

# The Post Office Electrical Engineers' Journal

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VOL 65 PART 4/JANUARY 1973



# THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

VOL 65 PART 4 JANUARY 1973

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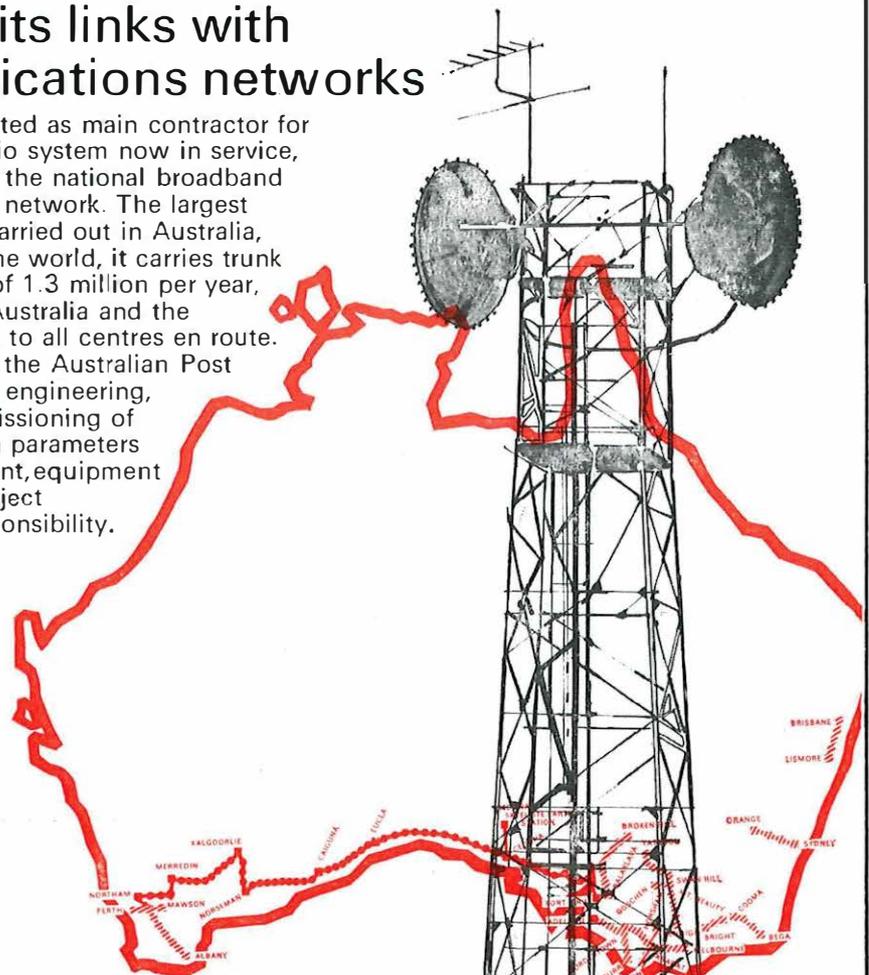
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## Australia extends its links with GEC Telecommunications networks

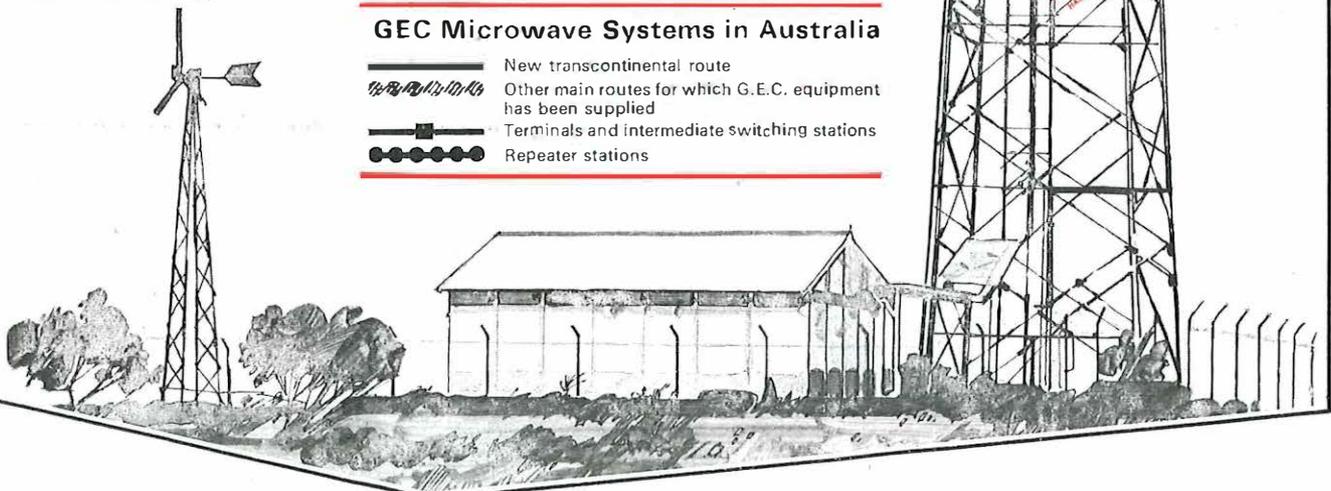
GEC of England is proud to have acted as main contractor for the East-West 2GHz microwave radio system now in service, which brings Western Australia into the national broadband trunk telephone and television relay network. The largest single telecommunications project carried out in Australia, and one of the longest systems in the world, it carries trunk telephone calls, at the present rate of 1.3 million per year, over 1500 miles between Western Australia and the Eastern States, and provides circuits to all centres en route. Working in close collaboration with the Australian Post Office, GEC was responsible for the engineering, manufacture, installation and commissioning of the radio equipment, and the design parameters for antennas and feeders, power plant, equipment shelters and towers, and overall project management—an A\$8,000,000 responsibility.

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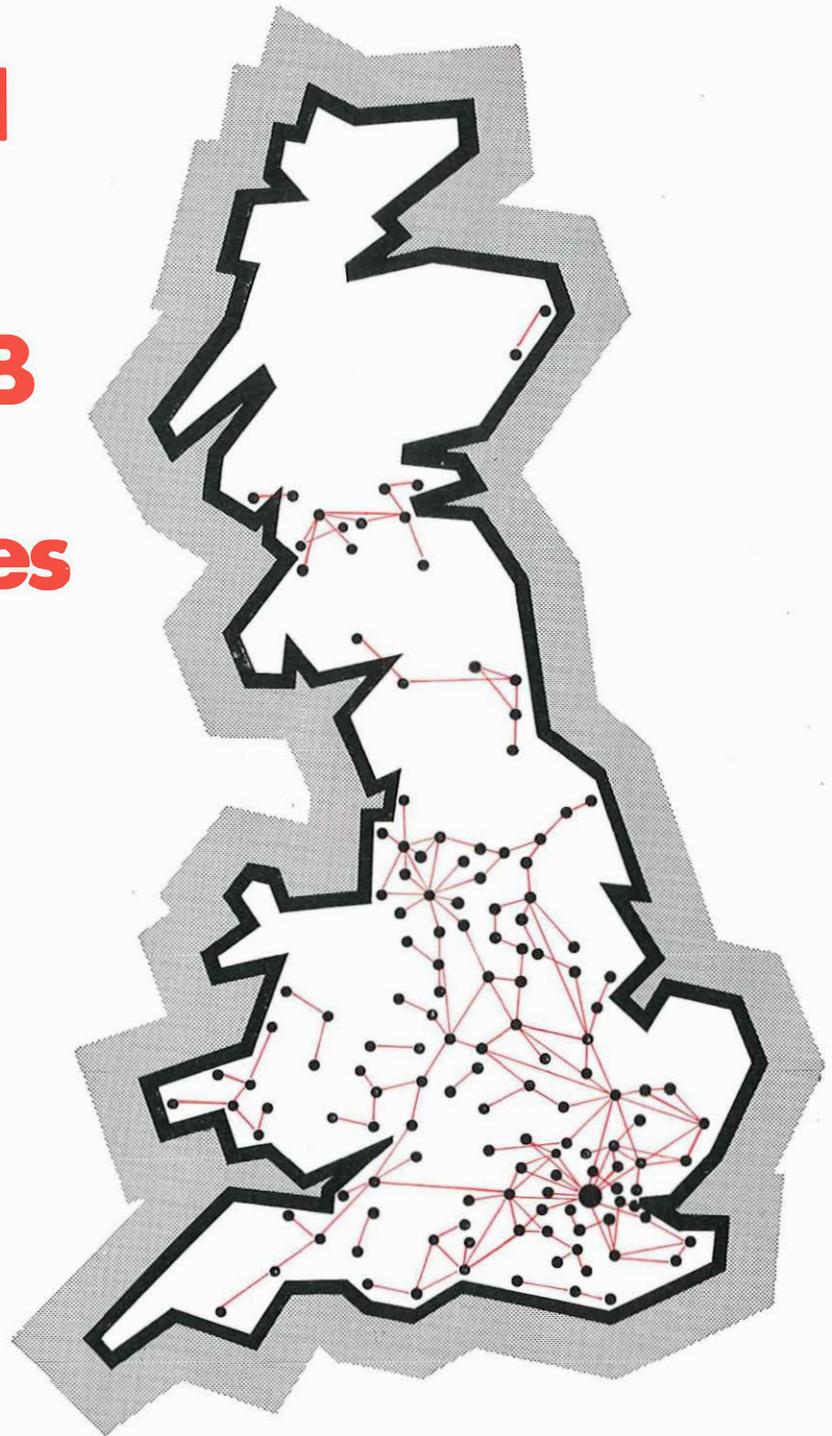
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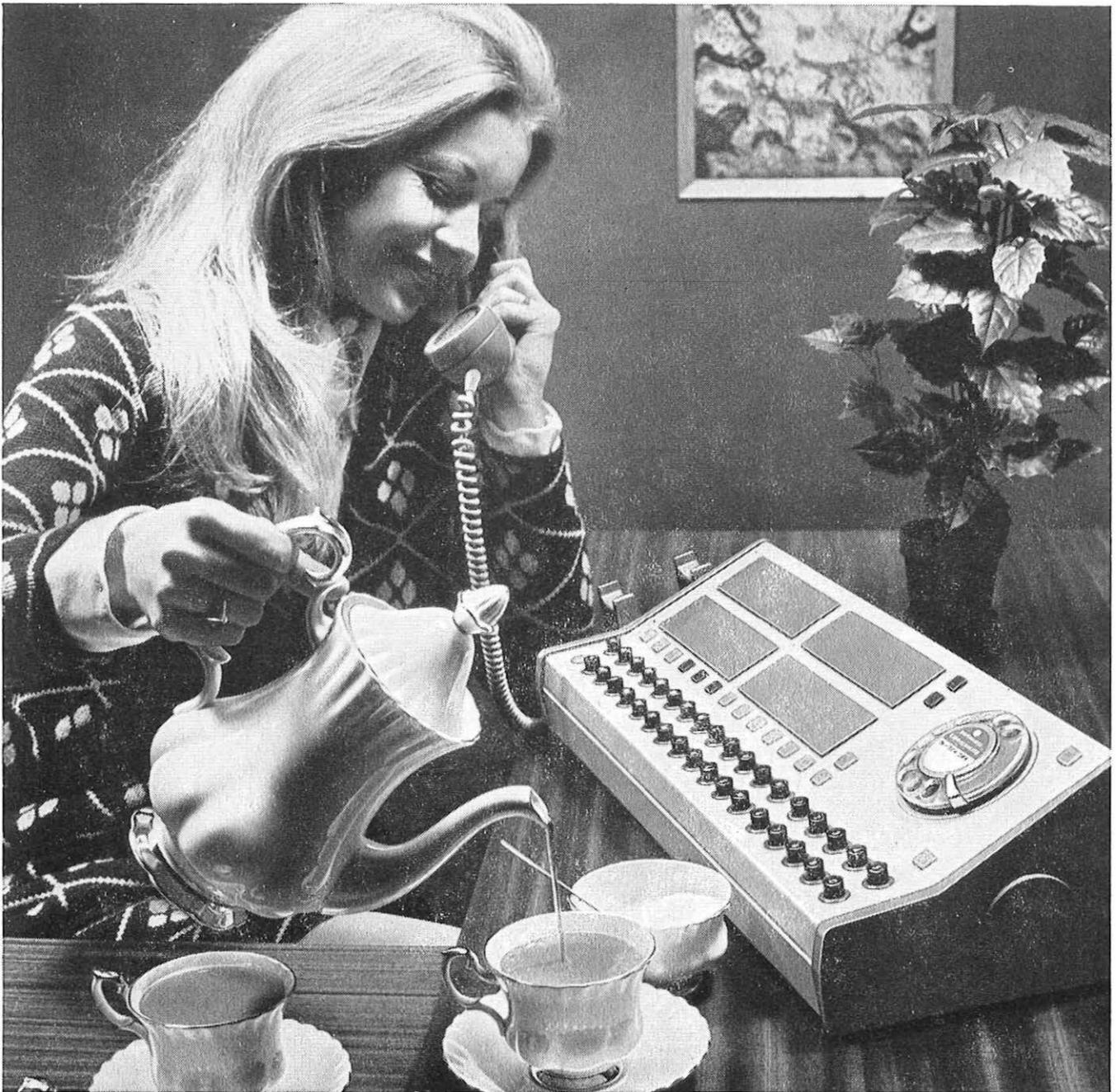


