).
A Tutortext book designed to give a working knowledge of the important principles of electricity without using advanced theory or difficult mathematics.

2860 *The Odd Book of Data.* R. Houwink (Dutch 1965).
An effective way of helping the understanding of nature's unimaginable dimensions by way of comparisons or images which, in themselves, are more or less susceptible to the imagination.

2861 *Worked Examples in Electronics and Telecommunications, Vol.* 1. B. Holdsworth and Z. E. Jaworski (Brit. 1965).
Covers University of London part II degree course in electronics, a portion of the part II course in electrical theory and measurement, and a portion of the part III course in electronics and telecommunications; uses actual examination problems from the past few years.

2862 *Chunnel.* C. A. Pequignot (Brit. 1965).
Everyman's guide to the technicalities of building a channel tunnel.

2863 *Electricity and Magnetism.* M. Nelkon (Brit. 1965).
Deals mainly with the classical principles of electricity and magnetism to a G.C.E. Scholarship-level standard, and assumes Ordinary-level knowledge of the subject.

2864 *Domestic Small Pipe Heating.* H. W. Holmes and W. J. G. Langstaff (Brit. 1965).
Describes the complete design of a small-bore heating system, this being carried out in stages in the relevant chapters dealing with the various aspects of central-heating design work.

2865 *Field-Effect Transistors.* L. J. Sevin (Amer. 1965).
A text-book for practising electronic circuit designers.

2866 *Electric Lighting.* C. E. Gimson (Brit. 1962).
Tries to establish the principles of good lighting in a way that can be understood by the non-specialist.

2867 *Technical Maths, General Course, Pt.* 2. A. Geary, H. V. Lowry and H. A. Hayden (Brit. 1965).
Planned to meet the requirements of the new scheme for the training of technicians and technologists.

2868 *Galileo Galilei* (1561–1642). L. Geymonat (Amer./Ital. 1965)
A biography and enquiry into his philosophy of science.

2869 *Light and Sound.* M. Nelkon (Brit. 1965).
Deals with the principles to G.C.E. Advanced stage, or Intermediate standard, and assumes a first school-certificate knowledge of the subject.

2870 *Printing Telegraphy—A New Era Begins.* E. E. Kleinschmidt (Amer. 1965).
A resumé of the problems and the progress made towards today's achievements in the art of telegraphic communication.

2871 *Michael Faraday.* L. P. Williams (Brit. 1965).
A biography.

2872 *How to Design and Install Warm Air Heating.* D. Herbert (Brit. 1965).
Many will find the installation of warm-air heating within their capabilities when given advice such as in this book.

2873 *The Thyristor and its Applications.* A. Griffin and R. S. Ramshaw (Brit. 1965).
A general coverage of thyristors and their use in engineering today.

2874 *Transistor Pocket Book.* R. G. Hibberd (Brit. 1965).
Intended mainly for students and technicians; the treatment is kept reasonably free of mathematics, emphasis being on practical considerations.

W. D. FLORENCE,
*Librarian.*

# Regional Notes

**Midland Region**

## FLOODING IN TELEPHONE HOUSE, BIRMINGHAM

At 5.45 a.m. on 25 March 1966 the trunk test officer in the basement of Telephone House, Birmingham, observed water flowing from the ceiling. Simultaneously, in the repeater station on the floor above, an urgent alarm occurred on the Birmingham–Lichfield radio-link equipment used to feed the Midlands Independent Television Authority (I.T.A.) transmitter. When this alarm was attended it was found that water was streaming down through the racks of the radio-link equipment, having followed coaxial feeds from the floors above.

The source of water was quickly found to be on the third floor behind a locked door in an almost finished building extension not handed over to the Post Office. No key was available and the door was forced. The leak was due to a pulled tee joint in a 1 in. pipe. It proved necessary to turn off the main valve for the building to stop the leak.

Power was switched off apparatus which appeared to be wet, waterproof sheets were erected to cover apparatus and cables, the flood water was controlled and disposed of, damaged equipment and cables were located and subjected to drying-out operations, alternative service was given where possible, and, eventually, service restored.

With the exception of the failure of the Birmingham–Lichfield radio-link, loss of service was surprisingly small. Newhall non-director trunk exchange, on the second floor, lost no service. The repeater station, on the first floor, had 42 private circuits and six public circuits faulty, some of which where given alternative service. Central exchange, on the ground floor, lost all its junctions to Edgbaston, but they were restored by 10.30 a.m. the same day.

Very soon, after the flooding had been brought under control, steps were taken to provide alternative service for the Birmingham–Lichfield television radio link. An outside-broadcast radio link was started by rigging temporary aerials on the masts at Telephone House and Lichfield in snowstorm conditions. At the same time the I.T.A. were informed of the situation and were advised that the morning program would be lost. Two Associated Television (ATV) engineers set about providing a temporary radio link between Alpha Studios, Aston (connected to Telephone House by coaxial cable), and the Lichfield transmitter.

This attempt proved unsuccessful and, since the ATV aerial was in position first on the Lichfield mast, it was re-orientated to receive the signal being sent from the temporary Telephone House aerial. Thus, a link was provided and accepted at 1.55 p.m. to carry a program at 2.00 p.m. The Post Office aerial and receiver were then set up, and the program was taken from it at the first convenient program interval, to release the ATV equipment.

Meanwhile, work had been proceeding on the restoration of the permanent link. At 2.30 p.m. channel 2 was working, but it was decided to continue using the temporary link until the permanent one had proved stable. At 6.30 p.m. channel 2 failed, but was restored again at 7.00 p.m. On 26 March channel 2 was used to carry program, with the outside broadcast link as a stand-by. On 27 March at 8.00 a.m. channel 2 failed again, to be restored at 10.00 a.m. By 3.30 p.m. the same day all channels were fully restored.

Service since has been satisfactory, and the outside-broadcast link has been recovered.

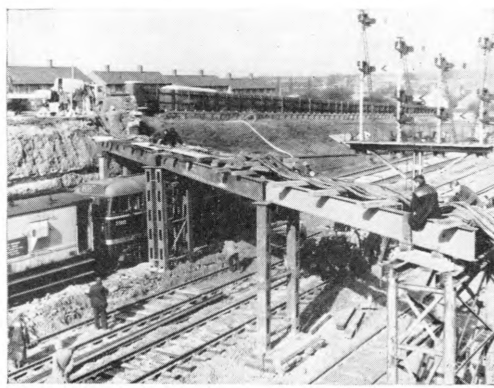
W.D. and S.S.P.M.

**London Telecommunications Region**

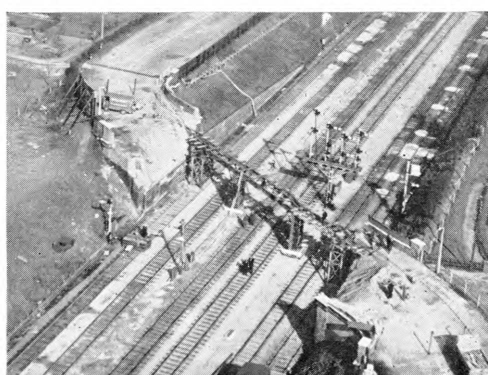
## COLLAPSE OF HATFIELD BRIDGE

A most unusual situation arose on Sunday, 20 February 1966, when the 116-year-old brick-built bridge known as Wrestlers Bridge, Great North Road, Hatfield, was reported to be collapsing. One of the three arches had started to crumble and a 3 ft dip in the road had appeared. All trains from King's Cross and all road traffic had to be stopped. There was also an immediate call for North Telephone Area engineering staff because nine Post Office cables, including the Cambridge–London No. 5, Hitchin–London No. 2, Baldock–Faraday, Faraday–Hitchin No. 1, Bishop's Stortford–Slough, and other smaller junction cables ran across the bridge. The seriousness of the situation from a Post Office point of view was soon realized, and staff from both maintenance and construction divisions responded quickly to calls for help.

The state of the bridge was such that it was completely unsafe for anyone even to walk on it, and the Railway Authority decided the bridge must be completely demolished in the interests of safety and to restore the rail services. They promised the Post Office every help after the demolition but said they could do nothing before; there was, therefore, no time to re-route the Post Office cables. This was an alarming situation as the bridge consisted of three arches over the five tracks of the railway and it seemed unlikely that the cables would survive when the bridge completely collapsed.



SUPPORT FOR POST OFFICE CABLES AFTER BRIDGE COLLAPSE



AERIAL VIEW OF CABLE SUPPORT

Hurried plans for interruption cables to be laid under the railway tracks were made; gangs were sent for and cable and jointers were mustered in numbers for the possible catastrophe.

A large iron ball was dropped by a crane, the first crumbling arch was broken, and within seconds the whole bridge swayed and crashed on to the railway—a most impressive sight. To the amazement of the Post Office staff their cables, complete with 9-way ducts, emerged swinging like a skipping rope. In view of the span of the bridge, this seemed miraculous. To assess the damage, the ducts were broken away and the cable inspected. The damage appeared slight, only one cable being badly gashed, and inspection of adjacent manholes revealed no broken joints, although all joints had been pulled some 2 ft through the manholes. Only 19 faults were reported and these were on the gashed cable.

During the following night and day hundreds of railway staff and contractors' staff were employed in clearing the rubble and restoring the tracks, and every co-operation was given to the Post Office. A temporary bridge of steel was erected for the Post Office cables by the Railway Authority. With two 30-ton steam cranes they then lifted the cables with great care and placed two rows of 18 in. rolled-steel joists across the verticals as shown in the photographs. Railway sleepers served as supports for the cables.

As soon as the temporary bridge was complete, the cable repairs were dealt with, and all cables were pressurized. Although interruption cables were laid under the railway track, they have not been needed. The temporary bridge has since been strengthened and the cables have been given further support, and can now remain in this state until a final decision on the rerouting or rebuilding of the bridge is made.

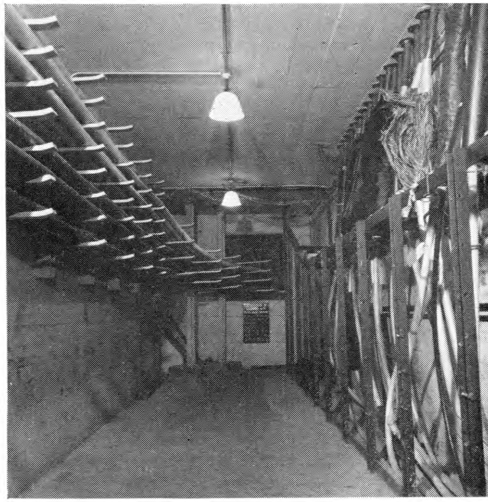
A.F.B.

## ELMBRIDGE EXCHANGE TRANSFER

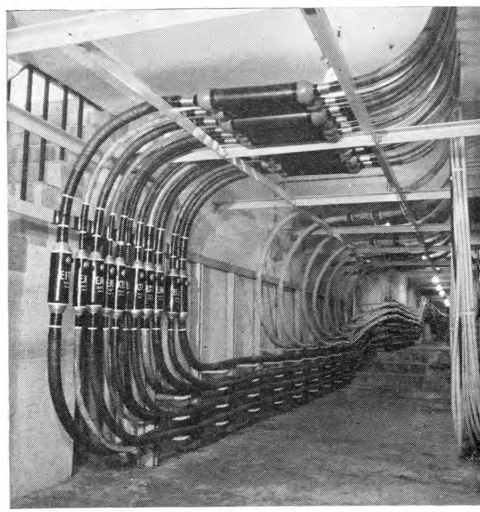
Preparations for the conversion of Elmbridge manual exchange to automatic working, and the provision of a second unit, involved a substantial extension to the building and to the cable chamber towards the rear. The new M.D.F. was placed at the rear of the building in line with the old frame, but growing towards it and the existing lead-in. It was first proposed to abandon the existing lead-in, construct a turning section at the rear end of the new cable chamber, and lay a 60-way lead-in along the entire side of the building to enable entering cables to run in the same direction as frame growth, in the conventional manner. However, as the existing 42-way lead-in was less than half full and several of the bores were occupied only by 800-pair and 1,000-pair local cables, it was decided to exploit the latest cable developments and techniques and continue using the existing arrangement.

For local cables, long-length 2,000-pair cables direct from the new M.D.F. to various points remote from the exchange were used, thus eliminating exchange manhole joints and the congestion of relatively small cables in the vicinity of the exchange. A change-over and teeing system, which would eliminate external teeing and would enable all cabling work to be fully completed 6 months before the transfer, was adopted, the only work to be done afterwards being the straightforward removal of the teeing cables from the new M.D.F. terminations. Local and junction cables were mixed in the lower half of the lead-in, and a planned cable-by-cable sequence of operations was adopted involving the recovery of each old cable in the lead-in before the next new cable was drawn in.

Ironwork was provided along the outside wall of the cable chamber to carry the 24 cables from the bottom four rows of the lead-in in a 3-deep, 8-high formation. Junction cables, in the four lower levels, were turned up along the wall at the end of the run, with air blocks in the vertical section below the conventional tacking bar and with the joints placed horizontally across the chamber on suitable overhead racking. Local cables were similarly swept upwards in the vertical plane with the air blocks in the horizontal overhead portion. When the bottom four rows of the lead-in are all taken into use in this way it is intended that cables from the top three rows should run along conventional ironwork on the other side of the cable chamber and turn up in the usual way. Should it ever be necessary to construct the deferred lead-in, the cables from it would thus pass over the three rows from the old lead-in and turn upwards from the fourth level of ironwork.



CABLE LEAD-IN AT ELMBRIDGE EXCHANGE SHOWING WALL CABLE SUPPORTS



DISTRIBUTION OF MAIN CABLES TO THE M.D.F.

Various methods of teeing were considered, and the method adopted was to run a 400-pair, 4 lb/mile conductor, polythene-insulated and polythene-sheathed cable from each vertical of the new M.D.F. to the corresponding enamelled, silk and wool insulated cable joint and change-over the silk and wool tails to these cables, thus freeing the old cables for recovery from the lead-in. These cables were taped and terminated on the permanent wiring tags of the new fuse mountings after the external cables had been terminated, each quad being passed through a collet inside the fuse mounting. It is anticipated that the use of the collets, together with a tape of contrasting colour, will enable each teeing quad to be positively identified, drawn forward, and disconnected without risk to the permanent cabling when the tees are removed.

The advantages of this turn-round and teeing system were that it permitted the continued use of the existing lead-in, despite the fact that the M.D.F. grows towards it, thus avoiding the considerable cost of the alternative lead-in and the associated manhole and duct works. There was also a substantial saving of extra cable which the alternative lead-in would have necessitated.

The teeing system, which was made possible only by the advent of the polythene cable used to link new terminations to the change-over point at the old joint, eliminated the fault liabilities and difficulties of the familiar teed joints and permitted a cable-by-cable sequence of operations. This enabled a tangled exchange manhole and lead-in arrangement to be converted to the ideal jointless set-up, a result which would have been impossible to achieve by the normal external teeing process.