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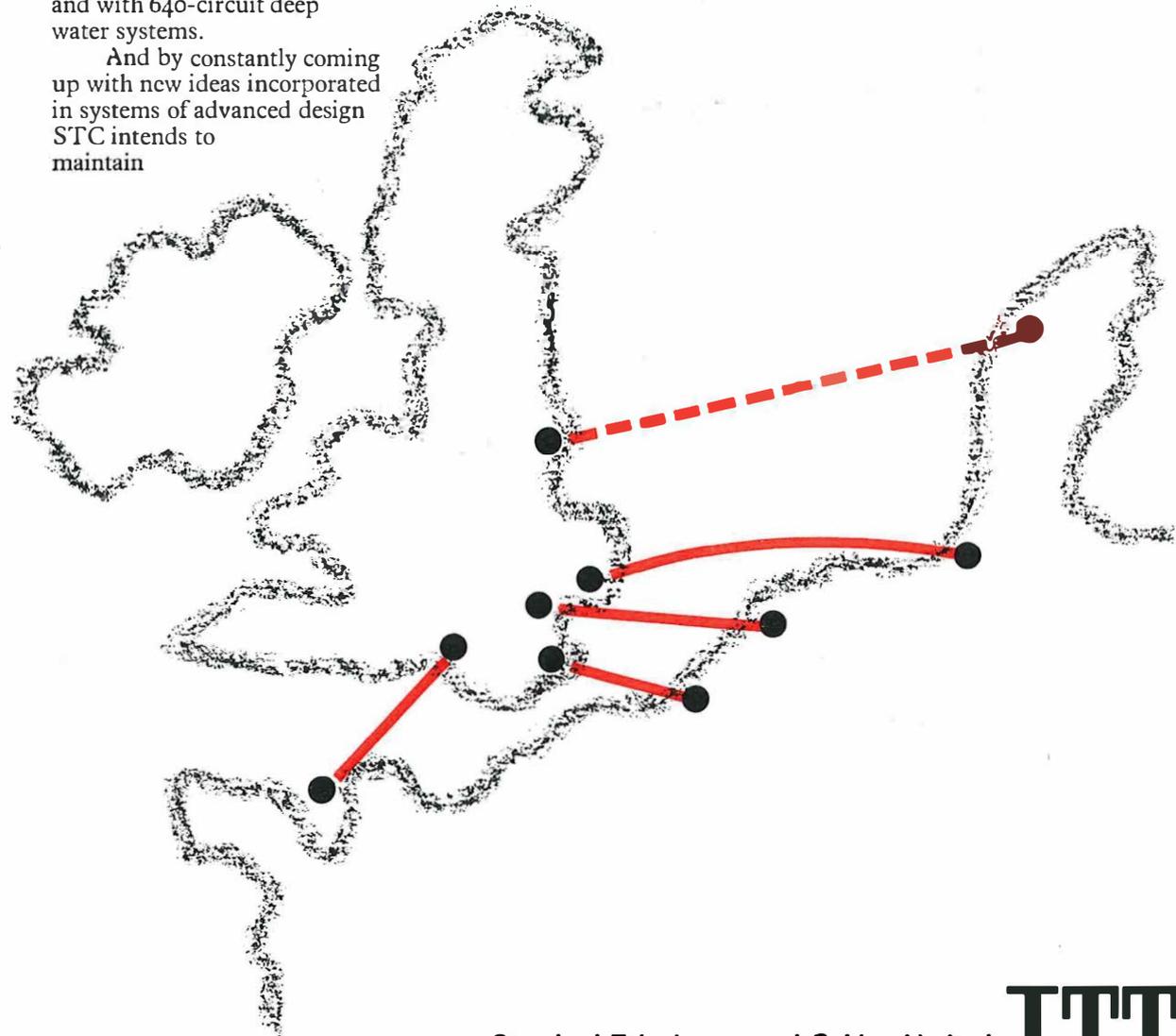
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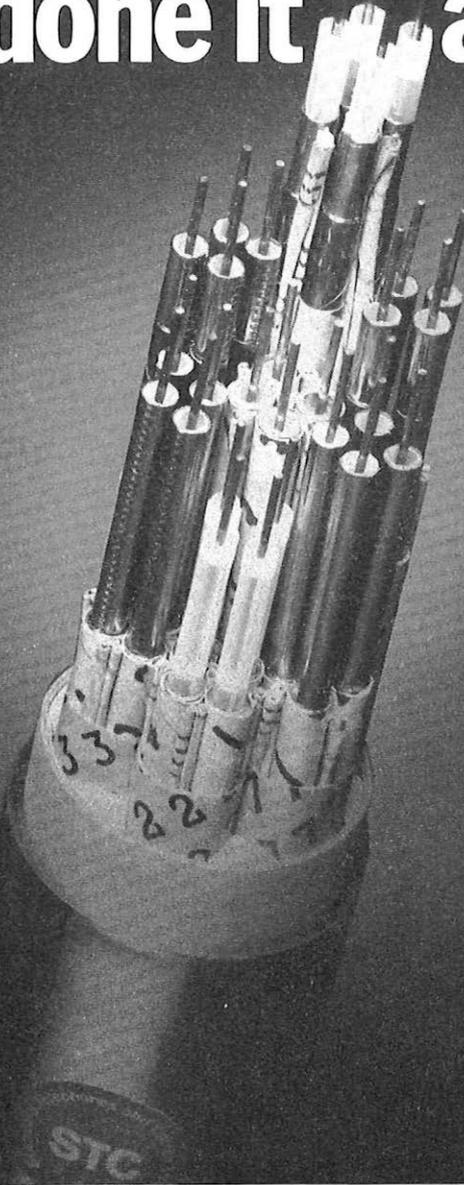


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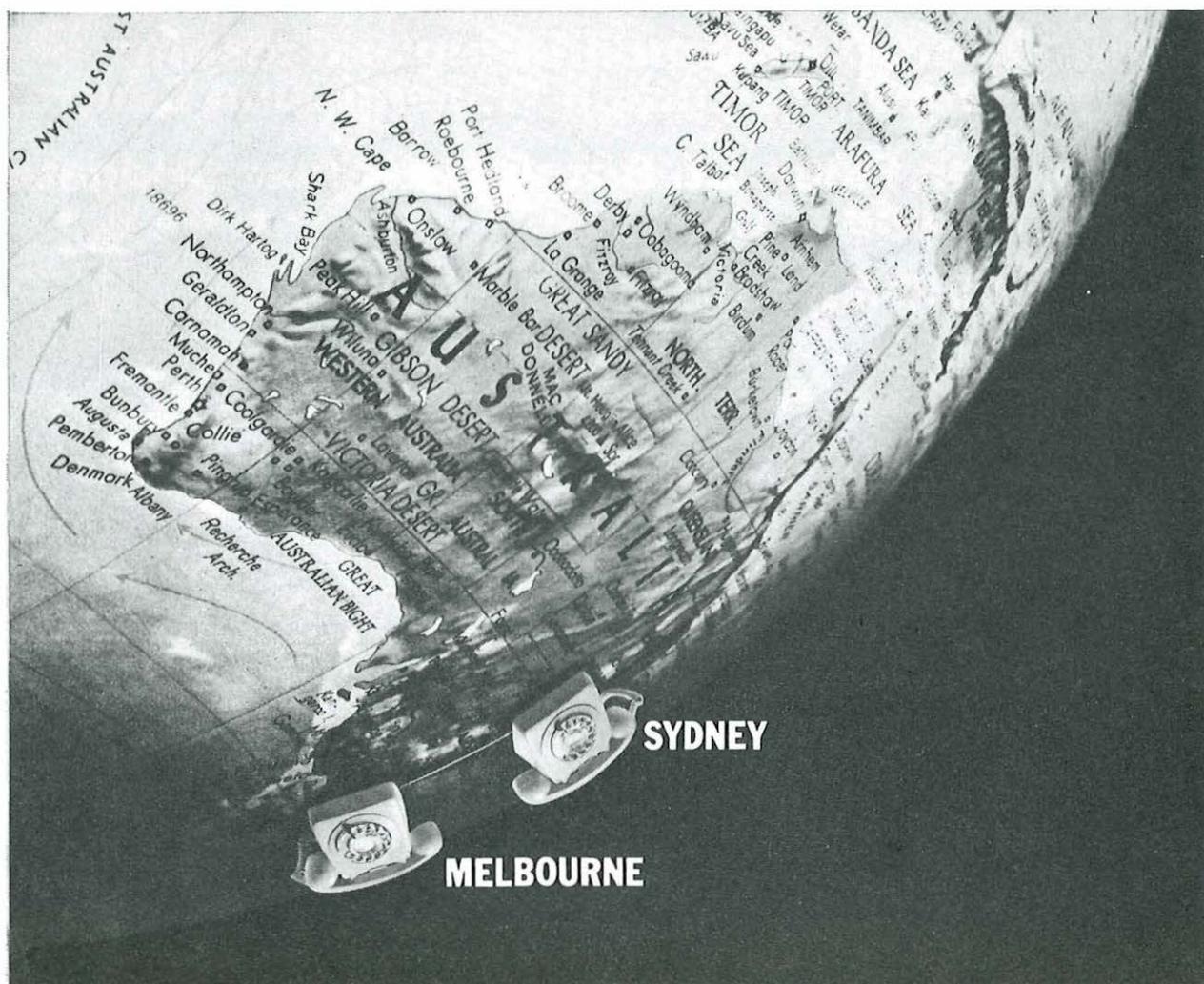
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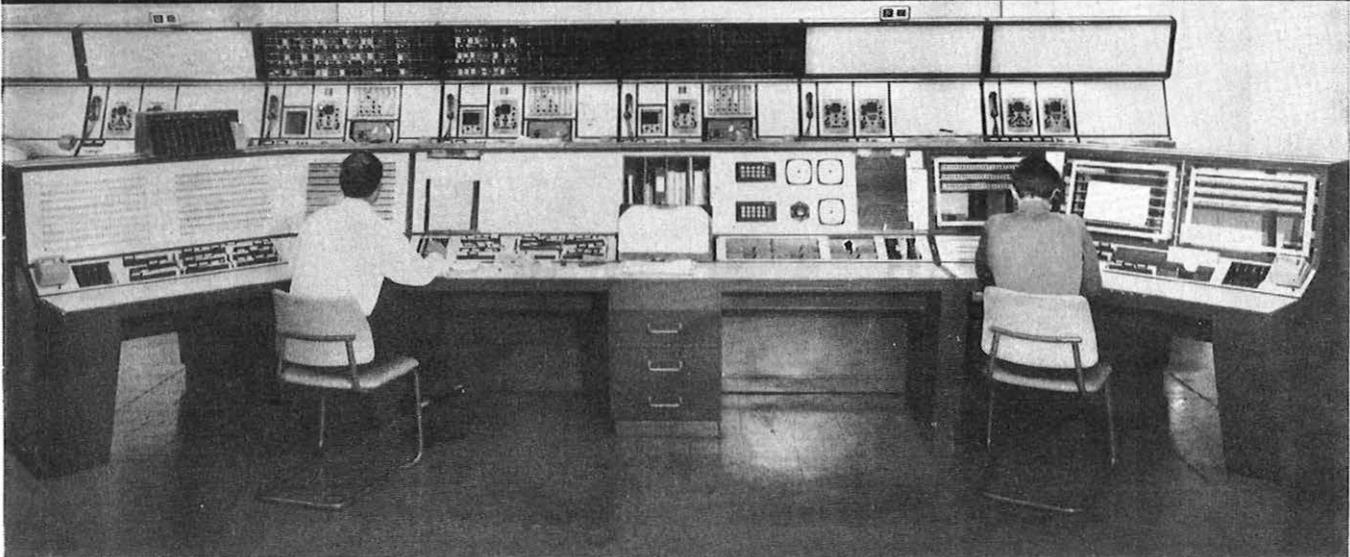
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On 31 December 1972, N. C. C. de Jong, B.Sc.(Eng.), C.Eng., M.I.C.E., F.I.Mech.E., F.I.E.E., Director Mechanization and Buildings, Postal Headquarters, retired after a full and distinguished Post Office career during which he gave unstinting support to the Institution of Post Office Electrical Engineers. In April 1967 he was appointed Chairman of Council and Chairman of the Board of Editors of the *Journal* and in these roles has displayed the same qualities of energy, zeal and high efficiency which characterized all his official work. An account of his earlier career was published in the January 1967 issue of the *Journal*. Only a few know, however, that, as a result of war-time service as a member of the SHAEF Mission to the Netherlands, he was awarded, exceptionally, the Bronze Star Medal of the United States of America and was made an officer of the Order of Orange-Nassau by Her Majesty Queen Wilhelmina of the Netherlands.

Mr. de Jong has been the driving force behind the plans to modernize and mechanize the processes of handling and sorting mail. He has travelled widely in his quest for the best solutions to postal mechanization problems and strongly supported British engineering achievement in this most difficult of disciplines. His initiative culminated in the highly successful first British Postal Engineering Conference in May 1970, the results of which were summarized in his series of articles in the *Journal* during 1970 and 1971.

The President of the Institution, Professor J. H. H. Merri-man has appointed Mr. J. F. P. Thomas to succeed Mr. de Jong as Chairman of Council. Frank Thomas, well known in the B.P.O. and the telecommunications industry, spent his early career on submarine cable system work leading to the first transatlantic telephone cable project. Since then he has been involved in the rapid expansion of the inland trunk network, and recently became Director of the B.P.O. Network Planning Department.

# A New Code Translator for the Letter-Sorting System

## Part 1—Postcodes and their Use

J. D. ANDREWS, C.ENG., M.I.E.E.†

U.D.C. 681.178:656.851

*Operational experience obtained from using the code-sorting system for handling letter mail has led to changes in its concept and, hence, to changes in facilities required of the machines. The decision to concentrate all sorting into about 100 offices has led to changes in the Postcode and to changes in the way machine codes printed on envelopes are used to control the sorting operation. Part 1 describes some of the features which have influenced the development of the Postcode and explains how codes are used to control the sorting of letter mail. Subsequent parts will describe the design of the new translator which has been developed to provide the new facilities now seen to be required.*

### INTRODUCTION

A system for the automatic processing of the letter mail service has been evolved by the British Post Office.<sup>1</sup> In this system, code marks are printed on envelopes when the address is first read and these code marks are used to control all subsequent sorting operations, hence the name which is given to it—the code-sorting system. The four major equipments in the system are:

- (a) mail-preparation machines which separate the mail into various sizes and priority classes,
- (b) coding desks which present the envelope to an operator for him to read the address and key a code obtained from it,
- (c) sorting machines controlled by the code printed on each envelope by the coding desk, and
- (d) a translator required, firstly, to convert the keyed sequence to a concise form for printing on the envelope and, secondly, to convert the printed code read automatically by the sorting machine to a sorting instruction appropriate to that stage of sorting.

The early years of operating the system showed the need for changes in facilities. Whilst many of these changes were accommodated by changes in the machines, one of them required a completely new design of translator. The advantages offered by the new facility were sufficient to justify the production of a new design—to be described in the second part of this article. In developing the new equipment, advantage was taken of advances in technology which had occurred since the development of the earlier design, more than a decade previously. The new equipment employs standard data processors with magnetic-drum stores and some tailor-made electronic equipment.

This first part describes the mail-sorting system which the translator must serve and also the development and application of the codes which it must translate.

### CODES AND THE MAIL FLOW

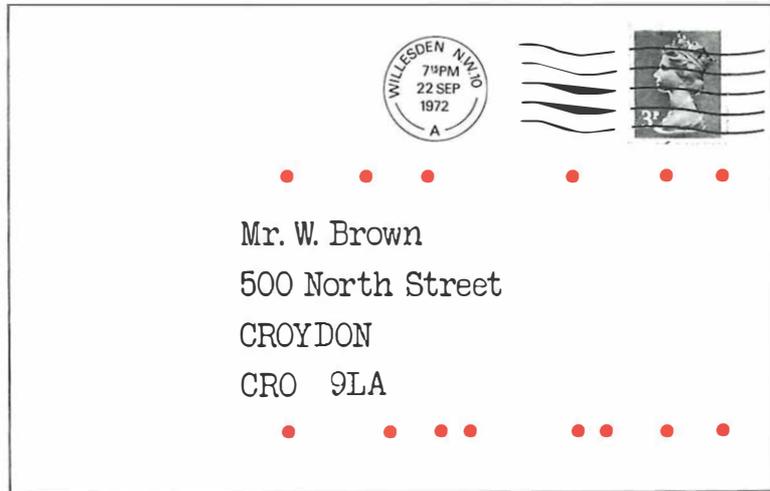
The mail-flow system, which has been evolved over more than a century to suit the manual sorting system in the United Kingdom, has sorting offices in about 1,700 post towns, the names of which form part of the correct address. Mail is collected and then sorted in one of these 1,700 offices and consigned to the destination post town, either directly or through an intermediate sorting office.

The sorting arrangements made within an office are designed to suit a 48-box fitting, this being the largest unit into which a postman can conveniently sort mail. The same fittings are generally used for all stages of sorting, both outgoing mail to other towns and mail incoming to a particular town. This 48-way "switch" is as much used in the postal business as the 10-way switch is used in telecommunication. Mail passes through, on average, 3·5 of these 48-way switching stages in its passage through the system to one of the 18 million delivery points.

The interconnexions used between post towns produce next-day delivery for 92 per cent of first-class mail, with 90 per cent of the second-class mail delivered one day later. To achieve this good service, a considerable number of direct selections must be made between one post town and another. Typically, 30 per cent of mail is for local delivery, 55 per cent for direct despatch to other towns, leaving only 15 per cent to pass through indirect forwarding offices.

The code-sorting system was originally required to operate within the constraints of the existing manual system. The Postcode and the machine code printed on the envelope were designed to provide the required sorting information in two separate parts, one for outward sorting to the destination post town and the other for inward sorting to the street in that town. This division was a natural choice because the number of post towns in Britain (1,700) is about the same as the number of streets in a typical post town. This equality allowed a 12-bit machine code to be used for each part and, thus, allowed common designs of code-mark printers, readers and code translators to be used.

† Postal Mechanization and Buildings Department, Postal Headquarters.



NOTE: The code marks are printed in a phosphor which is normally invisible

FIG. 1—An envelope bearing a Postcode and code marks

### The Original Postcode for Norwich

Postcodes were first applied in Britain to Norwich in 1959. The codes allocated were based on the assumption that each of the 1,700 post towns would have its own set of codes. NOR 12A is a typical Norwich code. NOR is a constant representing Norwich and there were to be about 1,700 such codes, one representing each post town. 12A is one of the 2,600 combinations of the fixed format of figure-figure-letter, which was adopted. These codes were allocated to parts of Norwich which are indivisible for delivery purposes. This Postcode, therefore, contains sufficient information for it to be used to control all sorting operations from the moment of posting to the assembly of an individual postman's walk (a delivery round of 2-3 hours). The code specifies the address but not the route and, thus, allows sorting plans to be rearranged to suit future needs.

### The Code Marked on an Envelope

Fig. 1 shows the two rows of code marks which are printed on each envelope passing through the code-sorting system. The lower row is a translation of the outward part of the Postcode (e.g. NOR) or of the town name if the Postcode is absent. The upper row represents the inward part of the Postcode (e.g. 12A) or the street name if the Postcode is absent. Each row of marks consists of 14 bits, the first and last being for start and parity, with the remaining 12 giving 4,096 ( $2^{12}$ ) combinations. The code marks are "read" at the input to each sorting machine and sent to a common translator for translation to routing instructions appropriate to that stage of sorting. In the system developed first at Luton and Norwich and now implemented in ten other towns, the sorting machines operate on only a 12-bit code drawn from one row of marks or the other. The translator was, therefore,

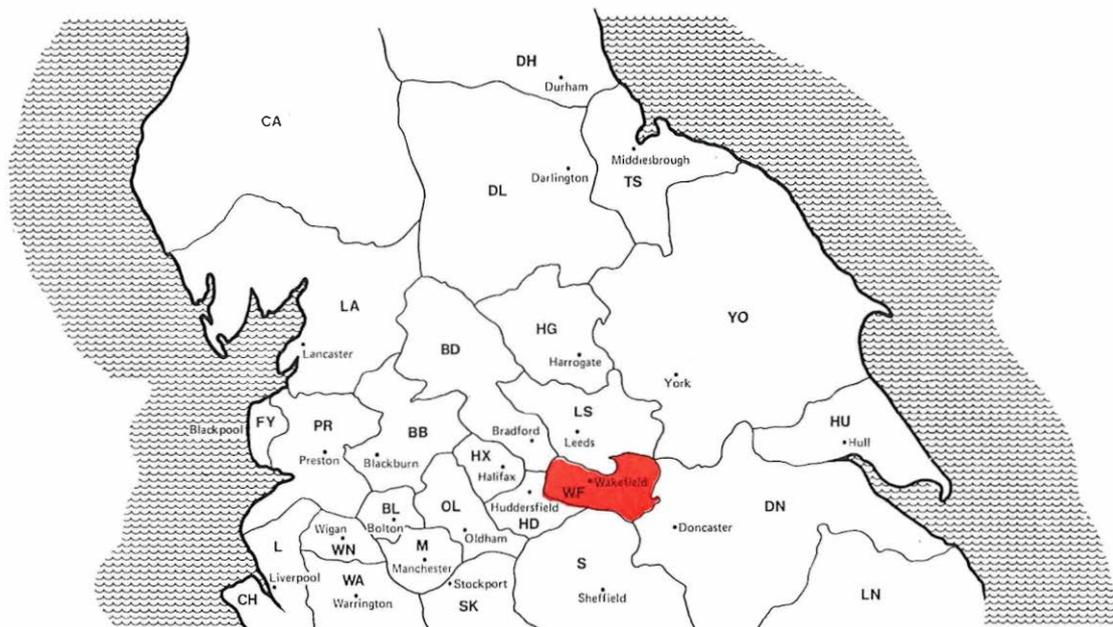


FIG. 2—M.L.O. areas in the north of England

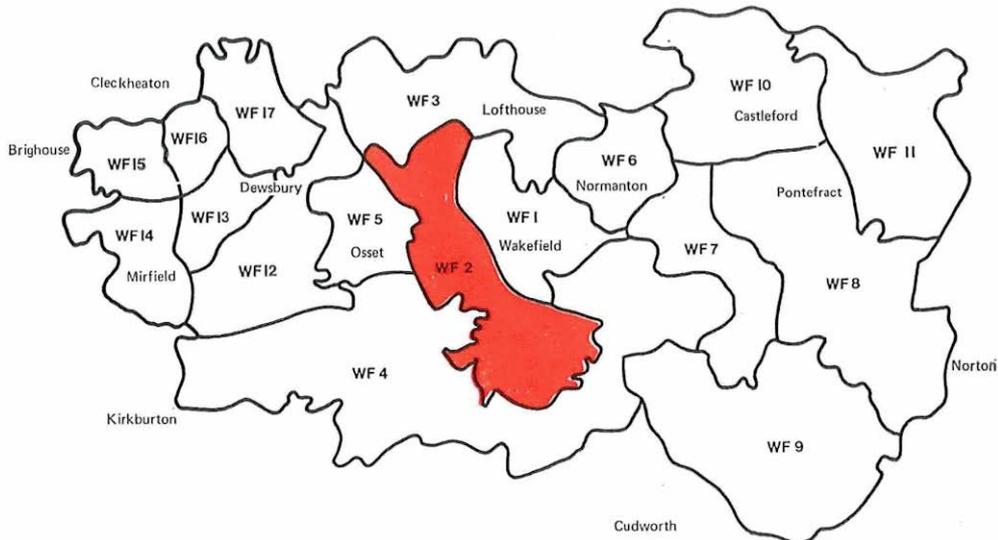


FIG. 3—The Wakefield M.L.O. area divided into districts

designed to recognize only  $2^{12}$  (4,096) different code patterns.

Operating experience soon showed that to mechanize the existing manual system would prove too expensive because machines located in all 1,700 offices would be under-utilized. An operating system was, therefore, devised which planned to concentrate all of the sorting work into about 100 mechanized letter offices (M.L.O.). These offices would each process several million items per week and, thus, adequately load the mail-handling machines. It was envisaged that each M.L.O. would have direct connexions to every other M.L.O. thus reducing the number of selections made when sorting mail to other offices, increasing the traffic on the fewer routes and eliminating the need for the mail to pass through forwarding offices.

#### THE NEW POSTCODE

The plans to concentrate all mail sorting into a few M.L.O.s introduced the need to translate a 24-bit code. To comprehend the need more clearly, it is first necessary to examine the way the Postcode was changed to accommodate the concentration into fewer offices.

The Postcode still retained the same "shape" with two nearly-equal parts—the first, outward, part to define the town and the second, inward, part to define a small part of a postman's delivery walk. Each M.L.O. is identified by the first part of the code which is unique to that M.L.O. Fig. 2 shows how the north of England is divided into M.L.O. areas each identified by one or two characters. The boundaries of these areas were chosen from the national postal-delivery boundaries which have existed for many years. In the code WF2 2AB, "WF" represents Wakefield. It is possible to have more than one set of letters to represent an M.L.O., e.g. DW might have been used for Dewsbury instead of WF12 and still have been served by the Wakefield M.L.O. It was, however, considered essential to employ only one set of characters for each M.L.O. in order to allow the manual sorting of unmachinable items, such as packets, to follow the same pattern as machine-sorted mail. (A human may remember the correct sorting for about 100 codes but not for 1,700.)

The first figures which follow these letters fall within the range 1-99 and are used to identify districts in the M.L.O. (Fig. 3). The districts normally conform to post towns in suburban and rural areas but large post towns may be divided into several districts using natural boundaries such as rivers and roads with, where possible, separate interests such as business, industrial and residential contained in individual districts. As an example, Pontefract occupies districts 7, 8 and 9 in the Wakefield code.

Except for Norwich, whose code is to be changed to conform to the national pattern, the inward part has a fixed format of figure-letter-letter, e.g. 1AB. All the numerals 0-9 are used but only 20 alphabetical letters, C, I, K, M, O and V being omitted because of possible confusion during reading with other characters. The numeral divides each district into sectors. Fig. 4 shows how the Wakefield district 2 is divided

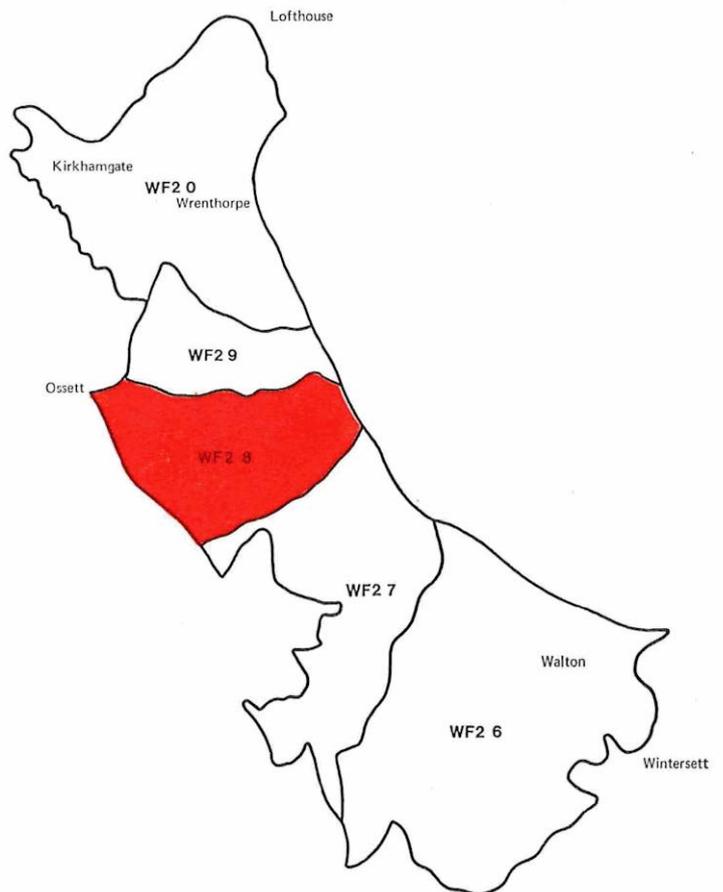


FIG. 4—Wakefield district WF2 divided into sectors

into five sectors. Each sector is then divided into code units. The units are allocated in a systematic way to allow any possible pattern of a postman's delivery walk to be assembled. To do this, each part of the town likely to remain indivisible for delivery purposes is allocated a separate code unit. One



FIG. 5—Allocation of code units within sector 8 of WF2

unit is generally allocated to all addresses in the part of a road between intersections. Fig. 5 shows a typical arrangement for part of sector 8 in WF2.

It is common to find that a postman's walk contains 20–30 code units. Individual units are sometimes allocated to single addresses—for instance, where the daily delivery exceeds about 20 items. Of the 400 possible codes within a sector, less than 200 are allocated initially in order to allow for growth. Spare capacity also exists in the sector numbering where only about one-third of the numbers are allocated. The reason for this under-employment of sector numbers lies in the inability of the translator-controlled sorting machines to react to both rows of code marks. To obtain full benefit from the concentration of mail-sorting into the planned 100 mechanized offices, it is essential that full advantage be taken of the ability of the sorting machine to operate to 144 selec-

tions. There is, however, no certainty that the mail destined for one particular district in an M.L.O. will fully utilize a machine and yet the equipment design was such that sorting must be done first using the outward row of 12 code marks (to districts of the M.L.O.) and then, on a second pass through a sorting machine, be sorted to the final address within a district using the inward row of 12 code marks. The under-employment of sector numbers is an attempt to allow sorting-machine loads to be adjusted nearer to optimum. With this technique, it is possible to group together certain district numbers when sorting on the outward row of code marks in such a way that, although several district numbers may be presented for secondary sorting, no confusion exists in sector numbers, i.e. not more than ten sector numbers are presented to the secondary machine.