This process enables all work to be completed long before the actual transfer, and permits easy removal of the tees with minimum disturbance or fault liability. The temporary change-over joints, between the silk and wool covered cable and the polythene cable, need no permanent closure. They can be taped up with polythene sheet, thus retaining easy access for fault location if required, and eliminating jointing costs. The system also lends itself to situations where old and new M.D.F.s are not adjacent, and it could be economically used, depending on the distance involved, for transfers between separate buildings.

W.E.W.

# Associate Section Notes

### London Centre

On 9 December a small party from the Central Committee visited Benenden Chest Hospital where Major E. B. M. Beaumont gave an illustrated talk on the Post Office Tower to patients and staff of the hospital. After the talk, which was very much appreciated by the audience, our party was shown round the hospital by the Matron. Unfortunately, we could only view the grounds from inside the building due to very heavy rain. Prior to our homeward journey we were entertained to tea by the Matron and one of the resident doctors, to whom we extend our thanks for a very enjoyable afternoon.

"Transistors and Their Application to Post Office Equipment" was the subject of our December lecture by Mr. J. A. T. French, Telephone Electronic Exchange Systems Development Branch, Engineering Department. Despite its common interest this talk was, unfortunately, not quite so well attended as it might have been.

For our January lecture we were again fortunate to secure the services of Mr. C. E. Clinch of the Main Lines Planning and Provision Branch, Engineering Department. The subject of this talk was "Public Mobile Radio Telephones." It proved most interesting, and a live demonstration via the normal network to a telephone in Fleet Building was a "first time" success.

Inspector P. Rowe of the City of London Police gave an excellent talk on "Modern Methods of Crime Detection" at our February meeting. Among the items of special interest were the make up of an Identikit picture and the display of locks of various types by Messrs Chubb & Sons. The result was a most enjoyable evening.

For a long time now we have been without a Librarian. If any member is interested in filling this post will he please contact his local representative for further details.

A very interesting lecture on sound reproduction was given by Mr. West of the Northern Polytechnic on 22 March. Mr. West illustrated his talk with a large assortment of equipment which ranged from one of the earliest moving-iron loudspeakers to a modern electrostatic model, and rounded the evening off by playing a 60-year-old phonograph. Mr. West was ably assisted by Mr. P. Clifford of Hawker Siddeley Co., Ltd.

On 26 April we were given a talk on routiners by Mr. R. J. Parker of Telephone Exchange Systems Development Branch, Engineering Department. Mr Parker explained the reasons for routiners and described, with the aid of slides, the changes in their make-up from inception up to the present day. Although mainly of interest to the maintenance man the talk proved quite enjoyable to those not quite familiar with this type of equipment.

"Operational Communications in the Automobile Association" was the subject of a talk by Mr. L. C. Standring (Senior Staff Officer of the A.A.) at our May meeting. Although rather poorly attended it was obvious from the number of questions that those who were present thoroughly enjoyed the evening.

Friday 20 May saw the final competition in the inter-Area Quiz. South-West Telephone Area beat West Telephone Area by 46 points to 41½ points. Our congratulations to both teams for a very good effort. We would like to thank our question master Mr. E. Hoare, the two adjudicators Mr. F. C. G. Greening and Mr. J. Prescott, the scorer Mr. G. M. Hitchman, and the timekeeper Mr. J. L. Mayle. We also wish to thank the Telephone Manager, South West Telephone Area for allowing us the use of the accommodation. The South West team will now represent the London Telecommunications Region against the Home Counties Region when the competition for the Inter-Regional Trophy takes place at a later date.

Visits this past session have been made to H. M. Dockyard, Portsmouth, Steward & Lloyds Steelworks, Corby and Southampton Docks. All the visits proved most enjoyable and, although we travelled in rain (snow as well when we went to Corby) part of the time, the actual visiting times were quite dry. Our sincere thanks to our hosts on these memorable occasions.

R.W.H.

### Stoke-on-Trent Centre

In the 1965–66 session we lost two more members of the committee on promotion to A.E.E., Mr. C. Bennion and Mr. A. P. Gee. We thank them for their work in the Centre, and offer them our best wishes for the future.

In his report at the annual general meeting, held on 21 April, the Chairman, Mr. J. A. Hart, remarked on the poor attendance at Centre lectures, despite the fact that all the speakers were distinguished in their subjects. Interest in the *P.O.E.E. Journal* continued to grow, he added, there now being a total of 175 members receiving copies.

Mr. Hart then introduced our new Telephone Manager, Mr. K. Gray, who generously accepted the presidency of the Centre.

The following lectures were given: "Subscribers' Telephone Instruments—Some Possible Future Developments" by Mr. T. C. Harding; "Character Recognition" by Dr. A. W. M. Coombes; "Some Problems of STD Working in Long-Distance Area" by Mr. F. C. Gould-Bacon; "Hydro-Electric Power in the Highlands—Recent Developments to Minimize Interference with Telephone Circuits" by Mr. J. Brown; "Program Planning and Providing Local Line Plant" by Mr. W. H. Dolan; and "Oil-Fired Heating" by Mr. P. E. Maddox. The Committee are very grateful to these officers and thank them for their visits.

The Centre is also indebted to the Principal, Centre Training School, for his kindness in permitting us to have the use of lecture aids.

The following officers were re-elected to serve with the President for the 1966–67 session: *Chairman:* Mr. J. A. Hart; *Vice-Chairman:* Mr. A. E. Fisher; *Secretary:* Mr. S. P. Hancock; *Assistant Secretary:* Mr. K. Bevington; *Treasurer:* Mr. E. A. Hudson; *Librarian:* Mr. E. J. Foden; *Committee:* Messrs C. Winfield, W. D. Paterson, W. Roberts and C. R. Head; *Auditors:* Messrs J. T. Yates and B. Colclough.

S.P.H.

**Exeter Centre**

The 1965–66 session has continued to be successful; the average attendance at meetings has been 53.

This increase reflects the keen and enthusiastic support of the officers and committee, and the Centre is indebted to them for their efforts.

The January meeting took the form of a visit to the laboratories of the Marine Biological Association of the United Kingdom at Plymouth. This event was particularly enjoyable and undoubtedly a complete success. The introduction of this type of meeting into the winter program is more than justified. On this visit, an introductory talk by the Director, Dr. W. J. Smith, was followed by two films on the work of the laboratory and a tour of the laboratories to see the research in progress. Afterwards, over coffee we were able to talk to members of the scientific staff.

In the past, visits of this type have formed part of the summer session and winter sessions have mainly been confined to technical papers. It is the intention of the committee to continue to include more non-technical papers and visits in the winter program, and it is considered that this will do much to increase attendance at meetings.

Another departure from tradition this year was a quiz held at the Royal Seven Stars Hotel, Totnes, when a team from Torquay pitted their wits against Exeter. Exeter won a closely fought battle by 39½ points to 36. The event, while not approaching the standard of "University Challenge," was quite successful thanks to the sporting participation of both teams, to Mr. E. H. K. Brown, who was question master and adjudicator, and to Messrs Powlesland and James, who were score and time keepers. A return match is planned for the coming winter and will be held at either Newton Abbot or Dawlish.

The last event of this session was a paper entitled "Exchange Contract Delays" given by Mr. H. J. Thurlow, of Exchange Equipment and Accommodation Branch, Engineering Department. Whatever members considered to be the reasons for delays in the contract program, one cannot help feeling that the Post Office must accept more blame than has hitherto been apportioned to them, and the speaker spent considerable time explaining various possibilities to alleviate the difficulties involved in assuring the completion of exchange contracts "on time." Question time heralded a barrage of opinion and the intervention of the secretary halted proceedings 30 minutes after the scheduled finishing time.

T.F.K.

**Bournemouth Centre**

During the past three months the activities of Bournemouth Centre have been confined mainly to two events.

Firstly, we were guests of Southampton Centre when we heard the paper "Computers and Their Use in the Post Office" by Mr. C. A. May, Organization and Efficiency (Maintenance and Computers) Branch, Engineering Department. This was an interesting and informative paper excellently presented.

Secondly, we were conducted round the British Aircraft Corporation (B.A.C.) production line for the B.A.C. one-eleven aircraft at Hurn Airport. This again was a very interesting evening, enjoyed by all who attended.

R.A.W.

**Swindon Centre**

The 1966 program commenced with a film show in January, and in February a talk was given by Mr. L. R. Page of the Government Communication H.Q., Cheltenham, on "Computers." Both of these meetings were reasonably well attended.

On Friday 18 March a joint meeting with Gloucester Centre was held at Circenester to hear a talk on "The National Microwave Radio Network" given by Mr. L. R. Mills, Inland Radio Planning and Provision Branch, Engineering Department. This was very interesting and with the attendance being just over 60 members and friends, it proved once again the success of these joint meetings. Maundy Thursday afternoon, a visit by 15 members was made to the B.B.C. Bristol.

W.H.B.

**Colchester Centre**

The year 1965–66 has been a very active one, there having been a total of 16 meetings with invitations to two more from the Ipswich Centre.

The summer program included visits to three engineering works and two connected with aircraft.

The winter program was made up of eight meetings, the average attendance at which was 39. The subjects covered by these meetings, included: "Prospecting for Oil," "The Ordnance Survey," "Stereophonic Music," "Motor Rallying," "The Post Office Tower," and "Fire Fighting."

It was decided during the year to provide members with individual notices of all meetings, and to use a distinctive colour. This has proved to be appreciated by members.

There have been no changes in committee members, but there has been a very welcome rise in the Centre's membership: it has increased during the year by 51 to reach the record total of 270. With this membership, and the excellent permanent accommodation that we now enjoy in the new Telephone Manager's Office, the Centre should flourish very well indeed.

The committee have considered disbanding the Centre's library, the contents of which are very little used. It was thought that perhaps its existence was too little known. Members were therefore circulated with a list of contents, but there was no resultant change in the lending rate. Disbandonment has, however, been deferred indefinitely.

Also discussed was the possibility of holding an annual social evening for Colchester Centre. All members were asked for comment. Only 12 questionnaires were returned: ten for and two against. The idea was therefore dropped through lack of interest.

Car-rally trophies were bought during the year, this being a proposal that was put to the vote at the last annual general meeting. The Centre's car-rally section has had an active season, presentation of trophies to successful contestants having been recorded by the local press.

A presentation of a record token was made to Mr. J. Shanks, in recognition of the services that he has rendered as secretary in the past.

The various items of projection equipment that we use throughout the winter program have been loaned this year by the North-East Essex Technical College, Colchester, and the Colchester Youth Employment Bureaux.

The last item worthy of record in this report concerns refreshments, at winter meetings. Mrs. M. H. Martin, who for many years has cut sandwiches and dispensed tea, has had to retire. Our difficulty in finding a permanent replacement has led to the introduction of a lighter form of refreshment.

J.A.H.

**Cambridge Centre**

The Centre was reformed in September 1965 after a lapse of over 11 years. The closure of the Centre in 1954 was mainly due to the inability to find a Secretary and it seemed that the same problem would arise on this occasion. However, it was resolved by the appointment of joint Secretaries until such time as the Centre found its feet again. At present there are 90 members of the Centre.

The following officers were elected for the 1965–66 session: *President:* Mr. A. E. Paterson, Area Engineer; *Chairman:* Mr. L. A. Salmon; *Vice-Chairman:* Mr. J. Wearn; *Secretaries:* Mr. R. J. Farrington and Mr. R. G. Greenwood; *Treasurer:* Mr. C. F. Nunn; *Committee:* Messrs T. Yates, R. Stewart, J. Norman and C. Thorogood.

We are particularly pleased to welcome Mr. Paterson after his services to the Stoke-on-Trent Centre.

In November, 45 members visited the Ely Sugar Factory, and this was followed in December with a talk on "Regional Problems" by Mr. A. H. C. Knox, Chief Regional Engineer, Home Counties Region. This took the form of a joint meeting with the Bishop's Stortford Centre, attended by over 40 members.

After Christmas we enjoyed a talk on "Satellite Communications" by Mr. H. E. Pearson, Space Communications System Branch, Engineering Department.

In February, 30 members had a conducted tour of the local newspaper works, The fifth meeting in March took the form of a talk on "External Work in Canada and U.S.A." by Mr. W. C. Ward, External Plant and Protection Branch, Engineering Department, and a demonstration of jointing machines by his assistant, Mr. P. Self. This should have been followed in April by a visit to Ford Motors at Dagenham, but unfortunately our hosts were forced to put off the visit until a later date due to major alterations at the works. We were, however, able to send two parties of 40 members in June.

Our main problem during the session has been financial. At our inaugural meeting it was decided to collect 2d. per week from members, this to be deducted from pay at source. Unfortunately, the rules of the Institution only permit the deduction of 1d. per week and despite numerous attempts to have the higher amount deducted locally we were unsuccessful. The situation has now been resolved by collecting 4s. per half year directly from the members. This method will continue until such time as the Associate Centres of the Institute can increase their rate of deduction from pay which we hope will be in the not too distant future.

At the annual general meeting in April, Mr. R. J. Stewart was elected joint secretary to replace Mr. R. G. Greenwood who has recently been promoted. All other officers were re-elected and the vacancy on the committee was filled by Mr. R. F. Halls. An additional committee member Mr. P. W. Gedge was also elected.

This has been a very successful and enjoyable first session and we look forward to many more interesting talks and visits in the future.

R.A.F.

**Middlesbrough Centre**

The annual general meeting of the Centre was held on Tuesday, 5 April, and the following officers were elected for the coming year: *Chairman:* Mr. E. E. Sparkes; *Secretary:* Mr. K. Whalley; *Treasurer:* Mr. R. G. Inns; *Librarian:* Mr. D. A. Pratt; *Assistant Secretary:* Mr. R. D. Parvis; *Committee:* Messrs K. Roe, R. Vipond, R. Clive and D. Campbell.

At the conclusion of the meeting four films, obtained from the Petroleum Film Bureau, were shown, which helped to make the evening an enjoyable occasion.

During the coming session it is hoped to hear an address by Dr. Harding of the British Association for the Advancement of Science, and to visit the planetarium at South Shields.

D.C.

**Aberdeen Centre**

The attendance at our first meeting of 1966 broke all records when 68 members and guests were present.

It was a double occasion as, first, we were honoured by the presence of Mr. H. J. Revell, Chief Regional Engineer, Scotland, who presented the 1965 I.P.O.E.E. Paper Award Certificates to Mr. I. M. Hogg, Aberdeen Centre, and Mr. A. J. Christie, Inverness Centre. Secondly, we had great pleasure in welcoming Mr. S. C. Gordon, Research Branch, to Aberdeen to give his lecture "Radio Communication Satellites," which he explained with the use of film slides and a sound film. Some of the features which he dealt with were the differences in orbital paths of Telstar and Earlybird, construction of the new aerial at Goonhilly, maser amplifiers, frequencies used, etc. Mr Gordon then demonstrated by using a tape recording, the effect of the delay in transmission which would occur on a global satellite system of the Earlybird type. Mr. Gordon then answered many questions concerning, among others, the advantages and disadvantages of parabolic and horn aerials and how a maser amplifier works. A thoroughly stimulating evening and decidedly the best meeting we have had for some time.

The subject of our February meeting was "CODA" which was given by one of our members, Mr. A. Webster, Aberdeen. The speaker dealt with the recently-installed Aberdeen–Peterhead "CODA" system. Using simple block schematic diagrams Mr. Webster explained the A and B terminals, intermediate repeaters and power-feeding arrangements. During question time Mr. Webster ably dealt with many questions which included power feeding, alarm circuits and routines, intermediate repeater boxes and faults experienced. An informative and constructive talk which was enjoyed by all present.

On Wednesday 2 March a party of our members visited the chemistry department of Aberdeen University. In this, the second largest department, the party were shown the students' laboratories and also a number of research projects. The research project which was particularly interesting was the application of electronics to the solution of problems in analytical chemistry. A very enjoyable and interesting evening was had by all.

Our March meeting consisted of a conducted tour of the postal-mechanization equipment in Aberdeen Head Post Office. Mr. R. Sandison and Mr. D. McPherson, two of our members, explained the mechanical, electrical and operational features of the equipment. Although the attendance at this meeting was very disappointing those present enjoyed a very informative evening.

G.D.A.

**Dundee Centre**

A paper on "S.T.D. at U.A.X.s" read by Mr. D. L. Miller (Associate Section Member) and Mr. L. E. Pinner (Senior Section Member) brought to a close a very successful program in the Dundee Centre. Our annual general meeting is to follow shortly when it is hoped that a large number of our new members will be present to bring new ideas to our notice. The committee wishes to thank members and friends for their continued support.

R.T.L.

**Edinburgh Centre**

The 1965–66 session concluded with our annual general meeting and dinner, which was held in the Iona Hotel. 35 members attended and enjoyed the meal which began the evening's proceedings. After the meal the annual general meeting was called to order, and the secretary's report on the past session was heard, followed by the treasurer's report and financial statement, the latter having been audited by Mr. K. Scott and Mr. J. Heatley.

The following office bearers were elected for the 1966–67 session: *Chairman:* Mr. R. P. Donaldson; *Secretary:* Mr. J. A. Coghill; *Assistant Secretary:* Mr. G. Robertson; *Treasurer:* Mr. R. Elder; *Librarian:* Mr. T. Woolard; *Committee:* Messrs M. K. Finland, D. Stenhouse, R. Renton, I. Finlayson, I. A. Barkley and J. Duncan.

### Glasgow Centre

Glasgow Centre has just completed another successful session. The secretary, Mr. R. M. Fraser, in his annual report to the Centre stated that membership now stands at 530 and recruitment is going forward in a most satisfactory manner.

The 1965–66 program has been much appreciated by the members and was planned to cover a wide range of Post Office activity. The second half of the session commenced with Mr. T. C. Harding, Subscribers' Apparatus and Miscellaneous Services Branch, Engineering Department, presenting his paper on the "Future Developments in Subscribers' Apparatus." This was a most interesting lecture which was excellently illustrated by slides. On display were a selection of telephones and associated equipment, many of which were on preliminary field trials in London. The members present were most impressed by the rapid developments and new techniques in this branch of the service, a fact which is not always appreciated by the engineers in the field.

The speaker at the February meeting was Mr. C. A. May, Organization and Efficiency (Maintenance and Computers) Branch, Engineering Department. His subject was "Computers and Their Uses in the Post Office." This lecture was an instant success with members; the subject was dealt with in a most clear, concise and expert manner, and from the information available it is evident that we are living in the computer age, and that the Post Office is amongst the leading organizations in this country in the use of the computer and ancillary equipment to bring about an increase in productivity and efficiency.

The final lecture in the session was presented by Mr. F. Haworth, Glasgow Telephone Area, who spoke on "External Construction Development." The subject embraced many facets of external work, a field which is large and comprehensive and is one of the most essential aspects of the telephone service. Mr. Haworth dealt with the theoretical and practical problems involved in external work, together with many current developments. Safety precautions were stressed as essential, and various mechanical aids used by the Post Office were shown by slides. The development of plastics has played a large part in recent advances in external work; examples are the new polythene ducts and cables which are now extensively used in subscribers' distribution. Pressurization of cables was also explained in some detail.

The Glasgow Centre is holding a local essay competition to stimulate interest in the Associate Section activities and it is hoped to give a full report on the result of the competition in due course.

R.M.F.

### Inverness Centre

The talk "Communication Satellites" by Mr. S. C. Gordon of Research Branch completely captivated the large audience at our January meeting. Questions were many and varied, and time was all too short.

On 17 March the members visited the I.T.A. transmitter at Mount Eagle, where they were shown round the station by the permanent staff.

W.C.

### Ayr Centre

At the annual general meeting of this Centre in June 1965 tribute was paid to Messrs A. Edgar and J. Halliday for their very valuable services over 10 and 8 years, respectively, as chairman and secretary. The 1965–66 session of this Centre opened in October with a talk on "Air Traffic Control" by Mr. D. MacPherson. The work of the Air-Traffic Approach Controllers was covered very fully and navigational procedures and radio aids were discussed at some length. In November a visit was paid to Kilmarnock automatic exchange and our members had the opportunity of observing new equipment techniques, including S.T.D., and transistor-type amplifier equipment.

Our January meeting, held at Kilmarnock, consisted of a talk on the subject "Iron and Steel Production," given by Mr. J. Evans, Scotland West Area. Mr. Evans spoke firstly of the historic methods of iron production, and then passed on to modern blast-furnace techniques, the latter being described in some detail. The Bessemer process, still in use for certain applications, was also fully described. A period of lively discussion followed.

In February Mr. W. N. Shannon spoke to us on the subject "Microwave Radio Links." The problems relating to the installation and maintenance of microwave stations, particularly under adverse weather conditions, were noted with great interest by our members. The attendance on this occasion was encouraging indeed.

Our March meeting, held in Kilmarnock, was a talk on the subject "The Post Office: Past, Present and Future" by Mr. W. T. Warnock, placing emphasis on the telecommunications aspect, and tracing Post Office progress, from early beginnings to the nationalization of the National Telephone Co., Ltd. followed by the first steps in automation. Present Post Office activities and policies were then discussed. Considerable interest was shown in the future plans for the development of the telephone service to the outer isles.

A.B.

### Central Training School Centre

The year has been fairly active and well supported by students and staff members. Attendances at lectures have been surprisingly high, an average of between 70–80.

The program consisted of the following four lectures: "Subscribers' Apparatus," by Mr. T. C. Harding, Subscribers' Apparatus and Miscellaneous Services Branch, Engineering Department; "Stereo Reproduction," by Mullard, Ltd.; "Colour Photography," by Kodak, Ltd.; "Pulse-Code Modulation," by S.T.C., Ltd.

Five visits were made during the session to the Royal Ordnance Factory, Swynnerton, a Cunard liner, the Mersey Tunnel control room, Port Sunlight, and Rolls-Royce, Ltd.

At the annual general meeting held on Tuesday 5 April the following are elected: *Hon. Chairman:* Mr. T. K. Bellew; *Vice-Chairman:* Mr. F. Clayton; *Secretary:* Mr. Wm. Paterson; *Treasurer:* Mr. A. Hughes; *Librarian:* Mr. C. Wright; *Committee:* Messrs Brunning, Nicholson, Taylor, Hart and Heggie; *Auditors:* Mr. R. S. Freestone and Mr. D. Awty.

No program has been fixed for the next year, but all attending the school on courses should watch the notice boards or contact any of the committee. Your support at the meetings is a great encouragement to, and is appreciated by, the committee. Lectures are normally held on Tuesday evenings.

W.P.

# Staff Changes

**Promotions**

| Name | Region, etc. | Date |
|---|---|---|
| *Staff Engineer to Assistant Engineer-in-Chief* | | |
| Freebody, J. W. H. | E.-in-C.O. | 1.5.66 |
| *Regional Engineer to Staff Engineer* | | |
| Horne, F. A. | L.T. Reg. to E.-in-C.O. | 1.4.66 |
| *Senior Executive Engineer to Assistant Staff Engineer* | | |
| Spinks, J. | E.-in-C.O. | 28.2.66 |
| Barton, R. W. | E.-in-C.O. | 11.3.66 |
| Holmes, D. | Mid. Reg. to E.-in-C.O. | 1.2.66 |
| *Area Engineer to Regional Engineer* | | |
| Rance, J. W. | Mid. Reg. | 10.2.66 |
| *Executive Engineer to Area Engineer* | | |
| Robinson, R. A. | H.C. Reg. | 18.2.66 |
| Sharp, J. H. W. | Scot. | 3.3.66 |
| *Executive Engineer to Senior Executive Engineer* | | |
| Moore, M. B. | E.-in-C.O. | 10.2.66 |
| Harris, J. L. | E.-in-C.O. | 10.2.66 |
| Haward, J. W. G. | L.T. Reg. to E.-in-C.O. | 10.2.66 |
| Pooley, A. B. | E.T.E. | 10.2.66 |
| Freere, S. E. | Mid. Reg. | 10.2.66 |
| Gore, J. S. | E.-in-C.O. | 23.2.66 |
| Meatyard, L. R. | E.-in-C.O. | 28.2.66 |
| Cunningham, J. F. | N.W. Reg. | 10.2.66 |
| Marsh, H. | E.-in-C.O. | 3.3.66 |
| Sudell, R. A. | E.-in-C.O. | 3.3.66 |
| Palmer, E. C. | L.P. Reg. | 25.3.66 |
| Marklew, S. S. P. | Mid. Reg. | 3.3.66 |
| Parsons, A. P. | Mid. Reg. | 3.3.66 |
| Coshan, D. C. M. | Mid. Reg. | 18.2.66 |
| *Executive Engineer (Open Competition)* | | |
| Gones de Mesquita, D. J. | E.-in-C.O. | 14.3.66 |
| *Assistant Executive Engineer to Executive Engineer* | | |
| Milne, A. O. | E.-in-C.O. | 2.2.66 |
| How, R. C. | E.-in-C.O. | 2.2.66 |
| Forey, W. A. | E.-in-C.O. | 2.2.66 |
| Hill, H. | L.T. Reg. | 23.2.66 |
| Sanders, F. S. B. | L.T. Reg. | 23.2.66 |
| Strevens, R. E. | L.T. Reg. | 23.2.66 |
| Stanley, E. R. | L.T. Reg. to E.-in-C.O. | 23.2.66 |
| Young, S. A. | E.-in-C.O. | 23.2.66 |
| Smith, K. W. | E.-in-C.O. | 8.3.66 |
| Kinston, F. | Mid. Reg. | 1.4.66 |
| Franklin, L. E. | Mid. Reg. | 1.4.66 |
| Miles, B. T. W. | E.T.E. | 1.4.66 |
| Bearon, J. W. | Mid. Reg. | 1.4.66 |
| Beeston, B. | L.T. Reg. | 1.4.66 |
| Kennett, P. | L.T. Reg. | 1.4.66 |
| Thompson, C. H. | Mid. Reg. | 1.4.66 |
| Smith, H. O. J. | E.-in-C.O. | 1.4.66 |
| Walters, R. C. | L.T. Reg. | 1.4.66 |
| Stokes, J. W. | N.W. Reg. | 1.4.66 |
| Watling, A. G. | H.C. Reg. | 1.4.66 |
| Chatfield, R. A. | Mid. Reg. to E.-in-C.O. | 1.4.66 |
| Hubbard, E. W. C. | E.-in-C.O. | 1.4.66 |
| Hunt, H. | Mid. Reg. | 1.4.66 |
| Simmons, H. H. | H.C. Reg. | 1.4.66 |
| Kershaw, R. J. | E.-in-C.O. | 1.4.66 |
| Roberts, S. | N.W. Reg. | 1.4.66 |
| Hunt, C. H. | Mid. Reg. | 1.4.66 |
| Freeman, S. L. V. | H.C. Reg. | 1.4.66 |
| Anderson, W. R. | Mid. Reg. | 1.4.66 |
| Jarvis, E. G. | E.-in-C.O. | 12.4.66 |
| MacBride, J. M. R. | Scot. | 18.4.66 |
| Felton, N. R. | N.W. Reg. | 1.4.66 |
| Sheppard, H. G. | E.-in-C.O. | 7.4.66 |
| *Inspector to Assistant Executive Engineer* | | |
| Gamblin, E. C. G. | S.W. Reg. | 10.1.66 |
| Shearer, J. M. | Scot. | 23.12.65 |