Fig. 6 shows the allocated codes in Wakefield. It will be seen

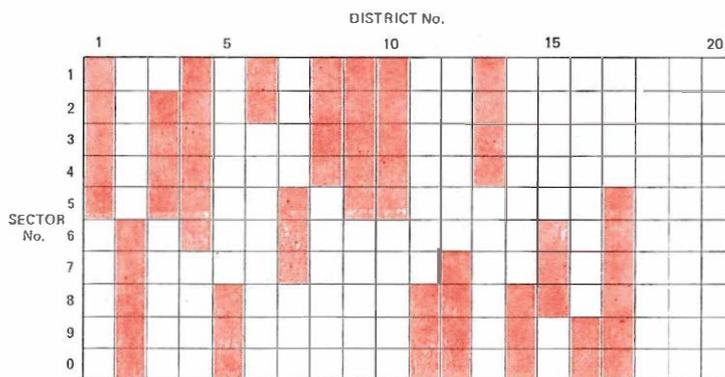


FIG. 6—Allocation of district and sector numbers in the Wakefield Postcode

that districts 5, 6 and 7 of Wakefield can be combined to form a load. This can later be changed to districts 5, 7 and 8 but it will be seen that this is of limited value because, for instance, districts, 1, 3, 4, 7, 9, 10 and 17 can never appear together on a sorting machine with the old translator because they each contain a sector number 5. This technique does not, therefore, justify the arrangement which restricts to about one-third the number of codes which are available. There is another reason for the generous allocation of district numbers. During the many years in which manual and mechanized office will exist together in the system, there is a need for the separate identities of each of the original post towns to be preserved in the Postcode. This has been done by allocating to each post town its own district number(s). Many of the post towns are small and do not, therefore, contain enough code units to fill more than a few sectors. Most areas have now been coded with the restricted allocation of sector numbering. The unused numbers are of some value in the redundancy which is offered; they also leave spare numbers which may be of value for expansion, but the price to be paid is an extra digit in the Postcode as the district number is forced above 9.

In addition to Norwich, there are some other departures from a constant format but these are all confined to the outward part of the code. A major reason for the departure from a fixed arrangement of three characters beginning with an alphabetical letter and finishing with a numeral (c.g. CR9 and WF2) was the decision that the code must incorporate all existing district numbering schemes such as occur in London. These have been in use for many years and already appear on about 90 per cent of mail to those places. This departure from standard has been worsened because of a need to sub-divide some of the London districts still further and this has been done by adding a letter to the existing numbering scheme, e.g. WC1A, B, C, etc.

Other abnormalities occur in Croydon where district 0 has been allocated (all others start at 1) and in Newport where district T has been allocated to make NPT in addition to the more normal NP1, 2, 3, etc. These departures from standard now appear to be undesirable because they may lead to a greater number of errors.

### The Development of Postcodes

It was inevitable that there would be some compromises in the code because many interests were involved during the decade of its development. During its evolution, note was taken, for instance, of public reaction and of advice from the Applied Psychology Unit of the Medical Research Council; the needs of current postal operating practice and of possible future optical character recognition (o.c.r.) systems for reading addresses were also major factors involved.

During the development of the Postcode in Britain it was not possible to use lessons learned abroad because the Norwich Postcodes were the first in the world. A Postcode was later developed in the U.S.A. and quickly applied as the ZIP CODE to the whole of that country in 1963. Its speedy application was possible because it employs a 5-digit number to identify only the existing delivery offices. These numbers were announced by public advertisement. The Postcode in Britain, however, must be allocated to each of the 18 million delivery points individually because it carries information to allow the whole sorting operation to be controlled and not just the easier, outward, part. Many countries, notably Australia, West Germany, Japan, U.S.S.R. and Italy, followed the American lead and introduced an all-numeral code to define only the "town" part of the address. This type of code is now seen to be of only limited value because sorting machines controlled by it, as for instance are all machines in Australia and Japan, can perform only half of the sorting operation. A technique is being developed in the U.S.A. to extract up to 15 characters from the address in order to allow sorting to the delivery postman *and* the sequencing of his mail so that

it is automatically sorted into delivery order. Other countries also are beginning to examine this line. Canada has started a postcoding program late enough to benefit from the experience of others and is now introducing a code to define the whole address, as in the British code, but with a fixed format of six characters—alternately alphabetical and numeral.

### The Extract Code

Less than half of the mail yet bears a Postcode and, to allow the code-sorting system to handle all mail, it is necessary to adopt a technique in which characters are extracted from the address according to fixed rules. These extracted codes are generally of five characters and are translated into the 12-bit machine codes on the envelope. The rules are:

- (a) For outward sorting, extract the first three and the last two characters from the post town name, c.g. Wakefield gives WAKLD;
- (b) For inward sorting, extract the first two and the last two characters from the street name followed by the first character of the thoroughfare type, e.g. Manor Crescent gives MAORC.

The use of these extracted codes is, however, much less effective because:

- (a) ten characters must be keyed to describe the address, instead of 5–7 for the Postcode,
- (b) about 5 per cent of the codes are ambiguous and this is worsened by that mail which is incorrectly addressed, e.g. by the use of a town name which is not a proper post town,
- (c) the extraction process must be done in two operations, one at the office of posting and the other at the delivery office where a memory for only those streets in the one M.L.O. needs to be stored and translated, and
- (d) in any future automatic reading system, a machine may be able to locate and read a Postcode but is much less likely to be able to read and extract one from a whole address.

### THE NEED FOR THE NEW TRANSLATOR

The plans to concentrate mail sorting into about 100 M.L.O.s instead of 1,700 post towns mean that, when sorting mail arriving for delivery at the M.L.O., it is necessary to consider information both in the outward part of the Postcode (the district number) and the inward part. This information is spread over both rows of 12 code marks. The sorting may be done by two sequential passes through a sorting machine, the first pass to divide the mail into, perhaps, 20 streams according to district number contained in the outward row of marks, and the second to pass these 20 streams separately through machines for sorting on the inward row of code marks. Because of the inefficiency of use of the present 144-box machine during the first pass it may then be necessary, sometimes, to include a third pass through a sorting machine to produce an adequately fine sortation. This wasteful technique must be adopted when using the current design of code translators as they were designed to operate on only a 12-bit code. The new translator (to be described in Part 2 of this article) allows a more efficient sorting arrangement to be adopted. The inability of the old translator to accept all 24 bits of the machine code and, thereby, separate, for instance, code WF1 IAB from WF4 IAB, will no longer apply. The new translator will allow each 24-bit code in an M.L.O. to be treated individually.

It is not, however, possible to translate the 24-bit codes for outward sorting to the whole country because this would imply a memory with answers to  $2^{24}$  (about 16 million) questions—nor is it necessary to do this. The original technique of outward sorting using only the one row of 12 code marks which represents the outward code is all that is required,

except for a few frequently-used addresses, e.g. football pools and mail-order firms. For these, the selection is made direct to the delivery address from the originating M.L.O. The new translator is designed to allow a limited number (at present a maximum of 100) of such codes for remote towns to be selected when outward sorting. All 24 bits of the code are read when outward sorting but the translator normally reacts only to the 12 outward marks and to the limited number of 24-bit codes which are appropriate to that particular M.L.O.

### Preparing the Coding and Sorting Data

Another major change included in the new translator system is a data preparation and modification system which has been designed to take full advantage of modern electronic data processing techniques. The system has been developed to allow the Post Office Data Processing Service (P.O.D.P.S.) to accept manuscript data from individual M.L.O.s, to check and process this data, and to return it as several million bits on punched paper tape for the M.L.O. to load on to its magnetic-drum memory. This system also allows minor changes in the information stored on the drum to be made locally in the M.L.O. by means of an easy-to-use conversational interaction between an operator, a processor and the drum stores. Data is keyed by the operator in response to simple commands printed by the control teletypewriter. These techniques for loading the memory replace the more laborious changing of code-wires, which was needed in the existing translator.

### THE WIDER USE OF POSTCODES

The postcoding of the whole country will be complete in 1973 with the exception of Norwich which will be re-coded less than two years later. When this is complete there will be, for the first time, a systematic address pattern for the whole country. Map makers are now beginning to include the boundaries on maps. Some organizations are beginning to use Postcodes as a basis for identifying customers, making up delivery rounds and costing delivery work. The Postcode file is now available for sale and many more commercial uses will undoubtedly be found for it. The Post Office has invested a large amount of effort in laying down the new address system and, now that it is nearly complete, can begin to recover the rewards in fields which are wider than just the sorting of mail.

### THE USE OF A STANDARD DATA PROCESSOR

As experience is gained in operating the M.L.O.s they will tend to depart from the traditional practices of the small office, which is busy for only a small proportion of the day while postmen prepare mail for the evening trains and, later, for morning dispatch. They will become mail processing factories; their number will be reduced from about 1,700 to little more than 100 but their size will not increase by the same ratio because sorting will be done more effectively in

the larger unit and because mail will be flowing at a constant rate for a large part of each day as a result of the greater advantage which can be taken from the load-spreading potential of the two-tier post.

To operate these new offices will need a greater contact between managers and the mail. Much more information will be available and greater possibilities exist for advantageous decision to be made to optimize the operation. There is, for instance, no accurate knowledge of the amount of mail which, at present, flows between the sorting offices—only a knowledge of the gross postings received from the public at each office. To gain this sort of information in the manual sorting system involves laborious manual counts which are normally done less frequently than once per year and are known to be inaccurate. This information has been sufficient to allow the old system to be shaped into one giving a performance better than almost anywhere in the world.

The design of the new translator described in this article and of LOCUM<sup>2</sup> (the machine-monitoring equipment described in the previous issue of this *Journal*) have been influenced by the certain need in the future for feedback of data to managers. These two equipments contact all of the mail-handling machines and already process, for other reasons, much of the data in which managers will be interested. Both equipments use the same type of small data processor which offer (as one of their advantages) the "open-endedness" of a program-controlled system. Many of the changes which will be called for when the need is seen to monitor or record certain events will be made merely by changes in software. Although the development effort required to change the software may be greater than that required for an equivalent change in hardware, the subsequent work in making the change to each installation will be much less. The two equipments will, thus, form an essential foundation for a modern and efficient letter-handling system.

### ACKNOWLEDGEMENT

The development of the plan for mechanizing mail handling and the design and allocation of the Postcode have been the work of many people. The responsibility for the work has rested with Planning and Operational Departments in Postal Headquarters and acknowledgement is made of this responsibility for their work and, in particular, to Mr. D. Stewart who has, for long, been involved.

The work is described in some detail here both to show the system to which the new translator operates and to record some of the influences on the design of the postal address coding scheme.

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# An Improved Radiophone Service for London— The Exchange Switching and Control Equipment

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*A previous article outlined the new improved radiophone system from the radio aspect. This article provides more detailed information on the use of specialized sleeve-control switchboard positions for handling various classes of radiophone traffic and outlines technically the equipment used.*

## INTRODUCTION

Two radiophone systems are in service at present, one in South Lancashire<sup>1</sup> and one in London.<sup>2</sup> The new improved system described in this article, the radio aspects of which were outlined in a previous article,<sup>3</sup> will eventually replace the existing London system.

The London Radiophone Service is controlled from Pimlico exchange in South West London. Prior to rearrangements for the new improved radiophone system, which is known as Radiophone System 3, the sleeve-control switchboard comprised a main suite of 46 positions and an 11-position island suite, the answering and outgoing multiples being common to all switchboard positions. Following the introduction of s.t.d. and the consequential reduction of assistance traffic, only the main suite was staffed, the island suite being virtually redundant. During the design of Radiophone System 3, it became apparent that there was insufficient answering-multiple capacity on the switchboard to meet the requirements of the new system, but, because a common dialling code was to be used for access from the public telephone network to both the existing Radiophone System 1 and the proposed Radiophone System 3, it was essential that both systems should appear on the same switchboard suite. Various methods of augmenting the common multiple were proposed but none was really feasible, particularly when future growth was considered. A decision was made to split the answering multiple of the two switchboard suites, so isolating the island suite from the common answering multiple, and providing, in effect, a completely new and unallocated multiple on the island suite. Subsequently, after allowing for growth of Radiophone System 3 traffic, some assistance circuits have been teed to appear on both switchboard suites. This serves to balance operator loading when radiophone traffic is light. The eleven positions on the island suite are technically and administratively split into two distinct groups, namely four combined booking/controlling positions which are normally used to answer incoming traffic from the public telephone network and then to call the required mobile radiophone via the control channel, and seven controlling positions used to complete calls to and from mobile radiophones over the traffic channels. During periods of light traffic, it is possible for booking/controlling positions to handle all traffic.

Radiophone System 3 was designed so that, wherever

possible, switchboard operating procedures and supervisory arrangements should follow standard telephone practice. All Radiophone System 3 users will have a national 5-digit number, the first digit of which will indicate the home system, for example, digit 1 for London. Each future provincial system will have its own discrete first digit.

## SWITCHBOARD ARRANGEMENTS

The switchboard arrangements are shown in Fig. 1.

### Booking/Controlling Positions

These positions are equipped with the standard key unit and sender for use on calls to the telephone network in place of the conventional telephone dial. The key unit is also used to transmit information direct to the control channel equipment on Radiophone System 3 calls. Each switchboard position is fitted with a key designated CONTROL CHANNEL SELECT and three lamps marked CONTROL CHANNEL SELECTED, CONTROL CHANNEL BUSY and CALL ACKNOWLEDGED, the key and lamps being mounted on the keyshelf adjacent to the key unit. The answering multiple associated with these positions will carry incoming traffic from the public telephone network to the radiophone service.

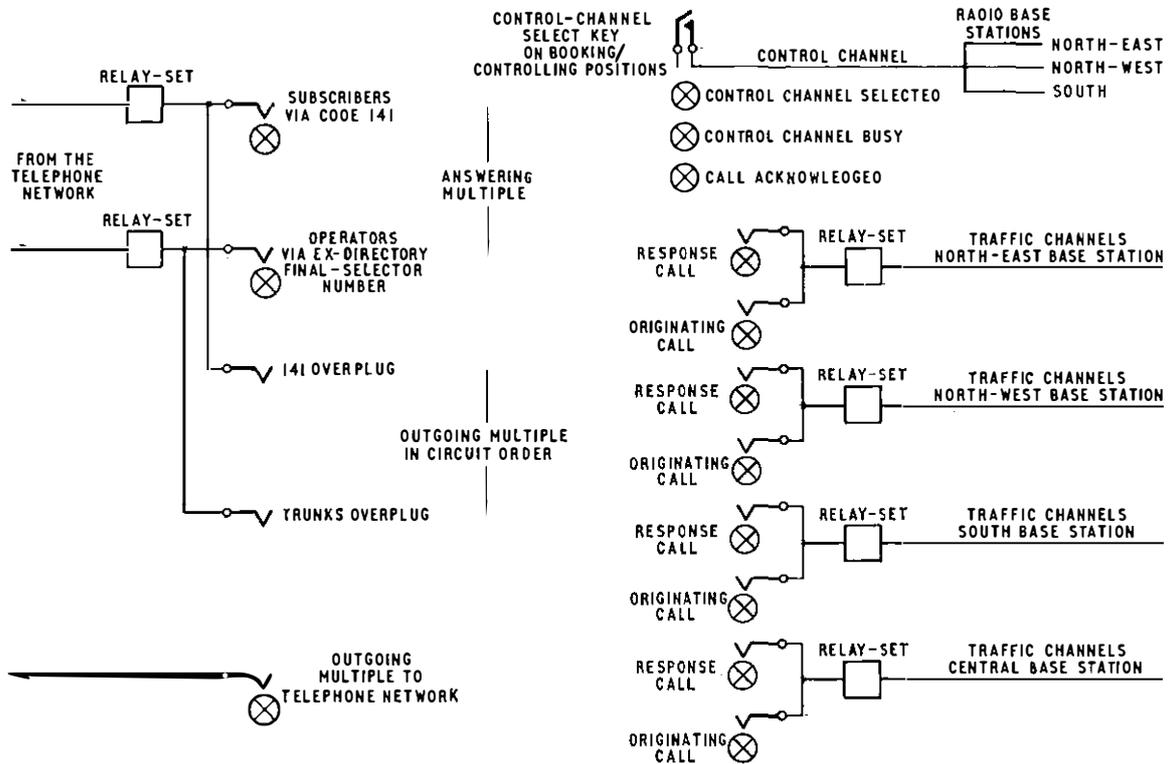
### Controlling Positions

These are standard sleeve-control positions with the answering multiple equipped mainly with traffic-channel jacks and lamps but, additionally, with any assistance circuits needed to balance operator loading. Each traffic channel has two lamps and, therefore, in the interest of simplicity, two adjacent answering jacks.