| Name | Region, etc. | Date |
|---|---|---|
| *Inspector to Assistant Executive Engineer—continued* | | |
| Neill, H. W. | N.I. | 4.1.66 |
| Burnett, J. T. | Scot. | 31.1.66 |
| Brown, J. V. | W.B.C. | 22.2.66 |
| Gibb, A. C. | Scot. | 24.1.66 |
| Bowcock, C. | Mid. Reg. | 2.2.66 |
| Patterson, A. | N.I. | 18.2.66 |
| George, R. W. | L.T. Reg. | 28.2.66 |
| Groom, J. H. | H.C. Reg. | 23.3.66 |
| Wickendon, C. D. | H.C. Reg. | 23.3.66 |
| Alexander, J. F. | H.C. Reg. | 23.3.66 |
| Tombs, H. B. | H.C. Reg. | 23.3.66 |
| Pike, J. | H.C. Reg. | 23.3.66 |
| Foot, C. J. | H.C. Reg. | 23.3.66 |
| Gilbert, K. | H.C. Reg. | 23.3.66 |
| Seymour, W. H. | S.W. Reg. | 8.3.66 |
| Sullivan, J. P. | L.T. Reg. | 11.3.66 |
| Howard, B. S. | L.T. Reg. | 11.3.66 |
| Parker, T. L. | L.T. Reg. | 11.3.66 |
| Macaulay, L. W. | L.T. Reg. | 11.3.66 |
| *Technical Officer to Assistant Executive Engineer* | | |
| Moon, B. B. | E.-in-C.O. | 7.2.66 |
| Edwards, P. J. | W.B.C. | 3.1.66 |
| Thomson, R. S. | Scot. | 4.1.66 |
| Adams, J. E. | S.W. Reg. | 3.1.66 |
| Edmunds, T. C. | W.B.C. | 31.1.66 |
| Griffiths, J. H. | Mid. Reg. | 17.12.65 |
| Hennessy, F. M. | S.W. Reg. | 3.1.66 |
| Bayliss, G. E. | E.-in-C.O. | 24.1.66 |
| Woods, E. F. J. | E.-in-C.O. | 24.1.66 |
| Crellin, R. J. | E.-in-C.O. | 24.1.66 |
| Bewley, A. W. | E.-in-C.O. | 24.1.66 |
| Manson, S. | Scot. | 1.1.66 |
| Bain, R. W. W. | Scot. | 14.1.66 |
| Smith, D. | N.E. Reg. | 18.1.66 |
| Cole, J. B. | N.E. Reg. | 18.1.66 |
| Horrocks, J. M. | N.W. Reg. | 3.1.66 |
| Flynn, M. W. | N.W. Reg. | 3.1.66 |
| Holden, D. | N.W. Reg. | 10.1.66 |
| Dessent, W. B. | W.B.C. | 21.1.66 |
| Ridsdale, G. T. | N.E. Reg. | 18.1.66 |
| Burton, J. W. | L.T. Reg. | 21.1.66 |
| Booker, C. P. | E.-in-C.O. | 24.1.66 |
| Finlay, D. H. E. | E.-in-C.O. | 24.1.66 |
| Dring, R. P. | E.-in-C.O. | 31.1.66 |
| Burdett, R. A. | N.W. Reg. | 24.1.66 |
| Smith, G. | N.W. Reg. | 17.1.66 |
| Eveleigh, G. A. | N.W. Reg. | 17.1.66 |
| Taylor, V. N. | L.T. Reg. | 2.2.66 |
| Stanway, H. E. | Scot. | 10.1.66 |
| Fisher, J. D. | Scot. | 17.1.66 |
| Hinman, J. W. B. | Mid. Reg. | 2.2.66 |
| Hurrell, A. V. | Mid. Reg. | 2.2.66 |
| Lee, B. | Mid. Reg. | 2.2.66 |
| Davies, E. | N.E. Reg. | 16.2.66 |
| Arthur, R. J. G. | Scot. | 7.2.66 |
| Kynoch, J. S. | Scot. | 7.2.66 |
| Spraggs, R. J. | S.W. Reg. | 3.2.66 |
| Judd, A. F. | S.W. Reg. | 14.2.66 |
| Wilkins, J. S. | S.W. Reg. | 3.2.66 |
| Elkins, D. H. V. | S.W. Reg. | 3.2.66 |
| Marshall, A. C. | S.W. Reg. | 3.2.66 |
| Smele, K. G. | S.W. Reg. | 3.2.66 |
| Pledger, S. F. | S.W. Reg. | 3.2.66 |
| Wright, N. W. | S.W. Reg. | 3.2.66 |
| Hodges, C. S. | E.-in-C.O. | 21.2.66 |
| Darby, K. W. | E.-in-C.O. | 21.2.66 |
| Blundell, F. M. | L.P. Reg. | 28.2.66 |
| Stapples, W. C. | L.T. Reg. | 28.2.66 |
| Evans, E. | L.P. Reg. | 28.2.66 |
| Wetherall, W. B. | L.P. Reg. | 28.2.66 |
| Campbell, M. L. | L.T. Reg. | 28.2.66 |
| Davies, V. J. | L.P. Reg. | 28.2.66 |

*Technical Officer to Assistant Executive Engineer—continued*

| Name | Region, etc. | Date |
|---|---|---|
| Smith, F. A. J. | L.T. Reg. | 28.2.66 |
| Morris, J. R. | L.T. Reg. | 28.2.66 |
| Woledge, D. C. W. | L.P. Reg. | 28.2.66 |
| Mahoney, M. C. | L.P. Reg. | 28.2.66 |
| Rossin, L. J. | L.P. Reg. | 28.2.66 |
| Hill, P. | N.E. Reg. | 16.2.66 |
| Bartlett, S. T. | Mid. Reg. | 22.2.66 |
| McGillivray, E. | Scot. | 6.9.65 |
| Balloch, J. A. | Scot. | 6.9.65 |
| McAllister, J. | Scot. | 3.8.65 |
| Paton, J. D. | Scot. | 23.8.65 |
| Cunningham, C. S. | Scot. | 27.9.65 |
| Dixon, J. M. | Scot. | 27.9.65 |
| Moran, J. J. | Scot. | 2.9.65 |
| McTavish, G. | Scot. | 25.10.65 |
| Irvine, R. B. | Scot. | 21.3.66 |
| Thompson, A. | N.W. Reg. | 21.3.66 |
| Brown, R. | Scot. | 17.1.66 |
| Foard, T. S. | Scot. | 10.1.66 |
| Harris, R. L. | Scot. | 17.1.66 |
| Appelbe, G. W. | Scot. | 31.1.66 |
| Robinson, M. | S.W. Reg. | 7.3.66 |
| Wheeler, M. | S.W. Reg. | 21.3.66 |
| Westman, A. D. | N.E. Reg. | 16.3.66 |
| Fraser, T. A. | Scot. | 7.2.66 |
| Anderson, M. F. | Scot. | 7.2.66 |
| Tanner, D. M. G. | S.W. Reg. | 22.2.66 |
| Sach, F. A. | H.C. Reg. | 23.3.66 |
| Beddis, R. F. J. | H.C. Reg. | 23.3.66 |
| Johnston, A. E. F. | H.C. Reg. | 23.3.66 |
| Padbury, A. P. | H.C. Reg. | 23.3.66 |
| Newton, E. V. | H.C. Reg. | 23.3.66 |
| Walker, R. A. | H.C. Reg. | 23.3.66 |
| Manning, R. C. | H.C. Reg. | 23.3.66 |
| Hughes, R. A. | H.C. Reg. | 23.3.66 |
| Smith, C. H. S. | H.C. Reg. | 23.3.66 |
| Dent, E. H. | H.C. Reg. | 23.3.66 |
| Leake, M. I. | H.C. Reg. | 23.3.66 |
| Toms, G. G. | H.C. Reg. | 23.3.66 |
| Bailey, E. W. | H.C. Reg. | 23.3.66 |
| Clipsham, A. G. | H.C. Reg. | 23.3.66 |
| Chitty, R. A. | H.C. Reg. | 23.3.66 |
| Winn, R. W. | H.C. Reg. | 23.3.66 |
| Cant, F. C. A. | H.C. Reg. | 23.3.66 |
| Johnston, W. | Scot. | 28.2.66 |
| Allen, R. | H.C. Reg. | 23.3.66 |
| Valentine, J. | H.C. Reg. | 23.3.66 |
| Phillips, J. | H.C. Reg. | 23.3.66 |
| Bunce, A. | H.C. Reg. | 23.3.66 |
| Simpson, J. | H.C. Reg. | 23.3.66 |
| Piddock, J. | H.C. Reg. | 23.3.66 |
| Delves, D. W. | H.C. Reg. | 23.3.66 |
| Hall, C. R. | H.C. Reg. | 23.3.66 |
| Ellis, G. G. | H.C. Reg. | 23.3.66 |
| Bratton, V. F. | H.C. Reg. | 23.3.66 |
| Sturtivant, G. A. W. | H.C. Reg. | 23.3.66 |
| Tooth, C. | H.C. Reg. | 23.3.66 |
| Lawrence, D. J. E. | H.C. Reg. | 23.3.66 |
| Glover, M. J. | H.C. Reg. | 23.3.66 |
| Smith, R. N. | H.C. Reg. | 23.3.66 |
| Brice, E. G. | H.C. Reg. | 23.3.66 |
| Taylor, B. W. | H.C. Reg. | 23.3.66 |
| Richards, E. | H.C. Reg. | 23.3.66 |
| Maslin, K. J. | H.C. Reg. | 23.3.66 |
| Clarke, B. C. A. | H.C. Reg. | 23.3.66 |
| Lewis, D. E. | H.C. Reg. | 23.3.66 |
| Clark, J. W. | H.C. Reg. | 23.3.66 |
| Silverson, R. B. | H.C. Reg. | 23.3.66 |
| Micklam, E. | H.C. Reg. | 23.3.66 |
| Thorne, C. J. | H.C. Reg. | 23.3.66 |
| Dawe, J. R. | H.C. Reg. | 23.3.66 |
| Taylor, J. H. | H.C. Reg. | 23.3.66 |
| Coles, W. R. | S.W. Reg. | 8.3.66 |
| Burt, W. R. E. | S.W. Reg. | 8.3.66 |
| Cruse, S. W. | S.W. Reg. | 8.3.66 |
| Abraham, J. | S.W. Reg. | 8.3.66 |

| Name | Region, etc. | Date |
|---|---|---|
| *Technical Officer to Assistant Executive Engineer—continued* | | |
| Chapman, S. J. | L.T. Reg. | 11.3.66 |
| Jones, A. L. | L.T. Reg. | 11.3.66 |
| Smith, D. E. | L.T. Reg. | 11.3.66 |
| Everett, A. F. G. | L.T. Reg. | 11.3.66 |
| Cooper, L. M. | L.T. Reg. | 11.3.66 |
| Taylor, J. E. | L.T. Reg. | 11.3.66 |
| Penfold, J. F. | L.T. Reg. | 11.3.66 |
| Darcy, P. | L.T. Reg. | 11.3.66 |
| Tanner, B. J. | L.T. Reg. | 11.3.66 |
| Wilson, A. H. | N.E. Reg. | 16.3.66 |
| Henderson, A. G. | Scot. | 14.3.66 |
| Areskog, J. E. | S.W. Reg. | 28.3.66 |
| *Draughtsman to Assistant Executive Engineer* | | |
| Bell, T. | Scot. | 7.3.66 |
| Olney, D. K. | H.C. Reg. | 23.3.66 |
| Burton, F. H. | H.C. Reg. | 23.3.66 |
| *Technical Officer to Inspector* | | |
| Bancroft, G. B. | N.W. Reg. | 28.1.66 |
| Haywood, K. J. | N.W. Reg. | 3.1.66 |
| Shirley, A. J. | L.T. Reg. | 18.1.66 |
| Milne, J. W. | Scot. | 21.2.66 |
| Mathews, A. J. | L.T. Reg. | 11.3.66 |
| Foard, K. | L.T. Reg. | 11.3.66 |
| *Senior Technician to Inspector* | | |
| Adams, E. F. | N.E. Reg. | 18.1.66 |
| Lally, W. | N.E. Reg. | 18.1.66 |
| Lea, V. | W.B.C. | 7.1.66 |
| Sydenham, A. J. | L.T. Reg. | 9.2.66 |
| Shiels, T. J. | N.I. | 1.2.66 |
| Gilchrist, C. C. | Scot. | 16.2.66 |
| Scott, J. | Scot. | 28.3.66 |
| *Technician I to Inspector* | | |
| McIntosh, I. R. | Scot. | 17.1.66 |
| Roberts, G. R. W. | W.B.C. | 31.12.65 |
| Cavanagh, P. J. | W.B.C. | 7.1.66 |
| Entwistle, W. | N.W. Reg. | 17.1.66 |
| Goldie, J. M. | Scot. | 31.1.66 |
| Bacon, J. | H.C. Reg. | 1.2.66 |
| Rowson, J. R. | H.C. Reg. | 1.2.66 |
| Steaggles, D. J. W. | H.C. Reg. | 1.2.66 |
| Hyde, S. W. B. | H.C. Reg. | 1.2.66 |
| Airlie, R. V. | H.C. Reg. | 1.2.66 |
| Burson, G. A. | H.C. Reg. | 1.2.66 |
| Stringer, R. G. T. | H.C. Reg. | 1.2.66 |
| Miles, B. A. | H.C. Reg. | 1.2.66 |
| Catchpole, G. | H.C. Reg. | 1.2.66 |
| Jones, J. | H.C. Reg. | 1.2.66 |
| Phillips, S. R. | H.C. Reg. | 1.2.66 |
| Gemmel, F. G. | H.C. Reg. | 1.2.66 |
| Abberley, L. C. | H.C. Reg. | 1.2.66 |
| Newman, D. N. | H.C. Reg. | 1.2.66 |
| King, D. W. | H.C. Reg. | 28.2.66 |
| Crittall, E. | H.C. Reg. | 1.2.66 |
| Meek, F. E. | H.C. Reg. | 22.2.66 |
| Ayers, C. M. | H.C. Reg. | 1.2.66 |
| Holliday, P. W. | H.C. Reg. | 1.2.66 |
| Whelan, A. | H.C. Reg. | 1.2.66 |
| Seaman, D. C. | H.C. Reg. | 1.2.66 |
| Hartill, J. W. | Mid. Reg. | 2.2.66 |
| Anderson, R. J. | Mid. Reg. | 2.2.66 |
| Gibbons, E. | Mid. Reg. | 22.2.66 |
| Smith, J. | Scot. | 7.2.66 |
| Streeter, J. E. | H.C. Reg. | 28.2.66 |
| Dunn, G. D. | Mid. Reg. | 28.2.66 |
| Halls, F. E. | H.C. Reg. | 28.2.66 |
| Dawe, T. G. | S.W. Reg. | 1.3.66 |
| Walter, D. M. | S.W. Reg. | 1.3.66 |
| Wright, G. | N.E. Reg. | 16.3.66 |
| Turpin, E. J. | S.W. Reg. | 3.3.66 |

## Promotions—*continued*

| Name | Region, etc. | Date |
|---|---|---|
| *Technician I to Inspector—continued* | | |
| Chappell, D. | S.W. Reg. | 1.3.66 |
| Simmons, M. S. | S.W. Reg. | 14.3.66 |
| Dunn, R. | S.W. Reg. | 1.3.66 |
| Massett, D. S. G. | S.W. Reg. | 14.3.66 |
| Wilton, H. P. | S.W. Reg. | 1.3.66 |
| Godbehere, G. A. | S.W. Reg. | 1.3.66 |
| Hannan, S. F. | S.W. Reg. | 16.3.66 |
| Palmer, K. | Mid. Reg. | 17.3.66 |
| Bracegirdle, J. | Scot. | 14.3.66 |
| Johnston, S. V. | N.I. | 4.3.66 |
| *Principal Scientific Officer to Senior Principal Scientific Officer* | | |
| Thomson, W. E. | E.-in-C.O. | 7.3.66 |
| *Assistant Experimental Officer (Open Competition)* | | |
| Stammers, J. F. (Miss) | E.-in-C.O. | 9.2.66 |
| Lemon, T. H. | E.-in-C.O. | 28.2.66 |
| Ali, A. S. M. | E.-in-C.O. | 31.3.66 |
| *Assistant (Scientific) (Open Competition)* | | |
| Abbott, J. R. | E.-in-C.O. | 2.2.66 |
| Carson, R. Mc. | E.-in-C.O. | 4.2.66 |
| Godsmark, D. | E.-in-C.O. | 8.2.66 |
| *Assistant (Scientific) (Open Competition)—continued* | | |
| Baldwin, N. F. | E.-in-C.O. | 9.2.66 |
| Marshall, J. F. | E.-in-C.O. | 15.2.66 |
| Sainsbury, C. (Miss) | E.-in-C.O. | 17.2.66 |
| Brown, D. | E.-in-C.O. | 16.3.66 |
| Ovenden, J. W. H. | E.-in-C.O. | 30.3.66 |
| *Technical Assistant to Motor Transport Officer III* | | |
| Heaven, P. S. | E.-in-C.O. | 11.3.66 |
| *Leading Draughtsman to Senior Draughtsman* | | |
| Storey, T. G. | L.P. Reg. to L.T. Reg. | 15.2.66 |
| *Draughtsman (Open Competition)* | | |
| Sykes, C. P. C. | H.C. Reg. | 31.1.66 |
| Bushnell, W. C. E. | E.-in-C.O. | 8.2.66 |
| Pearson, M. | N.E. Reg. | 11.2.66 |
| Blenkinsop, G. F. | N.E. Reg. | 7.2.66 |
| Chapman, D. | N.E. Reg. | 21.2.66 |
| Plumpton, E. | N.W. Reg. | 21.2.66 |
| Weston, D. | N.W. Reg. | 14.2.66 |
| Hill, A. O. | L.T. Reg. | 21.2.66 |
| *Executive Officer (Open Competition)* | | |
| Rawlins, S. C. | E.-in-C.O. | 21.2.66 |

## Retirements and Resignations

| Name | Region, etc. | Date |
|---|---|---|
| *Assistant Staff Engineer* | | |
| Mead, F. C. | E.-in-C.O. | 31.1.66 |
| *Senior Executive Engineer* | | |
| Porter, W. F. | E.-in-C.O. | 1.3.66 |
| Anderson, F. | E.-in-C.O. | 28.2.66 |
| *Executive Engineer* | | |
| Webb, A. J. | L.T. Reg. | 19.2.66 |
| Knight, J. S. | Scot. | 17.2.66 |
| Jones, W. A. | E.T.E. | 28.2.66 |
| Fable, F. P. | H.C. Reg. | 28.2.66 |
| Batchelor, H. R. | L.T. Reg. | 11.3.66 |
| Steward, D. H. | Scot. | 30.3.66 |
| Pollard, A. J. | L.T. Reg. | 31.3.66 |
| *Assistant Executive Engineer* | | |
| Walton, J. M. | Scot. | 31.12.65 |
| Richards, J. E. | Mid. Reg. | 1.1.66 |
| Ashcroft, J. E. | N.W. Reg. | 7.1.66 |
| Jenner, J. W. | E.-in-C.O. | 10.1.66 |
| Knight, H. | E.-in-C.O. | 18.1.66 |
| Woodnutt, H. | H.C. Reg. | 18.1.66 |
| Rickards, H. C. S. | H.C. Reg. | 18.1.66 |
| Mapes, R. J. (*Resigned*) | E.-in-C.O. | 28.1.66 |
| Taylor, R. W. (*Resigned*) | E.-in-C.O. | 28.1.66 |
| Myers, H. B. (*Resigned*) | Mid. Reg. | 31.1.66 |
| Pitwood, S. H. | H.C. Reg. | 9.11.65 |
| Kingham, M. W. E. | H.C. Reg. | 10.2.66 |
| Hurst, J. | Mid. Reg. | 15.2.66 |
| James, P. A. | S.W. Reg. | 18.2.66 |
| Deeny, F. H. | N.I. | 18.2.66 |
| Huke, C. J. | H.C. Reg. | 20.2.66 |
| Slade, H. C. | L.T. Reg. | 28.2.66 |
| Lock, R. D. (*Resigned*) | E.-in-C.O. | 25.2.66 |
| Atkins, G. W. (*Resigned*) | E.-in-C.O. | 28.2.66 |
| Maxwell, D. J. | Scot. | 28.2.66 |
| Trickett, A. | S.W. Reg. | 1.3.66 |
| *Assistant Executive Engineer—continued* | | |
| Hewitt, H. W. | L.T. Reg. | 3.3.66 |
| Hamilton, T. C. | Scot. | 7.3.66 |
| Doyle, B. R. H. | L.P. Reg. | 23.3.66 |
| Harris, A. G. B. | L.T. Reg. | 23.3.66 |
| Brady, J. | N.E. Reg. | 25.3.66 |
| Sundewall, J. R. | H.C. Reg. | 31.3.66 |
| Wood, R. | L.T. Reg. | 31.3.66 |
| Norris, T. H. | L.T. Reg. | 31.3.66 |
| Thornhill, S. | N.W. Reg. | 31.3.66 |
| West, J. | L.T. Reg. | 31.3.66 |
| Green, K. L. (*Resigned*) | E.-in-C.O. | 18.3.66 |
| *Inspector* | | |
| Darling, J. S. | Scot. | 10.1.66 |
| Morcom, S. E. | L.T. Reg. | 17.1.66 |
| Shaw, H. | N.W. Reg. | 17.1.66 |
| Randall, C. R. | S.W. Reg. | 19.1.66 |
| Aiston, A. H. | N.E. Reg. | 31.1.66 |
| Ayriss, S. J. | Mid. Reg. | 2.2.66 |
| Dawson, G. | Mid Reg. | 2.2.66 |
| Allcock, F. | N.W. Reg. | 15.2.66 |
| Day, J. | H.C. Reg. | 28.2.66 |
| Challinor, T. F. | N.W. Reg. | 28.2.66 |
| Greenaway, A. V. | L.T. Reg. | 20.3.66 |
| Larcombe, F. T. | S.W. Reg. | 23.3.66 |
| Rafferty, W. | N.I. | 26.3.66 |
| Lyster, R. E. N. | Mid. Reg. | 27.3.66 |
| Hiles, H. J. | L.T. Reg. | 31.3.66 |
| Parsons, G. E. | H.C. Reg. | 31.3.66 |
| *Assistant (Scientific)* | | |
| Stacey, E. C. (*Resigned*) | E.-in-C.O. | 29.3.66 |
| *Draughtsman* | | |
| Sillence, J. H. (*Resigned*) | Mid. Reg. | 1.2.66 |
| Lee, W. D. (*Resigned*) | E.-in-C.O. | 25.2.66 |
| George, E. V. (*Resigned*) | W.B.C. | 31.1.66 |

## Transfers

| Name | Region, etc. | Date | Name | Region, etc. | Date |
|---|---|---|---|---|---|
| *Senior Executive Engineer* | | | *Assistant Executive Engineer* | | |
| Shinn, E. | L.T. Reg. to H.C. Reg. | 14.2.66 | Fagg, D. E. | L.T. Reg. to E.-in-C.O. | 3.1.66 |
| Mayne, R. T. | E.-in-C.O. to H.C. Reg. | 7.3.66 | Caunt, E. | E.-in-C.O. to N.E. Reg. | 31.1.66 |
| Kyme, R. C. | S.W. Reg. to E.-in-C.O. | 7.3.66 | New, R. | L.P. Reg. to Ministry of Technology | 31.1.66 |
| | | | Barnes, H. E. | E.-in-C.O. to Malawi | 13.2.66 |
| *Executive Engineer* | | | Short, K. J. | E.-in-C.O. to Ministry of Defence | 21.2.66 |
| Kerr, A. S. | E.-in-C.O. to Scot. | 28.2.66 | Green, P. K. | E.-in-C.O. to N.E. Reg. | 1.3.66 |
| Robinson, E. L. A. | E.-in-C.O. to L.T. Reg. | 21.3.66 | Green, R. A. | L.T. Reg. to E.-in-C.O. | 1.3.66 |
| Redman, F. W. G. | E.-in-C.O. to L.T. Reg. | 31.3.66 | | | |
| Hyatt, J. L. | E.-in-C.O. to R.S.D./T.W.S. | 28.3.66 | *Executive Officer* | | |
| Keast, M.H. | W.B.C. to S.W. Reg. | 14.2.66 | Ives, T. G. | E.-in-C.O. to C.O.S.D. | 14.2.66 |

## Deaths

| Name | Region, etc. | Date | Name | Region, etc. | Date |
|---|---|---|---|---|---|
| *Senior Executive Engineer* | | | *Assistant Executive Engineer—continued* | | |
| Eccles, J. | E.-in-C.O. | 1.3.66 | Spink, I. P. | N.W. Reg. | 19.3.66 |
| *Assistant Executive Engineer* | | | *Inspector* | | |
| Gilbert, L. M. | H.C. Reg. | 7.1.66 | Bean, A. F. | W.B.C. | 16.1.66 |
| Jones, E. T. | W.B.C. | 6.2.66 | Henson, A. | N.W. Reg. | 4.2.66 |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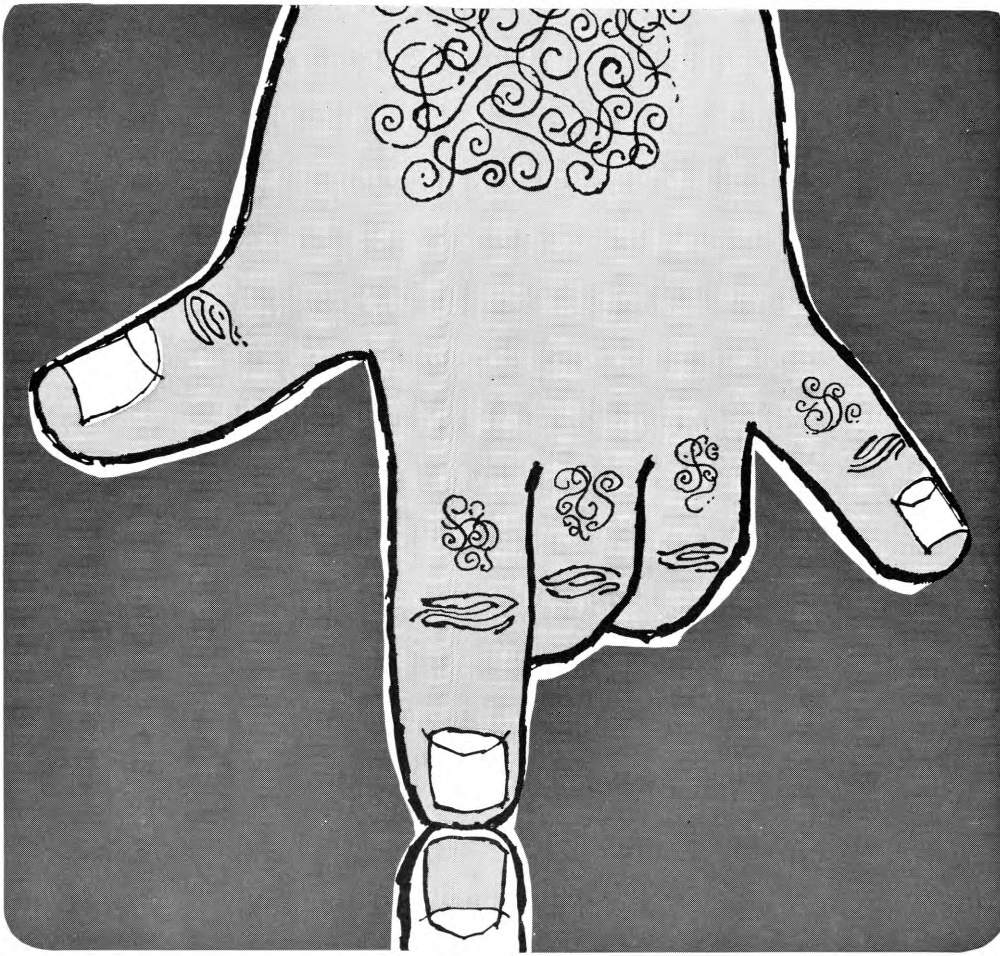


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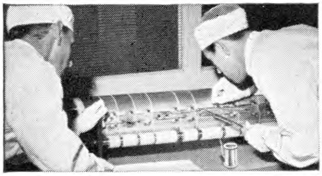

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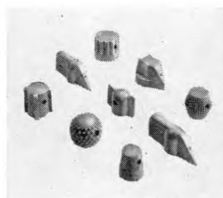
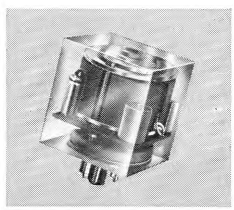
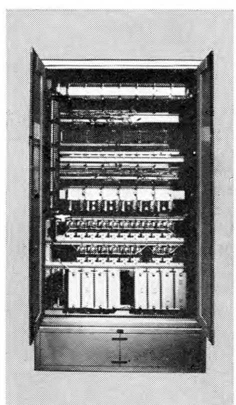
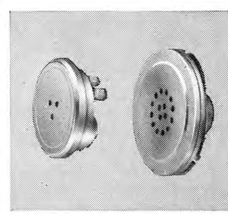




## provide a comprehensive service for the design & manufacture of electronic equipment & components





Whiteley Electronic Equipment & Components are designed and precision-built in the Company's own factories. Every operation is strictly controlled, every part is vigorously inspected and tested. Nothing is left to chance — hence Whiteley's enviable reputation.

**WHITELEY ELECTRICAL RADIO CO. LTD**

MANSFIELD · NOTTS · ENGLAND Tel: Mansfield 1762/5

London Office: 109 KINGSWAY, W.C.2 Tel: HOLborn 3074

WB185

# FERRANTI

## SILICON PLANAR TRANSISTORS

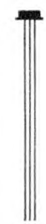
Designed and manufactured in Britain for you

You should specify

# *BURN IN

statistics show that this is the only way to achieve MAXIMUM RELIABILITY

T018
ZT80



T046
ZT110

* Every Ferranti transistor from the production line is FULLY DYNAMIC TESTED FOR 48 HOURS !

ZT87 (CV8615)
* ZT88 designed for ELECTRONIC TELEPHONE EXCHANGES
ZT89

| Rating or Characteristic | Symbol | ZT80 ZT110 | ZT81 ZT111 | ZT82 ZT112 | ZT83** ZT113 | ZT84** ZT114 | ZT86** ZT116 | **ZT87 ZT117** | **ZT88 ZT118** | **ZT89 ZT119** | Test Conditions |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Collector Base Voltage | $V_{CBO}$ | 25 | 45 | 45 | 60 | 60 | 100 | **25** | **100** | **70 volts** | $I_E = 0$ |
| Collector Emitter Sustaining Voltage | $V_{CEO(Sus)}$ | 25 | 35 | 35 | 45 | 45 | 80 | **25** | **80** | **70 volts** | $I_B = 0$ $I_C = 5mA$ |
| Emitter Base Voltage | $V_{EBO}$ | 4 | 4 | 4 | 5 | 5 | 5 | **4** | **5** | **5 volts** | $I_C = 0$ |
| Collector Peak Current | $I_{Cpk}$ | 500 | 500 | 500 | 500 | 500 | 500 | **500** | **500** | **500 mA** | |
| DC Collector Current Gain | $h_{FE}$ | 38-162 | 38-162 | 78-250 | 35-85 | 75-170 | 35-85 | **78-250** | **75-170** | **75-250** | $I_C = 10mA$ $V_{CE} = 6V$ |
| Collector Base Reverse Current | $I_{CBO}$ | 0·5 | 0·5 | 0·5 | 0·05 | 0·05 | 0·05 | **0·5** | **0·05** | **0·5$\mu$A** | $V_{CB} = V_{CBO}$ $T_{AMB} = 25°C$ |
| Collector Saturation Voltage | $V_{CE(Sat)}$ | 0·4 | 0·4 | 0·4 | 0·4 | 0·4 | 0·4 | **0·4** | **0·4** | **0·4 volts** | $I_C = 50mA$ $I_B = 5mA$ / $I_C = 10mA$ $I_B = 2mA$ |
| AC Current Gain (typical) | $h_{fe}$ | 10 | 10 | 10 | 10 | 10 | 10 | **10** | **10** | **10** | f = 20Mc/s $I_C = 10mA$ |
| Power Dissipation | $P_{tot}$ | 300 | 300 | 300 | 300 | 300 | 300 | **300** | **300** | **300 mW** | at 25°C ambient temperature |
| Minimum Burn-In Period | $t_{BPmin}$ | 48 | 48 | 48 | 48 | 48 | 48 | **48** | **48** | **48 hrs** | $P_{tot} = 150mW$ $T_{AMB} = 100°C$ |

** CV 7371 · CV 7372 · CV 7373

FERRANTI
*First into the Future*

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FE 258


# TELECOMMUNICATIONS CABLES

Pirelli General are in a position to advise on complete Telecommunications schemes and are organised to manufacture and install cables for distribution and trunk services; also carrier and all types of coaxial cables.