Discrete signalling from the mobile radiophone ensures that a user making an outgoing call causes the ORIGINATING lamp of the particular traffic channel to glow, whereas, when the mobile radiophone has been called by the operator over the control channel and is now calling the switchboard to complete the call, the traffic channel RESPONSE lamp glows. This multiple of traffic channel appearances also appears on the booking/controlling positions for use in periods of light traffic. Access is provided to the *overplug* multiple.

The *overplug* multiple is in effect an additional appearance in the outgoing multiple of the *incoming* circuits from the public telephone network but with the circuits in numerical order so that a particular circuit can be located quickly and easily. The auxiliary appearance of these incoming circuits is necessary to keep the radiophone operating procedure relatively straightforward.

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Note: All answering jacks, i.e. 141, trunks and traffic channels have a 3-panel repetition so that, when traffic is light, only one operator is required

FIG. 1—Outline of switchboard arrangements

Access is provided to an interposition circuit which appears on all booking/controlling positions. This circuit is required to enable operators answering *response* calls from mobile radiophones to obtain details from the booking operator of the circuit from the public telephone network used by the party requiring connexion to the mobile radiophone user.

### CALL FROM THE TELEPHONE NETWORK TO A MOBILE RADIOPHONE

The telephone subscriber obtains access to the radiophone switchboard by dialling the published code, where appropriate, usually 141, or via the assistance operator when direct access is not provided. Incoming calls from the public telephone network to the radiophone switchboard appear on the booking/controlling positions and the operator answering the call ascertains the number of the mobile radiophone required from the caller.

To call the mobile radiophone, the booking operator operates the CONTROL CHANNEL SELECT key if the control channel is free—CONTROL CHANNEL BUSY lamp dimmed—or waits for the channel to become free. When switched to the free control channel, the CONTROL CHANNEL SELECTED supervisory lamp glows to indicate that the equipment is ready to receive the required number. The booking operator then keys in the five digits of the number which are processed by the control-channel equipment and transmitted sequentially via each radio base station.

If the required mobile radiophone is within radio range and the mobile radio equipment is switched on, a calling signal is received from one or more of the radio base stations and locked on. Receipt of the calling signal by the mobile radiophone causes an automatic *call-acknowledged* signal to be returned to the booking operator via the radio base station. The CALL ACKNOWLEDGED supervisory lamp then glows on the switchboard and the controlling operator knows that the

mobile user's equipment is within range, switched on and has received the calling signal. However, this signal is not an answer signal nor does it indicate that completion of the call would necessarily follow as the mobile radiophone user may be away from the car and may not return for some time. On receipt of a *call-acknowledged* signal, the booking operator has no further use for the control channel and is automatically disconnected from the equipment to free it for use by other operators. Similarly, if a *call-acknowledged* signal is not received within a predetermined time period, automatic disconnection from the control channel occurs and, in each case, the CONTROL CHANNEL SELECTED lamp is dimmed. To obtain further access to the control channel, the operator must restore the CONTROL CHANNEL SELECT key, if still operated, and ensure that the CONTROL CHANNEL BUSY lamp is dimmed before attempting to re seize the circuit.

On receipt of a calling signal, the mobile user must call the radiophone switchboard on a traffic channel to enable the incoming call to be connected. A traffic channel is selected by the mobile user suitable for the area in which he is located using a map provided for the purpose and a call made to the switchboard. When a call is made to the radiophone switchboard subsequent to the receipt of an incoming calling signal, a discrete *response* call signal is sent to the switchboard to cause the appropriate lamp to glow on the controlling positions, ring tone being returned to the calling mobile. A RESPONSE call lamp glowing on the switchboard indicates to the operator that a calling cord should be used to answer the call, thus ensuring that, when the two parties are finally connected, the calling party from the public telephone network is on the answering side of the cord circuit to permit standard timing arrangements. Insertion of a calling-cord plug into the jack associated with the RESPONSE call lamp, causes the lamp to be dimmed, ring tone to be disconnected and transmission to be established between the controlling

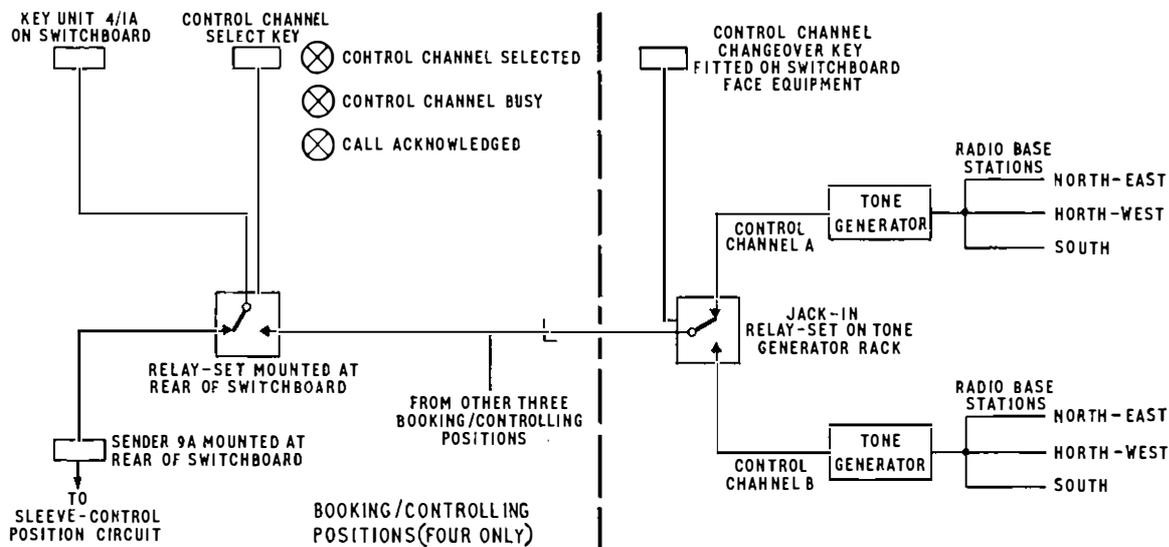


FIG. 2—Control-channel block diagram

operator and the mobile user. The operator then ascertains the number of the responding mobile and contacts the booking operator, direct, or via an inter-position circuit, to obtain details of the incoming circuit used by the party requiring connexion to the mobile user. The controlling operator then searches for the incoming circuit concerned in the *overplug* multiple and inserts the answering-cord plug into the appropriate jack. A clear supervisory is now given to the booking operator connected to that circuit and complete control of the call passes to the controlling operator. From this stage, the radiophone call follows standard procedures with the exception of the calling cord being in the answering multiple and vice versa. Normal supervisory signals are provided though flashing from the mobile unit is not possible.

#### CALL FROM A RADIOPHONE USER TO THE TELEPHONE NETWORK

A traffic channel appropriate to the area in which the vehicle is situated is selected and the call button operated. As there is no incoming calling signal present, a discrete *originating* call signal is sent to the radiophone centre to light the appropriate lamp on the controlling positions and cause ring tone to be returned to the mobile user.

A controlling operator answers the calling signal using an answer cord, insertion of the plug in the jack dimming the *ORIGINATING* call lamp and disconnecting ring tone. The controlling operator is aware from the discrete calling lamp that the mobile user is making an outgoing call, and not responding to a call from a booking operator. Therefore, the call can now be handled as for any other assistance call, with the calling cord used to complete the connexion to the required party. During periods of light traffic, originating calls may also be answered by the booking operator but procedures are unchanged.

#### CALL FROM A RADIOPHONE USER TO ANOTHER RADIOPHONE USER ON THE SAME SYSTEM

When a controlling operator answers an originating call signal and is informed that the calling party requires connexion to another mobile user on the system, contact must be made with the booking operator either direct or via the inter-position circuit to arrange for the required party to be

called. When the required mobile responds, the controlling operator contacts the booking operator to determine the circuit to be connected and is then informed that a mobile-to-mobile call is involved. This necessitates some liaison between controlling operators to complete setting up of the call.

#### TECHNICAL OUTLINE

The design of the Radiophone System 3 arose from the demand for service from potential customers and was carried out to a very short time scale. For this reason it was necessary to make use of known proven techniques and elements and of proprietary equipment. A technical outline of the system is given below.

#### Access to Radiophone Switchboard from the Telephone Network

Circuits of standard assistance relay-sets, as in use for System 1 in London, were modified as simply as possible to provide the *overplug* facility required for Radiophone System 3. This arrangement should be suitable for all future radiophone schemes as the number of equipments required is relatively small and does not warrant development of relay-sets solely for this purpose.

#### Traffic-Channel Termination

Eighteen traffic-channel relay sets were existing at Pimlico exchange, having been installed in readiness for Radiophone System 2. This system was originally intended to replace London System 1 but was subsequently abandoned on cost grounds. A relay-set was then designed using conventional relay circuitry to provide the facilities required for the new system but using only components available in the existing traffic-channel terminations. This arrangement permitted the British Post Office (B.P.O.) Factories Division to produce the eighteen relay-sets needed to open the service in a very short period of time.

#### Control Channel

The control channel (Fig. 2) is based on a proprietary remote-controlled sequential tone generator. It is, in essence, a device capable of receiving d.c. signals in decimal form from a key pad and encoding these signals into a voice-frequency form suitable for transmission sequentially to a maximum of three radio base stations. It can process a five-digit number

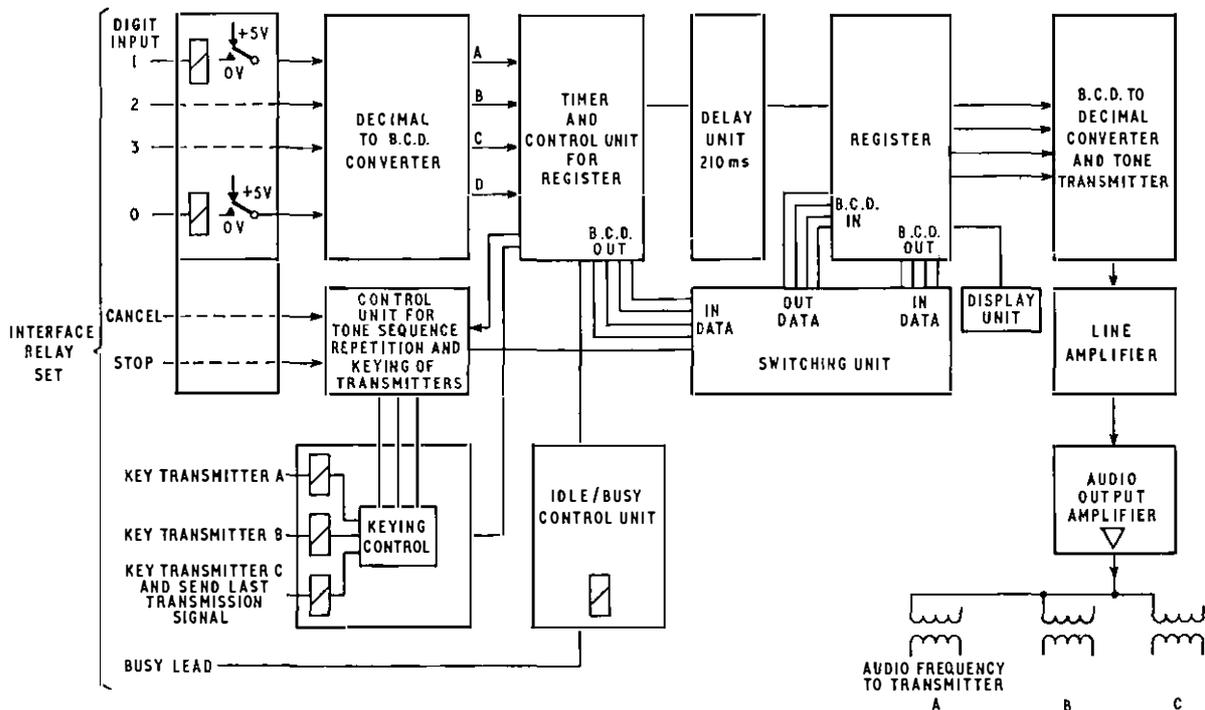


FIG. 3—Tone-generator block diagram

and also provides many operational facilities required by the B.P.O.

Associated with the sequential tone generator is a B.P.O. designed interface which provides the means of connecting sleeve-control switchboard positions, allotted as radiophone booking positions, to the control channel as required on a one-at-a-time basis, suitable guards being provided against such problems as dual seizure. The interface also enables the output of the standard sleeve-control key unit, which is normally directly connected to a 10 pulse/s sender, to be diverted into the sequential tone generator, so obviating the need for a special key unit for radiophone. Various timers are incorporated to provide time-out facilities as required for operational purposes.

The sequential tone generator uses mainly solid-state circuitry but diaphragm relays are employed in the input circuits. Similarly, all control circuits between the B.P.O. interface and the sequential tone generator are loop operated to achieve complete electrical isolation. The B.P.O. interface uses relay circuitry with solid-state devices in the timers, the types of relay used being dictated by functional and space considerations. To reduce wiring and cabling to a minimum, part of the interface equipment is mounted on the rear of the switchboard position, and the remainder on a standard jack-in relay-set base fitted on the sequential-tone-generator rack.

#### Remote-Controlled Sequential Tone Generator

Digits received by the tone generator (Fig. 3) from the switchboard keypad are transferred to a register which, on receipt of the fifth digit (complete number stored), produces up to 23 sequential pulses each of 70 ms duration. At the commencement of the first sequential pulse, a transmitter switch-on signal is sent to the first radio base station. The first two sequential pulses are not modulated and provide a 140 ms delay for the radio base station transmitter to become effective. Five sequential tones are then modulated by the information stored in the register, followed by three unmodulated pulses to provide a 210 ms pause between trans-

missions during which time the first transmitter is closed down and the second transmitter activated. A further five sequential pulses are then modulated to provide a second transmission of the required number. After the 23rd sequential pulse, a reset condition is applied to the tone generator. The tone generator can be strapped to cater for one, two or three radio base stations. Transmission can be discontinued if a *call-acknowledged* signal is received from the mobile radiophone before completion of the appropriate number of transmissions. The five modulated-tone signals are transmitted simultaneously to all base stations, but only one transmitter is switched on at a time.