Pirelli General also manufacture cables to meet special requirements of Public Utilities or of industry.

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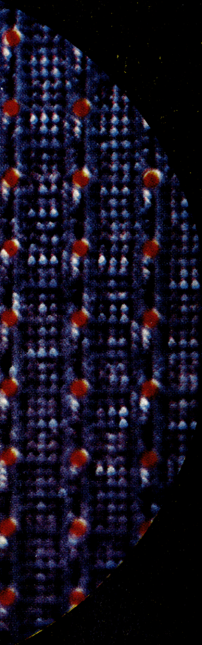
P9315

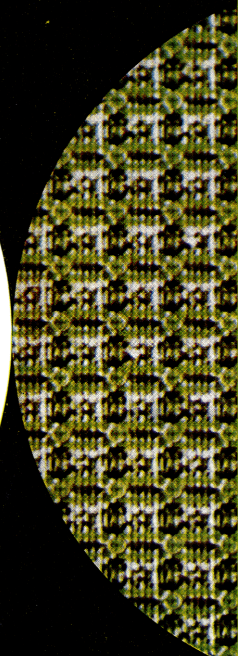
# REX®

THE REED ELECTRONIC EXCHANGE

NO. 18 SYSTEM



**serves a much greater area in far less space than a conventional exchange**



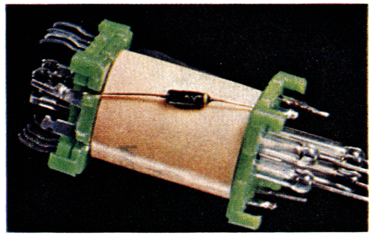
## DESIGNED FOR UNRESTRICTED EXPANSION

By providing electronic common control of reed relay spatial switching, the REX system offers an extremely compact and reliable solution to both the switching and control problems of modern exchange design. The REX exchange has been developed by AEI to integrate smoothly with existing automatic networks its exceptional flexibility ensures full growth capacity

AEI

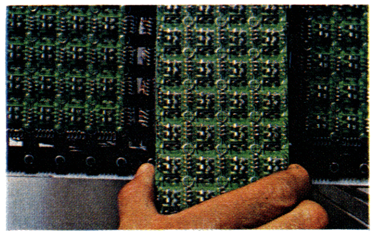
**REX**
THE REED ELECTRONIC EXCHANGE

# combines sophisticated electronics with building-block simplicity



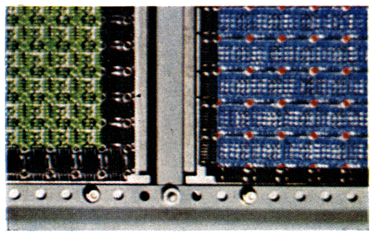
## THE REX SWITCHING ELEMENT

The basis of the REX system is this reed relay crosspoint switching element. It contains only nine components, compared with 200 in a bimotional selector, and its very simplicity makes it uniquely reliable. It gives highest quality transmission paths with gold at the point of connection, requires no routine maintenance, generates no vibration and therefore no microphonic noise. There's nothing to wear out and it is sealed completely to be immune to interference by dust or atmospheric pollution.



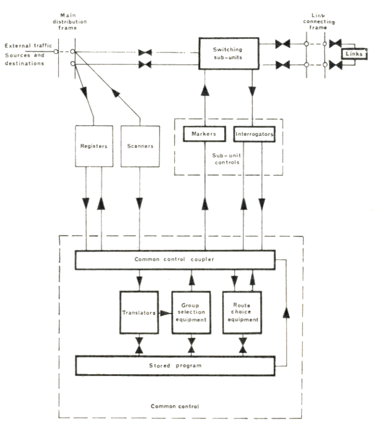
## THE REX SWITCHING MATRIX

Since multiple wiring across the end-caps is inherent in the reed relay crosspoint design, switching matrices can be built up in any form simply by clipping reed relay crosspoints together. Matrices may be enlarged in any ordinate simply by the addition of rows and columns of reed relay crosspoints to cater for any switching requirements. This means that unlimited provision for the growth of lines and links is built into the REX system.



## THE REX SWITCHING UNIT

Basic switching arrays (normally called sections) are built up out of matrices and assembled in parallel to form a REX switching unit. The number of sections supplied depends on the anticipated originating traffic per line. Typically, a 1000-line four-section unit would serve a community with an average calling rate of 150 call seconds per line in the busy hour; other calling rates can be accommodated by varying the number of sections.




## THE MULTI-UNIT REX EXCHANGE

Switching and linking arrangements are provided for all sections of each unit so that complete crosspoint path interconnection is made between all lines of the REX exchange. For purposes of security of service and simplicity of electronic control the units are divided into self-contained basic switching blocks termed 'sub-units'. Each sub-unit is linked only to adjacent sub-units, a linking pattern which provides for every traffic pattern and retains simplicity of control.

## THE REX ELECTRONIC CONTROL

Closely related in its simplicity to the 'building block' structure of REX switching equipment, the REX electronic control system has three main areas of activity:

**SCANNERS AND REGISTERS**
These determine the source and final destination of a call.

**MARKERS AND INTERROGATORS**
Provided on a per-sub-unit basis, these controls are concerned with interrogating the state of crosspoint paths and marking these paths through the switching sub-units.

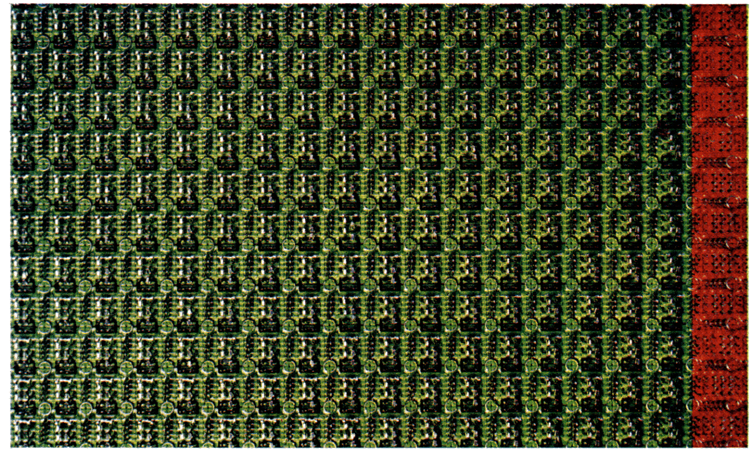
**COMMON CONTROL**
The control processes the necessary call setting data in accordance with instructions from the stored programme control in such a way that the calls are routed with maximum utilisation of the switching network.

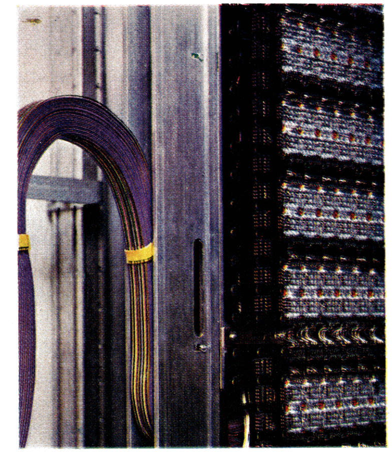
**REX**
THE REED ELECTRONIC EXCHANGE

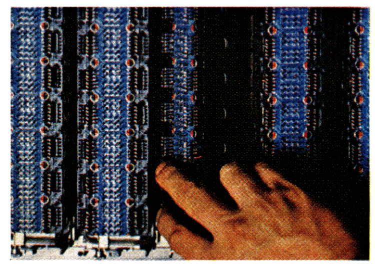
## serves a much greater area in far less space than a conventional exchange: every part accessible – every part replaceable!

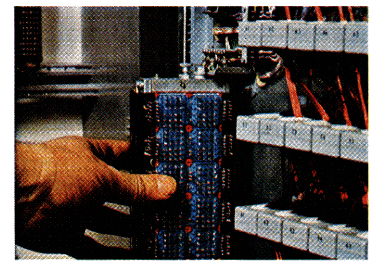
The REX subscriber's line circuit tolerates substantially wider line conditions enabling a REX exchange to serve an area much larger than that of a conventional exchange, permitting big reductions in line plant investment.

AEI engineers have devised the entirely new Reed & Electronic Modular Apparatus practice (REMA) for the REX exchange providing completely compatible mounting of reed relays and electronic circuit components. Combined with a new sliding frame installation system, the REMA practice allows more than 20,000 lines of REX equipment to be accommodated in the space normally required by a 10,000 line electromechanical exchange. In existing buildings this means more space for future expansion: in new exchanges it makes possible great savings in construction and installation costs.

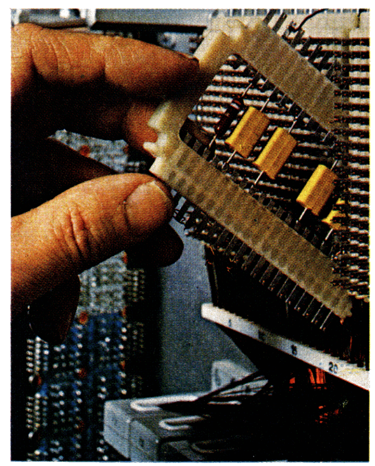


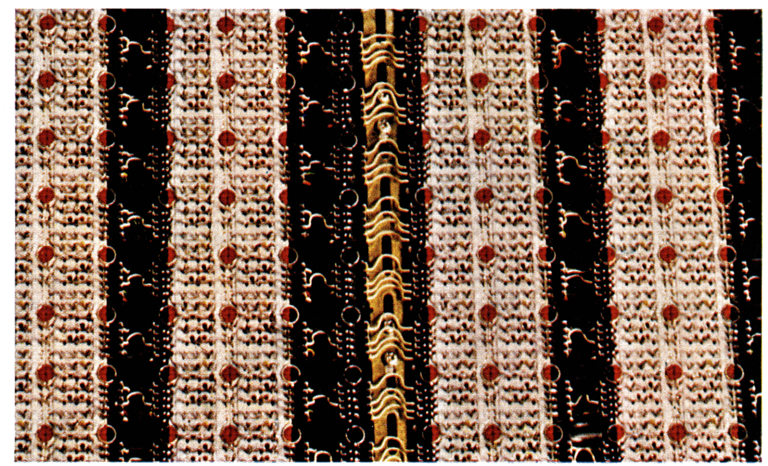






(TOP LEFT) Part of a cross-point switching frame also showing associated electronic modules.
(TOP RIGHT) A sub frame withdrawn for inspection showing the method of tape wiring.
(AT LEFT) Electronic modules can be arranged to revolve horizontally or swing down for inspection and maintenance.
(BOTTOM LEFT) Terminal wafers may be easily withdrawn from the main block to reveal circuit components mounted within the wafer.
(BOTTOM RIGHT) Frame assembly illustrating the wiring gutters used to accommodate the tape wiring.





REX
THE REED ELECTRONIC EXCHANGE

# checks and reports on its own performance automatically!

The high-speed electronic control system is programmed to provide complete self-checking and reporting facilities for maintenance purposes. A prototype reed electronic exchange supplied to the BPO at Leighton Buzzard has been designed for completely unattended operation and can report all servicing requirements to a remote maintenance control centre.
Exhaustive circuit design and testing during the development period, and replication of important items of equipment, enables a high degree of security of service to be offered.

## FUTURE FACILITIES

The basic design permits the provision of all future switching facilities likely to be required by a modern telecommunications network, including abbreviated dialling and subscribers' automatic transfer, together with all current standard features such as data for automatic message accounting. A stored programme control is provided to expedite inclusion of these facilities.

## REX—A SUMMARY

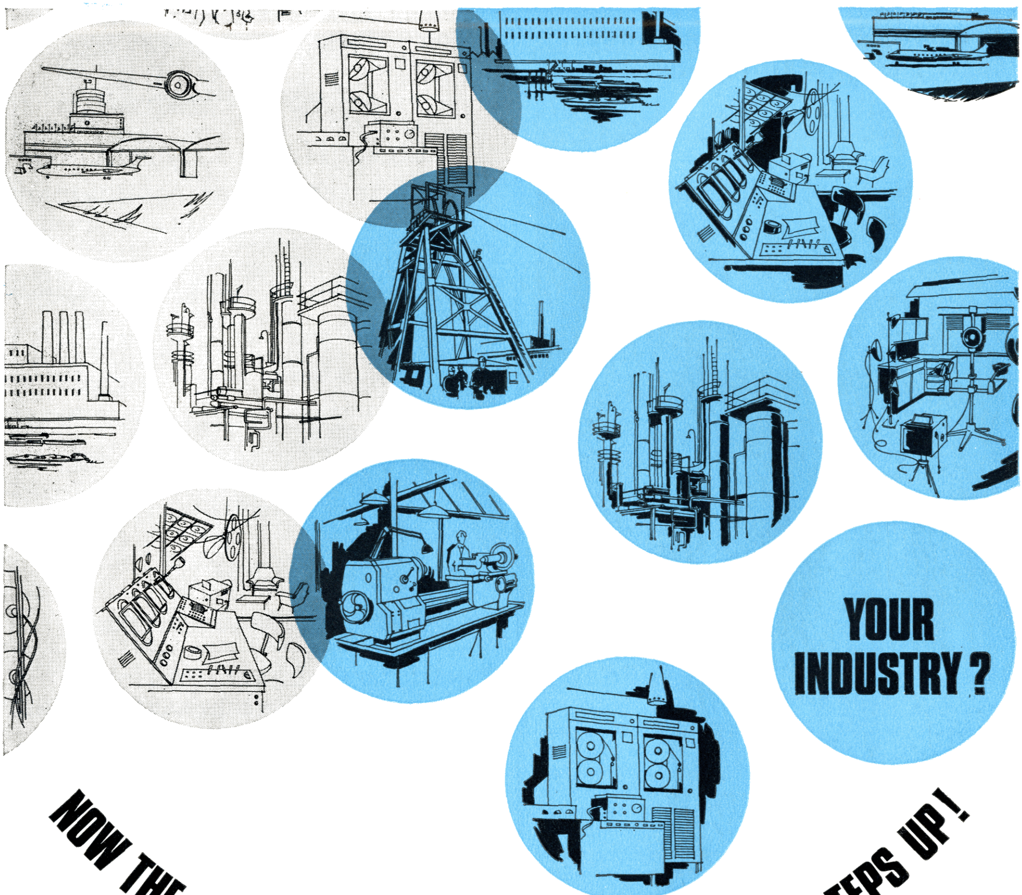
The exchange employs electronic common control of reed relay spatial switching arrays providing sealed precious metal contacts in the speech-path. The electronic control is simple in design and provides economic high-speed operation readily adaptable to provide expanded service and facilities.
Full security of service has been achieved in the system by exhaustive testing in the design stage, coupled with the multiple provision (with automatic changeover) of the vital control functions. At the same time REX offers dramatic savings in floor space with consequent reduction in the building capacity required for present switching systems in multi-exchange urban areas. The system is completely flexible to allow for the extension of lines and traffic growth. It requires minimal maintenance which is simple and largely automatic.