The tone generator, shown in Fig. 4, is built up from a number of sub-units each mounted on its own self-contained 80 mm module printed-circuit board. Digits from the telephone switchboard operator's keypad, in the form of d.c. signals, actuate a diaphragm relay associated with the particular signalling lead. This relay interface provides electrical isolation between the low-voltage (5 and 24 volts) tone-generator circuits and the 50-volt public-telephone-exchange equipment. Negative logic—key normal, no input but logic 1 on output—is used to transfer information from the relay interface to the decimal-to-binary-coded-decimal (b.c.d.) convertor. Four 8-input nand gates are used for decimal to b.c.d. inverted conversion, and four 2-input nand gates are used as inverters. The timer-and-control unit is composed principally of two separate circuits one of which consists of read-in gates for the b.c.d. input digit information and a clock-pulse generator. The second circuit is used to control the pulse generator and is a 70 ms astable multi-vibrator to count the two initial unmodulated pulses together with a monostable gate to produce the reset signal. The delay unit determines the interval between any two sequence calls. The gating circuit is blocked for 210 ms, by means of a monostable multi-vibrator which is activated by the end of the first transmission sequence.

Four 5-bit shift registers are used to store the 5 read-in digits, a special circuit detecting consecutive identical digits. The register unit also incorporates control and read-out

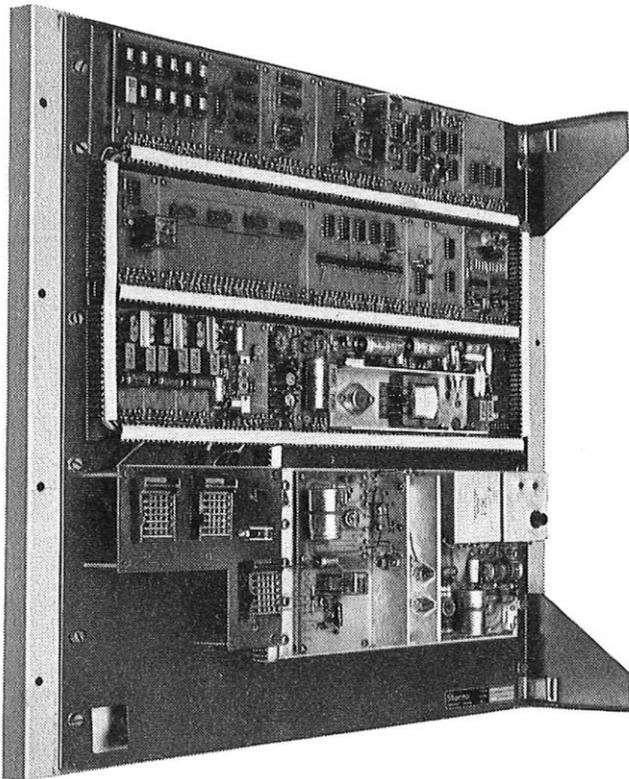


FIG. 4—Tone generator

gates for transfer of signals in b.c.d. form to the tone transmitter. After five digits are stored in the register, a start pulse from the control unit to the switching unit transfers the input of the register from read-in from the key pad to read-in from the output of the register. After the two initial sequence pulses, the register is read out to the tone transmitter in series b.c.d. form, and simultaneously the register output is fed back into its input. A stop pulse from the timer-and-control unit is applied after five digits have been read out and, after three stop pulses, a reset pulse clears the register. Logic read out from the registers in b.c.d. form is converted into decimal form by the b.c.d. to decimal converter for tone transmission via the line and output amplifiers.

#### Line Amplifier

The line amplifier consists of,

- (a) an attenuator which can be adjusted to obtain an output of  $-20$  dBm to  $+28$  dBm in steps of 2 dB with a 600-ohm input impedance,
- (b) a variable equalizer to compensate for line capacitance, and
- (c) an amplifier with overall gain of 35dB.

A transformerless class-B push-pull amplifier capable of delivering 2 W of output power is used as the final output stage.

#### Repeat Tone

The sequence tone receivers in the mobile radiophones are not capable of receiving two identical tone frequencies consecutively and, hence, a repeat tone signal (digit 11) is used. (See Fig. 5). Therefore, 515R1 is transmitted as 515R1, where R is the repeat tone signal.

As the first digit is transferred to the tone transmitter, it is also fed into the comparator. Simultaneously, the subsequent digit is fed from the shift register into the comparator and, if parity exists, an output is received on the D-bistable trigger. During the transmission of the first digit, a *set repeat*

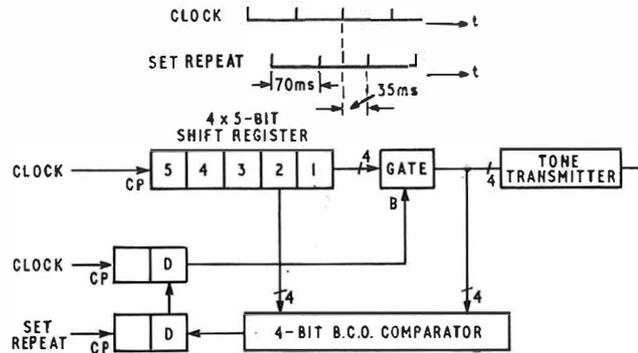


FIG. 5—Repeat-tone element

clock pulse transfers the condition on the first D-bistable trigger to a second similar element. On receipt of the next clock pulse, the shift register moves the read-in information one place forward and, at the same time, the second D-bistable trigger produces an input at terminal B of the gate. The gate then closes, preventing transfer of the second digit from the shift register to the tone transmitter. Instead of this, a b.c.d. digit 11 is fed into the tone transmitter. On receipt of the next clock pulse, the output from the shift register is again read into the comparator but this must be different from the digit 11 being transmitted, and, therefore, there is no blocking signal to the gate.

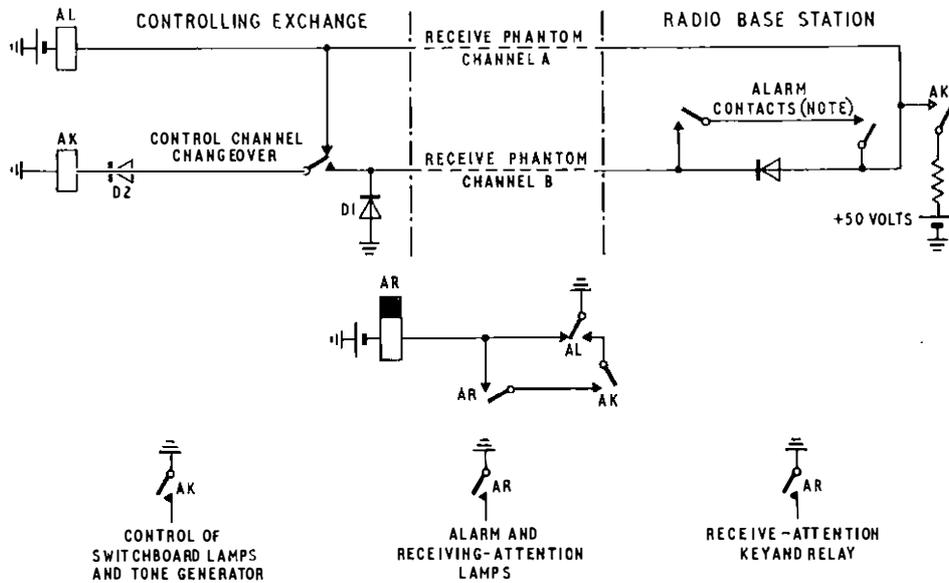
#### Call Acknowledge and Alarm Control

As part of the system security arrangements, duplicate control channels are provided to each base station. Use is, therefore, made of the receive signalling phantoms to return *call-acknowledge* signals to the controlling exchange and, additionally, provide a monitor circuit for certain line faults and extension of radio base-station alarms. (See Fig. 6).

Receipt of a *call-acknowledge* signal by either, or both, of the radio base station receivers associated with the control channels causes a positive battery to be applied to the looped phantoms to operate relay AK. Operation of relay AK initiates clear-down of the tone generator and causes the CALL ACKNOWLEDGED lamp to glow on the appropriate switchboard position. Earth via diode D1 on the receive phantom of control channel B is extended via alarm contacts in the radio base station to the receive phantom of control channel A and the AL relay in the controlling exchange. Relay AL is, therefore, normally held operated. In the event of a break in the alarm circuit, either by the release of an alarm relay at the radio base station or due to a line disconnection, relay AL releases and operates relay AR. Although alarm conditions prevail at a radio base station, it is probable that the station is still operative. Therefore, as calls are set up, *call-acknowledge* signals are still returned. Relay AL then re-operates in parallel with relay AK but relay AR holds to prevent resetting of the switchboard alarms.

#### Overplug Facility on Incoming Circuits from the Public Telephone Network

The incoming calls from the public telephone network are answered by a booking/controlling operator in the normal manner by means of an answering-cord plug inserted in the appropriate jack on the switchboard to operate relay S. (See Fig. 7). When a controlling operator wishes to connect the called mobile radiophone to this circuit and take control of the call, insertion of her answering-cord plug into the overplug jack operates relay P. Contacts of relay P provide a hold circuit for relays P and S and extend an 85-ohm earth on the sleeve of the answering multiple as a clear signal to the booking/controlling operator. The controlling operator now has charge of the call and the booking/controlling operator can withdraw her cord-circuit plug.



Note: Contacts normally operated.

FIG. 6—Call-acknowledge and alarm-control element

### MAINTENANCE AND RESERVE EQUIPMENT

Two control channels are provided and used alternately on a daily basis, changeover being under the control of the supervisor. Likewise, should a fault develop on the control channel which is in use, changeover can be made to the other channel. To provide a greater degree of security, three sequential tone generators are provided, two of which are patched by means of flexible cords, one to each of the two control channels. The third tone generator is spare so that, if one becomes faulty, the spare can be used to restore service to the control channel concerned in the shortest possible time. The interface equipment fitted on the sleeve-control position is not duplicated in any way as a fault would only affect one position, but a spare relay-set is available for the part of the interface mounted on the sequential-tone-generator rack.

To assist the traffic staff in operating the radiophone service, the radio base station alarms appear on the radiophone switchboard in addition to the normal arrangements. These alarms are only advisory as far as the radiophone switchboard is concerned, and, on receipt of an alarm, the RECEIVING ATTENTION key is operated to dim the warning lamp and cause the RECEIVING ATTENTION lamp to glow.

Having received an alarm, the supervisor then makes a test call on both control channels. The result of the test calls determines which control channel, if any, should remain in service and whether any special advice is necessary to the operating staff on the radiophone switchboard. To enable test calls to be made by the operators without the co-operation of another party, a *test mobile* arrangement is provided at the radiophone centre. The *test mobile* has aeriels arranged so that it can receive signals from all base stations and, when a call is made to the test number and connexion made with the *test mobile*, a *call-acknowledged* signal is returned to advise the testing operator of the successful setting-up of the call. Three keys are provided on the switchboard so that, when any key is operated, signals are transmitted and received only from the appropriate base station. This feature provides the means by which the traffic staff can attempt to locate any difficulties appearing on the control channel to either the common equipment at the radiophone centre or to a radio base station. A warning lamp glows on the switchboard should the *test mobile* not be available for testing due, perhaps, to its use for engineering tests.

For engineering test purposes a test panel is mounted on the sequential-tone-generator rack and provides facilities for

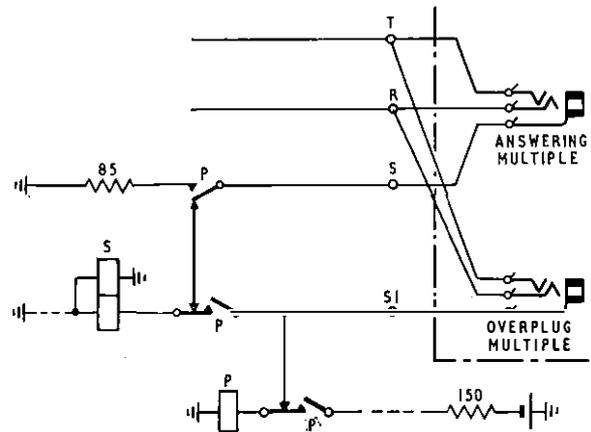


FIG. 7—Overplug element

testing the tone generator by checking output signals against the input signals. If a sequential tone generator is proved faulty, it is returned to the manufacturers for repair.

### CONCLUSIONS

Generally, the whole Radiophone System 3 exercise, which originated as a scheme for London only, but was subsequently documented in standard form for national use, has been an excellent example of co-operation between various branches of Telecommunications Headquarters, the manufacturers of the sequential tone generators and the Regional and Area staff concerned. Much work was carried out with very limited information and many changes had to be made during development, but everyone concerned accepted these events as an inevitable outcome for achieving the earliest possible opening date for Radiophone System 3 in London.

### ACKNOWLEDGEMENT

The authors express their thanks to Storno Ltd. for permission to outline details of their remote-controlled sequential tone generator.

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# Digital Techniques in Communication Satellite Systems

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U.D.C. 621.369.946:621.396.41:621.376.56

*Various transmission systems using digital techniques have been developed, or are in the course of development, for use in communication satellite systems. The need for such systems is discussed, the background to them is examined, and two such systems, and the different roles that they will play, are described briefly.*

## INTRODUCTION

At the present time, transmission through communication satellites is by frequency modulation (f.m.) of the radio-frequency carriers emitted by the earth stations. For the INTELSAT IV satellites, which are now carrying the traffic of the INTELSAT‡ system, f.m. carriers ranging in capacity from 24 up to 1,872 telephone channels are used. The INTELSAT IV satellite has 12 transponders (frequency translating repeaters) each of 36 MHz usable bandwidth and, except when an earth station has sufficient traffic to load fully an entire transponder, the capacity of each transponder is usually shared between the carriers from a number of earth stations. Each carrier is allocated an appropriate portion of the transponder's bandwidth with sufficient guardband to prevent interference, a technique known as frequency-division multiple access (f.d.m.a.).

The main opening for digital techniques in future satellite communication systems will be to overcome some of the disadvantages of f.d.m.a. by permitting the use of time-division multiple access (t.d.m.a.). However, this is not the only application. Another digital system, which will be introduced much earlier in time than the t.d.m.a. system, is a specialized application aimed at increasing the efficiency with which traffic can be carried on lightly-loaded routes. This system,<sup>1</sup> known as SPADE,\* will be introduced into one transponder of the Atlantic INTELSAT IV satellite early in 1972.