## INFORMATION SERVICE FOR ADMINISTRATIONS

AEI Telecommunications Group can supply technical information on detailed aspects of REX which will be of interest to experts in the field of automatic telephony. In addition, courses of technical lectures have been prepared, together with detailed lecture notes, and AEI would welcome invitations for a team of lecturers to be sent to provide, for the engineering staff of interested Administrations, a short introductory course on the principles of the REX system. Later, more detailed courses could be arranged for an Administration's key personnel in our UK factories, and detailed on-site instruction would be provided during the actual installation of REX exchanges. AEI are also prepared to consider setting up and staffing training schools in those territories where it is proposed to standardise on reed-electronic exchange switching equipment.
Please write for fully illustrated REX brochure.


AEI TELECOMMUNICATIONS

Public Telephone Systems Department (Electronic)
Telecommunications Group
Associated Electrical Industries Limited
Woolwich, London SE18.
*Tel:* Woolwich 2020 *Telegrams:* Assocelect London SE18.

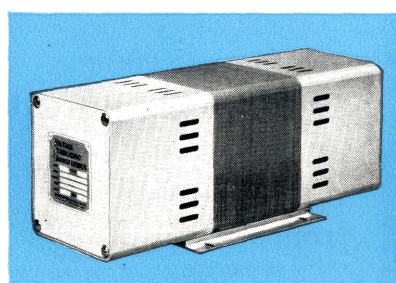



# NOW THE BIG SWING TO ASTRALUX V.S.T. REALLY STEPS UP!

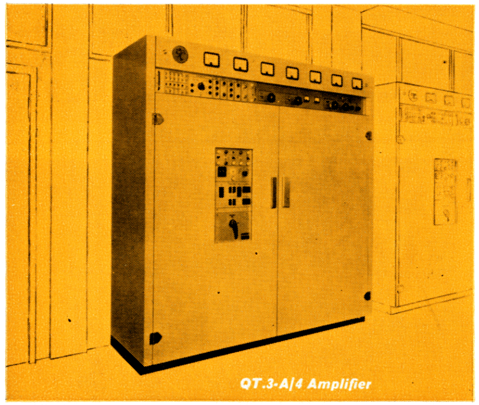
## Everywhere Astralux Voltage Stabilising Transformers outperform and outdate conventional C.V.T. systems

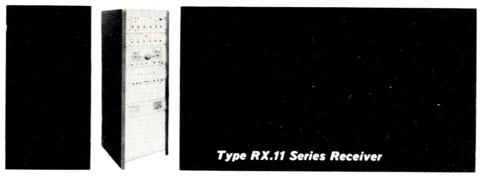
**HERE'S WHY ASTRALUX V.S.T. IS REPLACING C.V.T. IN INDUSTRY AFTER INDUSTRY:**

**Better Performance.** That means improved Output Voltage Stability—output voltage maintained within ± 0.5% for input voltage changes of + 10% —20%. Even when the voltage fluctuation is as great as + 10% to —30% the V.S.T. will maintain the output voltage to within ±1%. ● **Latest Materials.** High temperature (Class F) materials give optimum reliability and increased safety margins on operating temperatures. ● **Low external field** The latest techniques in magnetic core design give improved performance, coupled with high efficiency, while still offering low external fields. ● **Stable Voltage—Stable Prices.** ASTRALUX prices remain stable over long periods, so costing a job ahead is facilitated with this advanced system. ● **Over 10,000 models!** The ASTRALUX V.S.T. Standard Range consists of ten basic models with over a thousand variations on each. *No other manufacturer* offers such a choice, or can offer such economical prices. ● **Low Cost Specials.** You can order V.S.T. 'specials' at little more than the cost of standard units. Our design department will be happy to prepare prototypes to your specification, for incorporation into equipment under development.
Free illustrated booklet giving full details of ASTRALUX V.S.T. from



**ASTRALUX** *dynamics limited* TRANSFORMER DIVISION · BRIGHTLINGSEA · COLCHESTER · ESSEX · TELEPHONE: BRIGHTLINGSEA 417

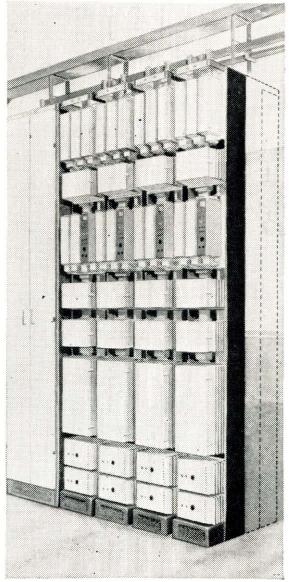

*QT.3-A/4 Amplifier*

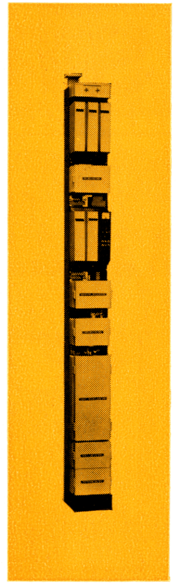

*Type RX.11 Series Receiver*

## Complements in communications

In a modern radio link station all equipment must be to a uniformly high standard of quality. A transmitter with high stability synthesizer frequency control must be matched with an equally stable receiver. STC supplies HF equipment to this standard. The QT.3-A/4 10 kW ISB and general purpose linear amplifier for telephony and single or multi-channel telegraphy, the fully transistorized RX.11 receiver with a stability of 1 in $10^7$ per week and held on tune to 1 c/s by motorised a.f.c., the ancillary equipment, all designed for exceptional reliability and maintainability. Both transmitter and receiver have facilities for autotune with local or remote control. Maximum ease of operation is combined with minimum need for servicing.

*For further information please write, phone or telex Standard Telephones and Cables Limited, Radio Division, Oakleigh Road, New Southgate, London, N.11. Telephone: ENTerprise 1234. Telex: 261912.*





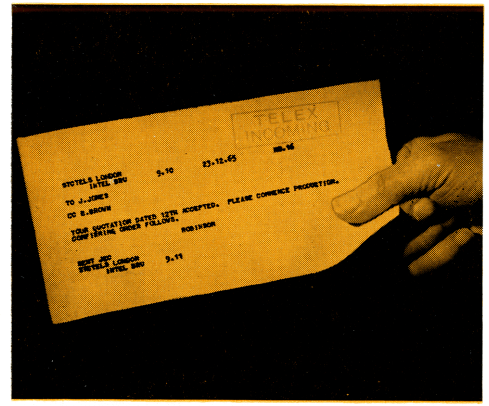
## New slimrack microwave equipment

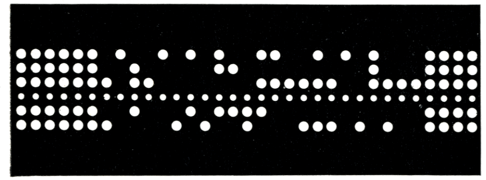
Nearly 50% reduction in floor space requirements is attained with the new STC "slimrack" modular construction used in the all solid state 4 Gc/s microwave system, type RL4H. Terminal/repeater radio equipments mounted on "slimracks" incorporate new electrical and mechanical features in a design fully compatible with larger equipments.

The RL4H is a mainline system providing 960 telephone circuits, or colour TV, on each of up to 6 radio channels; all radio channels use the same aerial. Systems can be supplied on a "turnkey" basis to include aerials, towers, buildings and terminal multiplex equipment. Other features of the RL4H are: CCIR performance, switching for N+1 or N+2 protection channels, dropping and insertion facilities at repeaters and wayside channels, and cassegrain antenna for single or bi-polar operation. Receiver noise figure is better than 8 db and repeater power consumption is only 100 watts.

*Standard Telephones and Cables Limited, Transmission Systems Group, Basildon, Essex. Telephone: Basildon 3040. Telex: 99101. (STC Basildon).*







## The message is your business ...speeding it through is ours

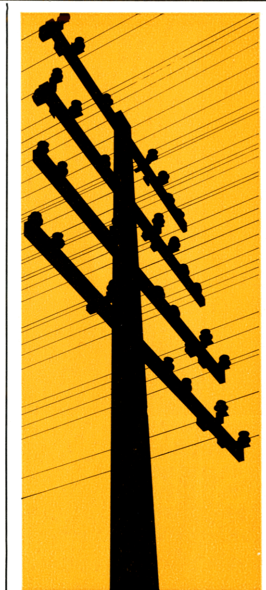
STC know telegraphy inside out and outside in, provide a complete range of equipment—and equally complete skill and experience—for direct and indirect systems, large, medium and small.

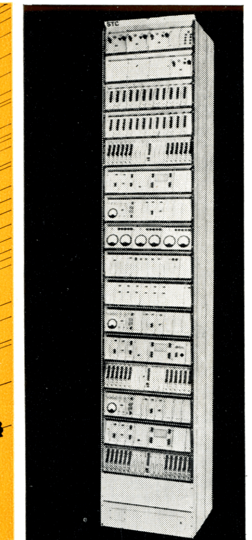
Telex switching, international and local, is an STC speciality no less than the provision of private networks for the police, railways and similar bodies.

And, throughout the world, STC message switching systems—from the simplest manual transfer right through semi- and fully-automatic systems—speed the vital messages of corporations, civil airlines and commercial networks of every kind.

The moment *you* have any telegraphic problem it's just good business to phone, write or telex STC.

*Standard Telephones and Cables Limited, Telephone Switching Division, Oakleigh Road, New Southgate, London, N.11. Telephone: ENTerprise 1234. Telex: 261912.*




SOJ-12E THREE SYSTEM TERMINAL

## New generation open-wire transmission equipment

Employing semiconductors in all active circuits and engineered in the new Mark 6 Construction (BPO 62 type), the SOJ-12E and SOX-12B open-wire telephone systems set a new standard in compactness and reliability for open-wire transmission equipment. Ease of installation and maintenance, high reliability and great flexibility are inherent advantages with both systems.

The SOJ-12E system provides twelve 2-way speech circuits over one pair of open-wires and occupies the line frequency band 36-143 kc/s. The SOX-12B "high frequency" system, occupying the line frequency band 160-300 kc/s provides an additional 12 circuits on an open-wire pair already carrying a 3 circuit and a 12-circuit system. Comparable performance with that of standard 12-channel main line systems is achieved by equipping all speech channels with syllabic compandors.

A single 2743 mm (9 ft) high SOJ-12E or SOX-12B rack mounts all the equipment necessary for either three system terminals or three 2-way repeaters.

*Standard Telephones and Cables Limited, Transmission Systems Group, Basildon, Essex. Telephone: Basildon 3040. Telex: 99101 (STC Basildon).*

# STEPMASTER PABX

## Two models of efficiency

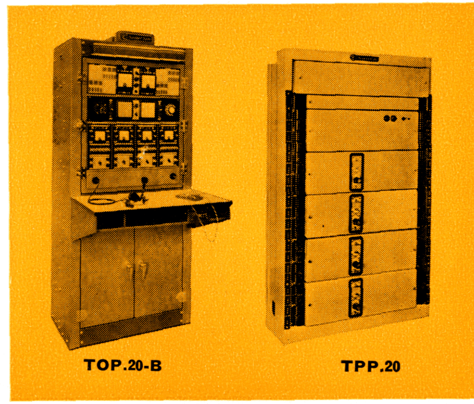
The STC Stepmaster PABX gives you the fast, foolproof communications you need, while leaving the operator beautifully unruffled.

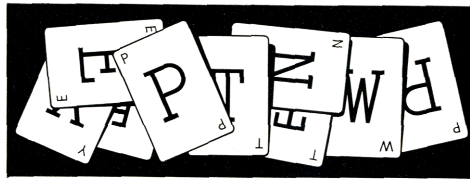
It meets the most up-to-date requirements for a Cordless Private Automatic Branch Exchange of advanced design and compact proportions.

And the use of keysender marking techniques, plus the very simple working procedure, so ease the operator's task that a secretary or receptionist can comfortably work the switchboard in addition to her other duties.

☐ 20, 50 and 100 line units ☐ Smart, modern switchboard ☐ New lightweight high performance handset ☐ B.P.O. type 'long-life' components ☐ Transistorized ringing and tone circuits ☐ All 'plug-in' type equipment ☐ Quick and easy extension to full capacity ☐ Simple installation and maintenance.

*Standard Telephones and Cables Limited, Telephone Switching Division, Oakleigh Road, New Southgate, London, N.11. Telephone: ENTerprise 1234. Telex: 261912.*



## Privacy in radio telephony

Whether it's a matter of discussing an important business deal or just saying hello to Mother, most international administrations operating into radio links consider privacy to be essential. STC provides this facility through the TPP.20 four-wire fully transistorized five-band speech scrambler equipment.

This advanced equipment is designed to operate with h.f. radio link control terminals such as the STC TOP.20-B.

Both the TPP.20 and the TOP.20-B handle four speech channels: both are extremely compact and embody modern techniques of transistorization and module construction.