This article outlines the main characteristics of both the SPADE system and a typical t.d.m.a. system.

## THE SPADE SYSTEM

At present, channels in the f.m. basebands are preassigned to specific circuits, and the number of circuits on each route is calculated according to the busy-hour traffic and the required grade of service. For many routes, the traffic flow is small, few circuits are needed, and so their availability is poor. For other routes, the traffic flow is too small to justify even one direct circuit. A demand-assignment system overcomes these problems by providing a pool of satellite channels available to all the participating earth stations. These channels are

allocated to particular routes, as the demand arises, on a call-by-call basis.

In the SPADE system, the required flexibility is obtained by using a separate radio-frequency (r.f.) carrier for each telephony channel. The frequency for this carrier, and that for the return-channel carrier, are allocated by the earth station's control system when it receives a request for a circuit. The system is designed for a total pool of just under 800 channels (400 circuits) and to use one transponder of an INTELSAT IV satellite.

The SPADE equipment is broadly divided into three sections (Fig. 1), the terrestrial interface unit, the channel units, and the demand-assignment signalling and switching (d.a.s.s.) unit.

The terrestrial interface unit interfaces the SPADE system with the terrestrial network at voice frequency. Its main purpose is to carry out the signalling conversion between the terrestrial signalling system and the SPADE signalling system.

The channel unit contains a pulse modulator, a p.c.m. codec (coder/decoder), a voice detector, a frequency synthesizer, a channel synchronizer, and a 4-phase phase-shift-keyed (p.s.k.) modem (modulator/demodulator). The pulse modulator samples the voice signal 8,000 times a second and the p.c.m. codec encodes each sample into a 7-bit word using non-linear (A-law) encoding.\*\*

The voice detector controls the carrier so that it is transmitted only when a person is talking. This enables more satellite power to be allocated to each channel since, on average, no more than about 350 of the 800 channels are likely to be active simultaneously. As a consequence, synchronizing information must be transmitted at the beginning of each speech burst to enable the receiver to acquire word synchronization; this information is inserted many times during a speech burst to ensure that word synchronization is maintained. The channel synchronizer inserts this information, which results in the transmitted bit rate being increased to 64 kbit/s from the 56 kbit/s emitted by the p.c.m. codec.

The frequency synthesizer generates the necessary carrier frequency as determined by the d.a.s.s. unit. The p.s.k. modem requires a bandwidth of 45 kHz and interfaces with the earth station's intermediate frequency (i.f.) equipment through an i.f. sub-system.

† Telecommunications Development Department, Telecommunication Headquarters.

‡ INTELSAT—International Telecommunications Satellite Consortium.

\* SPADE—Single channel per carrier, p.c.m. multiple-access, demand-assignment equipment.

\*\* C.C.I.T.T. Draft Recommendation G711 (C.C.I.T.T.—International Telegraph and Telephone Consultative Committee).

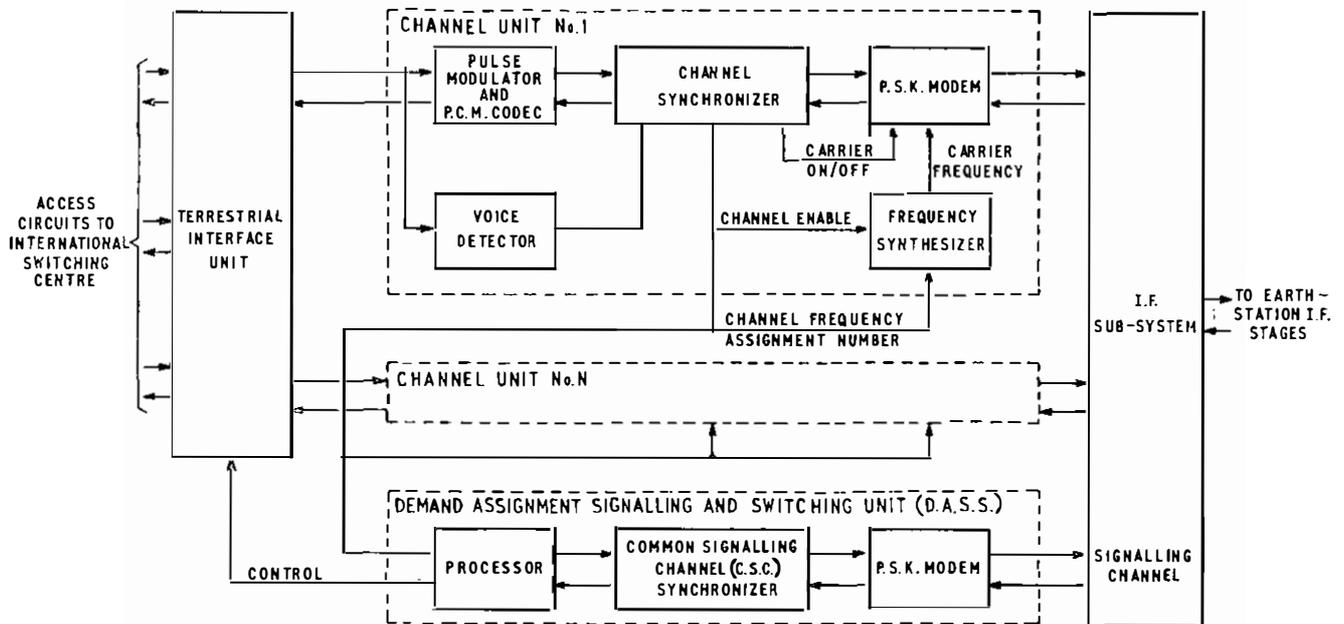


FIG. 1—SPADE system—simplified block diagram.

The d.a.s.s. unit is the heart of the SPADE system and controls the setting up of calls in conjunction with similar units at all the other stations. To provide the communication link between the d.a.s.s. units, there is a common signalling channel (c.s.c.), which is also used, on a non-priority basis, for the transmission of management and circuit-status signals.

A call request is initiated by the d.a.s.s. unit in the originating country selecting a free circuit and requesting, over the c.s.c., the distant station's d.a.s.s. unit to accept the call using the nominated circuit. In order to carry out this function, the d.a.s.s. unit stores information concerning the present state of the channels in the system. At least one station will probably also be equipped with additional processing capability in order to analyze the statistics of the number and duration of calls from each participating earth station. The capability may also be used, at some time in the future, to determine charges on the basis of the degree of use of the satellite capacity. However, for the present, charges are fixed, being based on the number of SPADE access channels and not on the time for which channels are used.

## T.D.M.A. SYSTEMS

### Background

Interest was originally shown in time-division multiple access (t.d.m.a.) as a possible method of overcoming some of the disadvantages of f.d.m.a. In t.d.m.a., earth stations transmit their information through the satellite in non-overlapping bursts. Perhaps the first experimental t.d.m.a. system was a three-terminal, 72-channel system,<sup>2</sup> called MATE,\* which was designed and built by COMSAT† on behalf of INTELSAT. This system, operating at 6 Mbit/s, was tested over the INTELSAT I satellite (Early Bird) during 1966, and proved the feasibility of t.d.m.a. It was then decided to design and build a t.d.m.a. system incorporating additional features, using the most up-to-date technology,

and operating at the higher bit rate of 50 Mbit/s. This system, originally known as MAT-1,<sup>3</sup> is now known as TDMA-1, and was tested over an INTELSAT III satellite during 1970.

Both Japan and Germany have built experimental t.d.m.a. systems. The Japanese system<sup>4</sup> also operates at 50 Mbit/s and was tested over an INTELSAT III satellite during 1970. The German system was designed for use with the French-German experimental satellite *Symphonie*, and operates at 100 Mbit/s; however, for tests over an INTELSAT III satellite in 1971, the system was modified to operate at 50 Mbit/s.

In November 1969 an international conference, sponsored jointly by INTELSAT and the I.E.E., was held in London at which the various existing and proposed systems were described and many of the problems and advantages of digital communications through satellites were discussed.

In order to have a t.d.m.a. system suitable for INTELSAT, the technical sub-committee of the Interim Committee on Satellite Communications (I.C.S.C./T.) decided to set up a t.d.m.a. working group with the objective of defining and introducing such a system.

There is also under discussion at present by C.E.P.T.\*\* and E.S.R.O.†, a possible European communication satellite system, in which t.d.m.a. would be used.

### Advantages

There are two main advantages in t.d.m.a. over f.d.m.a. Firstly, it makes more effective use of the satellite capacity because it avoids the problems arising from intermodulation between carriers and, secondly, it is considerably more flexible in adapting to changing traffic requirements.

A satellite transponder has a non-linear gain characteristic, especially for high input levels. Thus, when two or more carriers are transmitted simultaneously through a transponder, intermodulation products arise. To reduce these to an acceptable level, the input has to be reduced in level by a few

\* MATE—Multiple-access time-division experiment.

† COMSAT—Communication Satellite Corporation.

\*\* C.E.P.T.—Conférence Européenne des Administrations des Postes et Télécommunications.

† E.S.R.O.—European Space Research Organization.

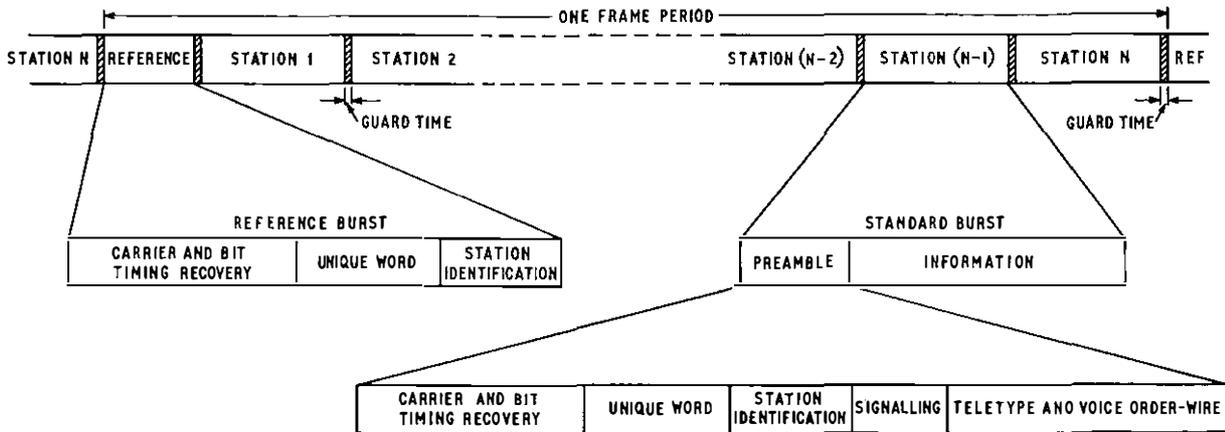


Fig. 2—Typical frame and burst format for a t.d.m.a. system.

decibels in order to operate on a more linear portion of the gain characteristic. The output power, thus, is reduced, which in turn reduces the total number of channels which can be transmitted through a transponder. A t.d.m.a. system allows one carrier only to be transmitted through the transponder at any one time. The transponder, thus, may be operated at saturation, which maximizes the output power and, therefore, the capacity. Some capacity is wasted because of the preamble associated with each station's burst, but the reduction in capacity in t.d.m.a. is much less than the reduction caused by backing off the transponder in f.d.m.a.

Another big advantage of t.d.m.a. is its flexibility. With f.d.m.a., considerable equipment changes are necessary whenever rearrangements of carriers are made to cater for changing traffic patterns. With t.d.m.a., however, each burst can be readily adjusted to cater for the station's exact requirements, within the limits of the transponder. Moreover, rearrangement of the traffic does not require any equipment modification and can be achieved at very short notice.

### Outline of Principles

As mentioned before, the principle of t.d.m.a. is that each station transmits its information in bursts that are arranged to pass through the satellite in succession within an overall frame period—one frame being one cycle of bursts from all the stations (Fig. 2).

The timing control is one of the most important aspects of a t.d.m.a. system, since it is essential for each station to know when to transmit its burst and when to expect to receive bursts. Should a burst be transmitted at the wrong time, it may overlap another burst and information will be destroyed. To provide synchronization for the system, one station transmits a reference burst at the start of each frame, and this is used by the other stations to control the times at which their bursts pass through the satellite. Each one compares the position of the received reference burst with that of its own burst received back from the satellite and adjusts the time at which it transmits to ensure that the relative positions are correct.

Receiving is a more straightforward function. Each earth station searches for the reference burst and, when found, locks on to it and uses it as a reference point from which it calculates the expected arrival times of bursts from other stations. Since the position of the satellite may change slightly, the loop-transmission time is not constant, and each receiving station has to allow for very small variations in the positions of each station's bursts from one frame to the next.

Fig. 2 shows how one frame is made up of bursts from

different stations. After an appropriate guard time, each burst starts with a preamble which typically consists of:

- (a) an alternating sequence of binary digits,
- (b) a unique word,
- (c) a station-identification code, and
- (d) signalling and order-wire bits.

The guard time prevents the possible overlapping of bursts caused by short-term variations in the earth-station clock and by the varying transmission time owing to movement of the satellite.

The alternating sequence of binary digits has two functions; it permits receiving stations to recover the carrier phase for the coherent detection process and it assists in the recovery of bit timing.

The unique word is designed to enable the station to determine when the information in the burst starts. The incoming bit stream is correlated with a stored replica of the unique word so that, at a certain time, a correlation spike is produced, identifying the position of the unique word and, thus, the precise start of the following information.

The station identification code merely identifies the transmitting station. This information may often be implied by the position of the burst within the frame; however, in some systems, it is possible for bursts to move their positions within the frame, and station identification may then be essential.

One group of signalling bits may be used to broadcast management control signals. Another completely independent group of signalling bits may be used to broadcast the signals derived from a terrestrial signalling system such as C.C.I.T.T. No. 6.\* The order-wire bits provide teleprinter and voice service channels for system management.

The information follows the preamble, and there is considerable freedom not only in what goes into this part of the burst but also how long it is. It is possible to vary the length of the burst and its position within the frame to take into account varying demand by the earth station.

The t.d.m.a. system interfaces with the terrestrial network, which, at present, is mostly analogue. Thus, all signals arriving at an earth station through such a network must be suitably encoded for transmission as the information part of the burst from a t.d.m.a. terminal. The analogue signals may be voice, voice-frequency data, f.d.m. blocks, facsimile, television, and others. Suitable codecs have already been developed for some of these services and others are in the process of being developed. These codecs, and buffer stores to permit conversion to

\* C.C.I.T.T. Recommendation Q251.

the burst mode of operation, will thus be a necessary part of the interface. When digital links are installed between earth stations and the international switching centres, the codecs will no longer be necessary and only speed conversion will be required.