**Five Band Speech Scrambler Type TPP.20**

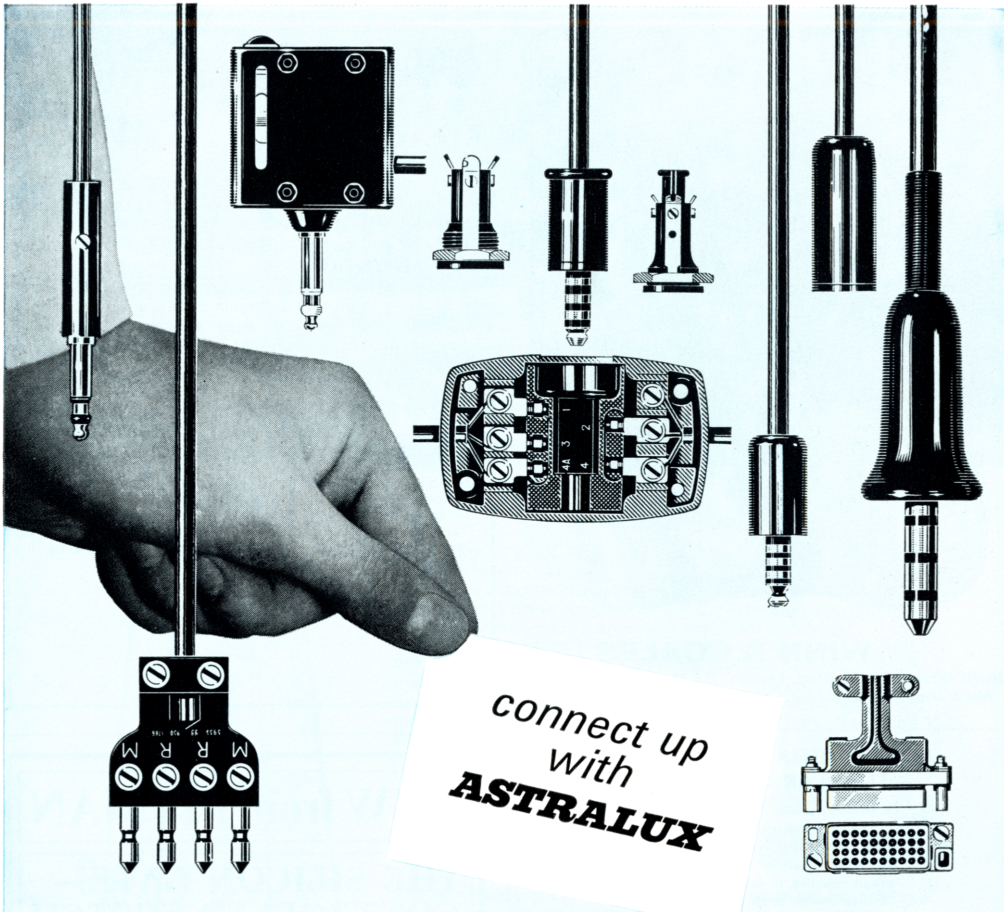
- Four speech channels
- Fully transistorized
- 4-wire system (separate send and receive paths)
- Remote selection of combinations
- Compact yet extremely accessible
- Cabinet 36 in (91,4cm) high x $20\frac{1}{2}$ in (52cm) wide x $8\frac{3}{4}$ in (22 cm) deep

**Radio Link Control Terminal Type TOP.20-B**

- Four speech channels
- Fully automatic
- Relay type VODAS switching
- Built-in shifter and inverter for each circuit
- Automatic station identification for each circuit
- Console 75 in (190,5cm) high x 33 in (83,8cm) wide x 19 in (48,3cm) deep

*For further information please write, phone or telex Standard Telephones and Cables Limited, Radio Division, Oakleigh Road, New Southgate, London N.11. Telephone: ENTerprise 1234. Telex: 261912.*

world-wide telecommunications and electronics **STC**

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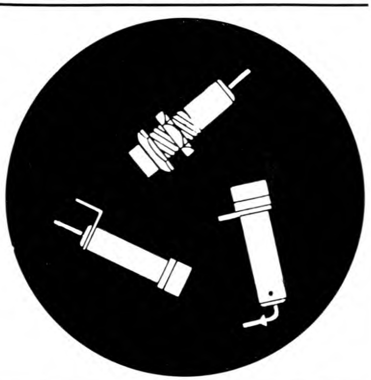

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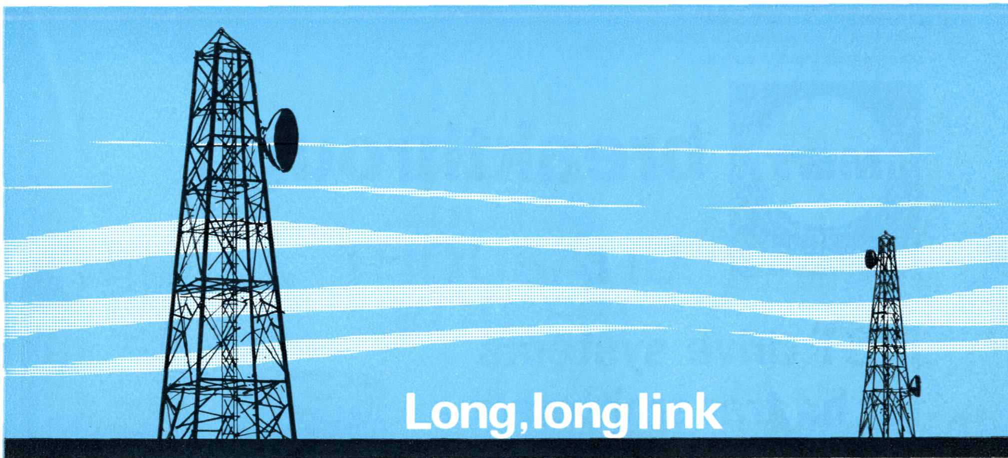

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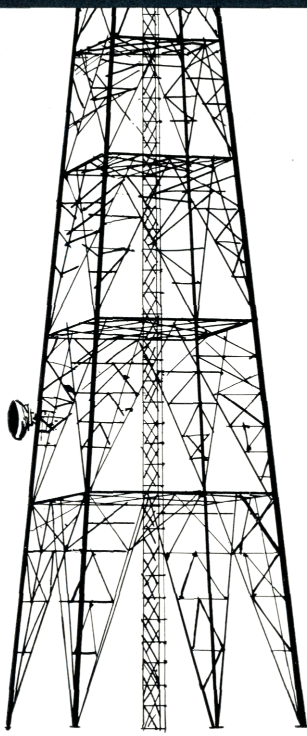

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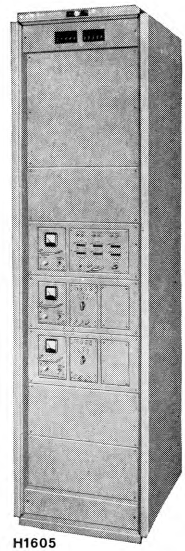
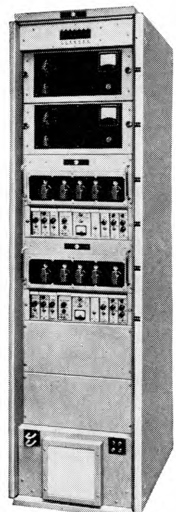


H1605



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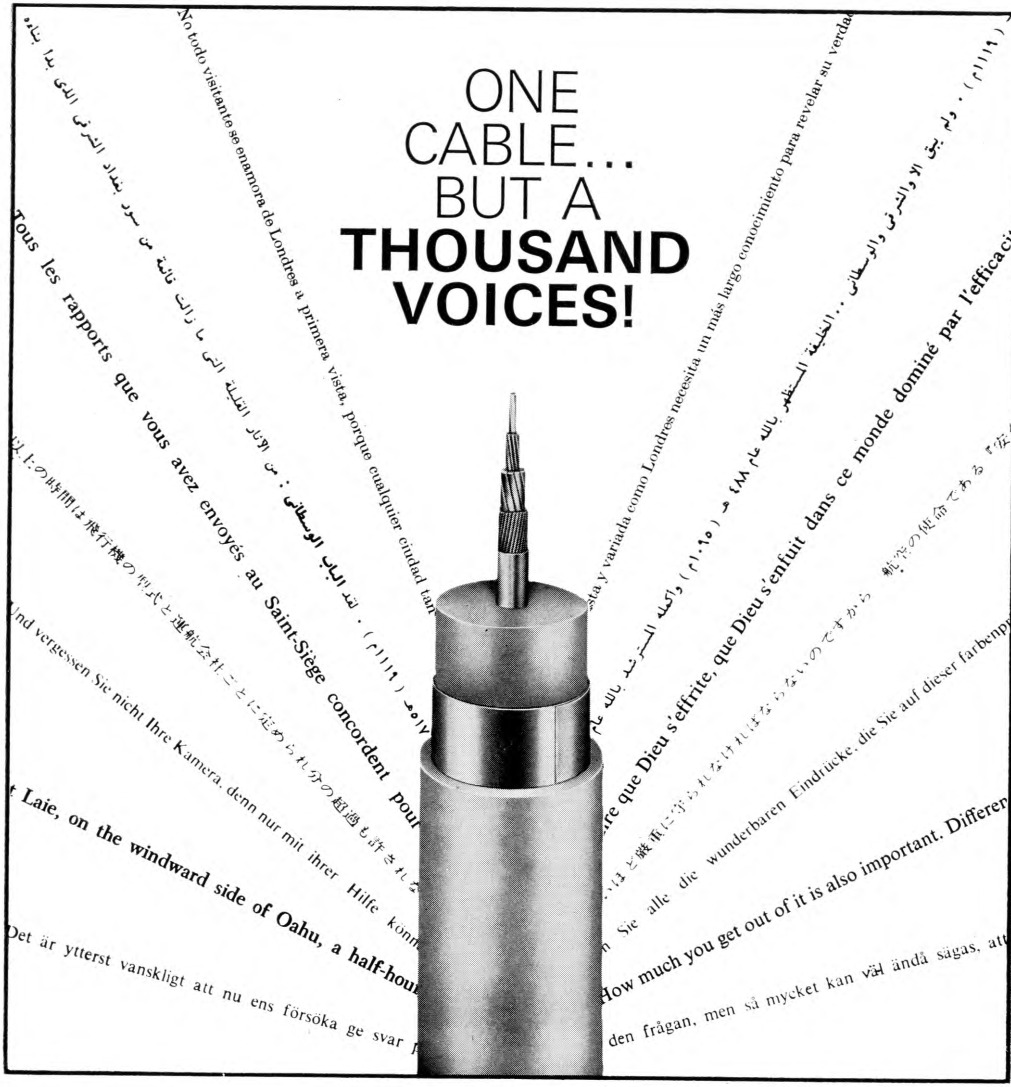


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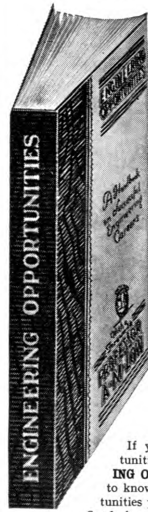


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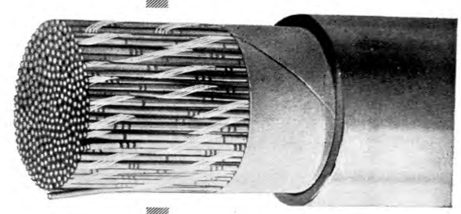


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## INDEX TO ADVERTISERS


| | Page |
|---|---|
| Adcola Products, Ltd. | 12 |
| Associated Electrical Industries, Ltd. | 3, 7–10 |
| Astralux Dynamics, Ltd. | 11, 17 |
| Avo, Ltd. | 26 |
| British Institute of Engineering Technology | 24 |
| Connollys (Blackley), Ltd. | 25 |
| Electro-Dynamic Construction Co., Ltd. | 2 |
| Fine Wires, Ltd. | 24 |
| Ferranti, Ltd. | 5 |
| G.E.C. (Telecommunications), Ltd. | 19 |
| Insuloid, Ltd. | 12 |
| Light Soldering Developments, Ltd. | 25 |
| Lustraphone, Ltd. | 24 |
| Marconi Co., Ltd., The | 20 |
| Multicore Solders, Ltd. | 4 |
| Oxley Developments Co., Ltd. | 18 |
| Pirelli General Cable Works, Ltd. | 6 |
| Pitman, Sir Isaac, & Sons, Ltd. | 18 |
| Preformed Line Products (Great Britain), Ltd. | 27 |
| Pye Telecommunications, Ltd. | 28 |
| Radiospares, Ltd. | 23 |
| Standard Telephones & Cables, Ltd. | 13–16 |
| Submarine Cables, Ltd. | 21 |
| Telephone Cables, Ltd. | 22 |
| Whiteley Electrical Radio Co., Ltd. | 4 |
| Winn & Coales, Ltd. | 18 |



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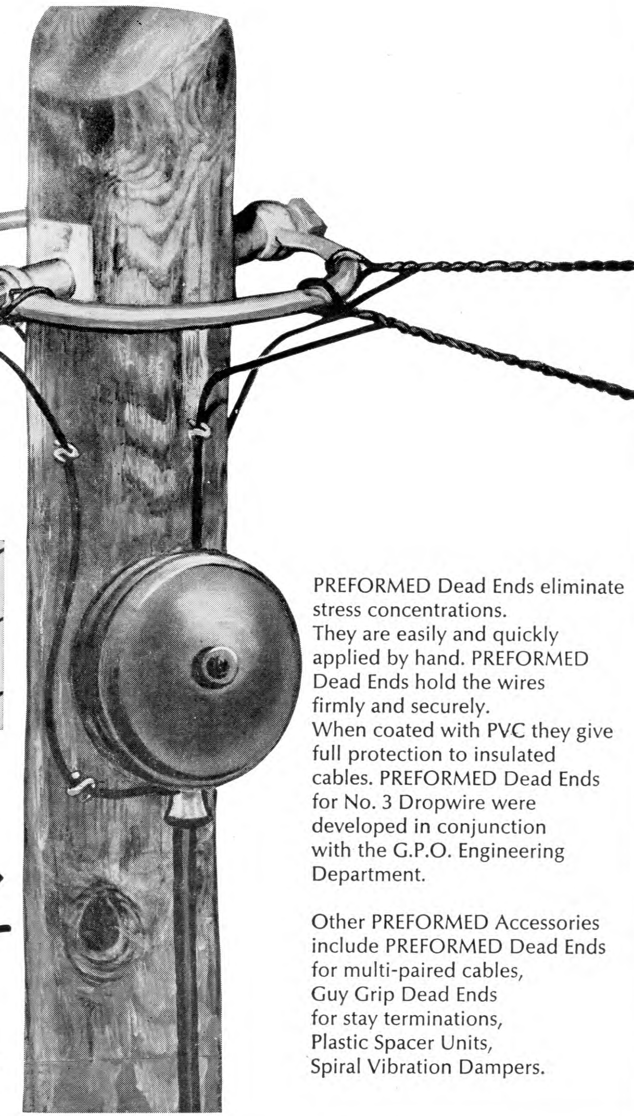

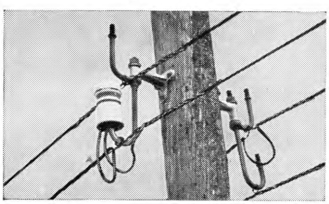

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