### THE FUTURE FOR DIGITAL SATELLITE COMMUNICATIONS

SPADE equipment is being, or is shortly to be, installed in many countries, including the United Kingdom, that operate to the Atlantic region INTELSAT IV satellite, and some equipment will become operational early in 1973.

The specification for a prototype INTELSAT t.d.m.a. system should be available by the beginning of 1973, with field trials scheduled to start during 1974. The operational system is expected to be introduced into the INTELSAT network around 1977, after which it is likely to take over gradually the major transmission role from f.m./f.d.m.a.; its existence will be a considerable advantage in easing interconnexion problems when the terrestrial network also starts using digital transmission techniques on a wide scale.

If the proposed European Communication Satellite system<sup>6</sup> materializes, t.d.m.a. would probably be used from

the start for all telephony traffic. The operational date for such a system would be 1980 or later.

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# Teletraffic Aspects of the S.T.D. Junction-Hunter Scheme in Director Exchanges

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U.D.C. 621.395.31:621.395.72

*Junction-hunters introduced in director exchanges to make more efficient use of subscriber trunk dialling junctions cannot be considered as a single switching stage from a traffic engineering point of view, but form part of a "link system". The traffic capacities of junction-hunter schemes currently in use have been found to fall short of that for which they were designed. Other difficulties have been experienced in the field with the allocation of junction-hunters to conventional gradings in order to obtain an even spread of traffic. Evaluation of the existing scheme and the development of an improved scheme has been assisted by the use of computer traffic simulation techniques.*

### INTRODUCTION

When subscriber trunk dialling (s.t.d.) was introduced in director exchanges it was necessary to reduce the availability of outlets from 20 to 10 on the first-code selector s.t.d. level, to accommodate the metering-over-junction facility.<sup>1</sup> For a given value of telephone traffic, at the same probability of loss, a 10-availability grading requires more circuits than a 20-availability grading. Therefore, the reduction in availability represented an increase in the cost of routing s.t.d. traffic to the relevant register-translator centres, in terms of the number of junctions required. To enable the s.t.d. junctions to be used more efficiently, a cross-connexion scheme has been devised to give pseudo full-availability conditions to the junctions.

The first-code selector s.t.d. level is graded to groups of junction-hunters (uniselectors) and the banks of the hunters are trunked away to full-availability groups of junctions; this increases the number of junctions to which any first-code selector can gain access. In addition, by use of a "group-busy control", the overall efficiency of the scheme is improved such that the traffic capacity approaches that of a full-availability group consisting of the same number of circuits. The scheme offers an economic advantage where the s.t.d. traffic is in excess of 15.0 erlangs. A sketch of the trunking arrangements is shown in Fig. 1.

### DESCRIPTION OF JUNCTION-HUNTER ARRANGEMENT

The junction-hunters are arranged in groups of 30 or 40 bank multiples, each hunter having 25 outlets, two of which are used as home positions. Each hunter group can,

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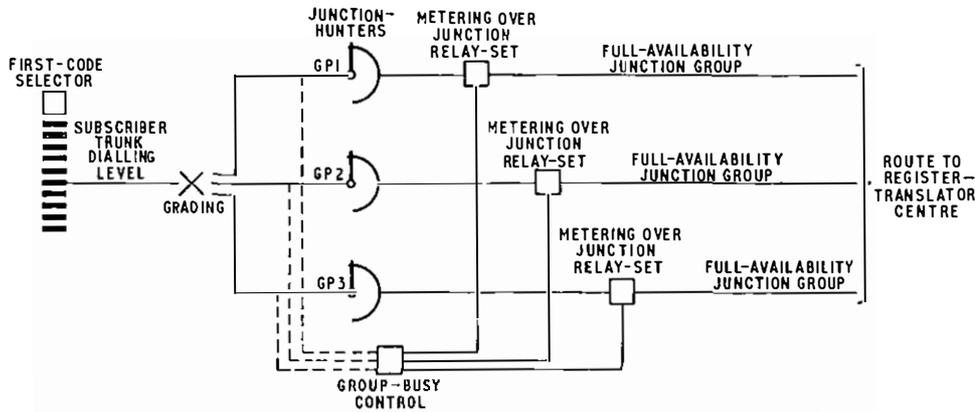


FIG. 1—Block diagram of a three-group junction-hunter scheme

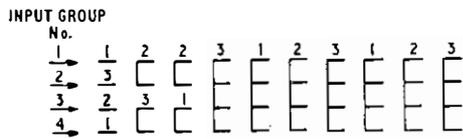


FIG. 2—O'dell grading showing principles of allocation to the junction-hunter groups

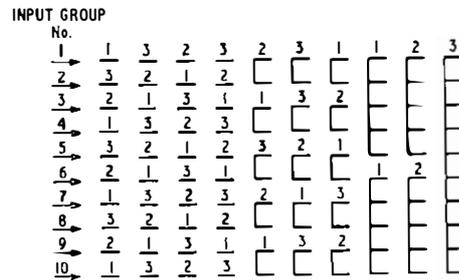


FIG. 3—New design grading showing allocation to three junction-hunter groups

therefore, serve up to 23 junctions connected as a full-availability group. The particular value of s.t.d. traffic to be carried determines the following

- (a) the number of groups that are to be used; these can be from a minimum of two to a maximum of 10,
- (b) the number of junction-hunters per group,
- (c) the number of junctions required.

Dimensioning is based on an end-to-end probability of loss of one per cent from first-code selector to junctions.

### GRADINGS

The connexions between the first-code selector banks and the junction hunters are made by the use of a conventional O'dell grading.<sup>2-3</sup> The hunters are allocated in such a way that the traffic is evenly distributed over all the junction-hunter groups and also, as far as possible, each grading input has access to all the junction-hunter groups. A simple grading illustrating this principle is shown in Fig. 2; this only shows the allocations of junction-hunter groups to which the outlets have access.

Allocations of junctions to the banks of the junction hunters are such that the number of junctions per hunter group is as equal as possible.

### THE EFFECT OF GROUP-BUSY CONTROL

Use of a group-busy control ensures that when all junctions in a particular junction-hunter group are occupied then the remaining free hunters within that group cannot be seized by a first-code selector. This is achieved by a busy condition being placed on the free junction-hunters associated with the busy group. Traffic is, therefore, distributed only to junction-hunters within groups that have access to a free junction.

The overall effect is to change the traffic considerations of the system, from an arrangement where two separate switching stages could be considered, to one where switching at the first stage becomes dependent upon free circuits being available from the second stage. This is known as conditional selection and the system, therefore, behaves as a link system where, the junction hunters are effectively the links.

### CONTROL

In order to maintain the required grade of service, traffic measurements are taken on the outgoing junctions, an overflow meter being provided on the eleventh step of the first-code selector level to give an indication of congestion within the system.

If additional junctions are required to carry an indicated rise in the quantity of traffic, then it is also necessary to provide additional junction-hunters and hence, regrading is required between the first-code selector banks and the junction-hunters.

### RECENT DEVELOPMENT

Practical experience in the field has shown that the expected traffic capacities of the scheme have often not been realized before excessive traffic overflows occur from the first-code selector level.

In order to assess the performance of the scheme a series of computer traffic simulation studies have recently been carried out. Results have indicated that in order to maintain an end-to-end probability of lost calls of one per cent, two basic requirements should be met. These are

- (a) a more generous provision of junction-hunters,
- (b) to ensure sufficient links from each grading input group to each hunter group, no one scheme should contain more than four junction-hunter groups.

It was also evident that some difficulties were being experienced in the field to allocate junction-hunters to O'dell gradings so that the traffic over the hunter groups was evenly spread. To overcome this problem new forms of grading or interconnexion patterns have been developed which have the following characteristics

- (a) a near-even distribution of traffic to each junction-hunter group,

(b) each grading input group having a near equal access to all junction-hunter groups.

Because each grading input group can only have access to 10 junction hunters, equal access to all hunter groups can only be achieved if the number of junction-hunter groups is a factor of 10. Therefore, for three junction-hunter groups the best possible arrangement would be that each input group should have access to three hunters in each of two groups and access to four hunters in the remaining group.

An analysis of the O'dell grading in Fig. 2 shows that input groups 2 and 4 do not have the best possible access arrangement outlined above, see Table 1.

**TABLE 1**  
**Analysis of O'dell Grading**

Grading Input Group No.	Number of Bank Contacts with Access to Junction-Hunter Group		
	1	2	3
1	3	4	3
2	2	4	4
3	3	3	4
4	4	2	4

It should be noted that this grading does not contain enough trunks to be considered a typical junction-hunter grading, but serves to illustrate the point.

**A new grading design**

Part of one of the new grading designs is shown in Fig. 3 and an analysis of grading input group to hunter group access is shown in Table 2 which shows that the best possible arrangement has been achieved.

A considerable number of simulation studies have been carried out of the 2, 3 and 4 junction-hunter group schemes using the new grading designs and assuming that the hunter groups were fully provided with 40 hunters in each. The results have enabled new standards for the provisioning of junction-hunter schemes to be formulated. These are as follows

(a) only 2, 3 and 4 group schemes will be used, each group will be fully provided with 40 hunters,

(b) the first-code-selector bank-contacts will be connected to the junction-hunters using the new grading designs. These will be published for various input group sizes for each of

**TABLE 2**  
**Analysis of New Grading Design**

Grading Input Group No.	Number of Bank Contacts with Access to Junction-Hunter Group		
	1	2	3
1	3	3	4
2	3	4	3
3	4	3	3
4	3	3	4
5	3	4	3
6	4	3	3
7	3	3	4
8	3	4	3
9	4	3	3
10	3	3	4

the three schemes, complete with junction-hunter group allocations,

(c) control of the traffic capacity of the schemes will depend only upon the quantity of s.t.d. junctions provided and not upon both the quantities of hunters and junctions, as in the original scheme. The actual number of junctions required to be determined from special tables. The methods of traffic measurement will remain as before.

These new standards will mean that regrading between first-code selectors and junction hunters will seldom be necessary when a change in the traffic capacity of a scheme is required. The new tables will ensure that the end-to-end probability of lost calls of one per cent is met.

**CONCLUSIONS**

The junction-hunter scheme behaves as a link system in which the junction hunters effectively serve as the links. The use of computer simulation techniques has confirmed the short comings of the original scheme, and has enabled the development of new interconnexion formations and dimensioning rules which will overcome the practical difficulties encountered in the field. Junction-hunter schemes dimensioned to the new rules will be easier to control at the probability of loss required.

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<sup>2</sup> BERKELEY, G. S. *Traffic and Trunking Principles in Automatic Telephony*, p. 141. (Ernest Benn Ltd, London, 1949.)  
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# A Miniaturized Version of Signalling System A.C. No. 9

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*At the present time, the main in-band signalling system in the British Post Office (B.P.O.) national trunk network is Signalling System Alternating Current (S.S.A.C.) No. 9. The B.P.O. has developed a miniaturized version of this signalling system which increases the packing density and mean-time-between-failures, whilst reducing the power consumed.*

*This article describes the technology and circuitry of the miniaturized S.S.A.C. No. 9 equipment and also its physical realization.*

## INTRODUCTION

The expansion of subscriber trunk dialling (s.t.d.) using frequency division multiplex transmission<sup>1</sup> systems has made the Signalling System Alternating Current (S.S.A.C.) No. 9 the major signalling system in the British Post Office (B.P.O.) national trunk network. Currently, there are some 200,000 S.S.A.C. No. 9 relay-sets in service with a forecast growth in the order of 15 per cent per annum over the next five years. The increasing cost of providing and maintaining telephone exchange accommodation, with, in some cases, the impossibility of extending existing buildings, meant that substantial savings could be made if the packing density of relay-sets could be increased. The original design of S.S.A.C. No. 9 relay-sets used relays for the logic and timing functions and valves in the electronic circuits—these were later transistorized.

A B.P.O. study compared current technologies in terms of packing density, reduction in power, reduced maintenance, life and initial costs. Cost studies showed that, if the initial costs were no more than that of existing equipment, large overall savings could be made.

Investigation showed that a design based on low-power transistor-transistor-logic (t.t.l.) packages most nearly met all the requirements. The use of sensitive logic in the hostile environment of a Strowger exchange raised a number of problems which had to be overcome in the interface design.

A packing density of 132 signalling units per 62-type rack has been achieved, an increase in the order of six to one, and the design incorporates a test-access facility permitting any signalling unit to be connected to a portable tester, routiner or the test desk, via a common highway.

## BACKGROUND TO DEVELOPMENT

The logic, timing, buffer-amplifier and receiver functions of the S.S.A.C. No. 9 system are an ideal vehicle for utilizing electronic techniques and with miniaturized components the overall savings that could be made in space, maintenance and power are considerable, even without an additional bonus of a possible reduction in cost compared with the existing equipment.

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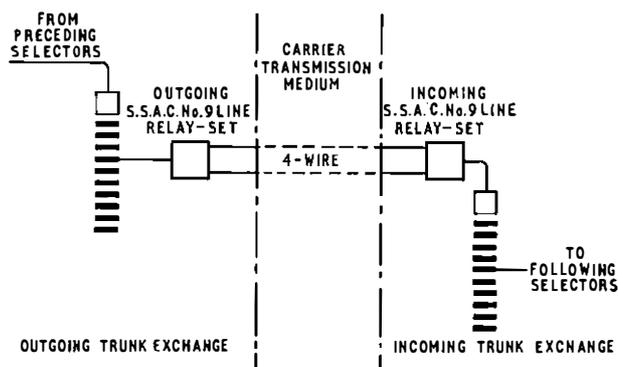


FIG. 1—Typical trunking diagram

The initial terms of reference were that the packing density should be increased by a factor of four to one with commensurate reduction in power dissipation such that, when used in existing installations, natural ventilation would provide sufficient cooling.

The demand for both-way equipment was likely to be too small to justify its inclusion in the development, therefore, effort was concentrated on miniaturizing the unidirectional outgoing and incoming relay-sets.

The specification prepared for the development incorporated all the existing facilities of the S.S.A.C. No. 9 system and included test-access equipment and a portable tester. Special reference was made to the protection of the units from high voltage surges known to exist on the power distribution and junction circuits as electronic circuits would be used.

## OUTLINE OF S.S.A.C. No. 9 APPLICATION

S.S.A.C. No. 9 is a single voice frequency (1.v.f.) in-band signalling system using a frequency of 2,280 Hz. The typical trunking diagram, Fig. 1, shows that the signalling unit is the interface between the exchange switching and carrier transmission equipments. The outgoing signalling-unit converts the loop disconnect signals on the 2-wire line into tone pulses of 2,280 Hz for transmission over the 4-wire carrier medium. The tone pulses are recognized on the 4-wire side of the incoming signalling unit by length and sequence, and con-

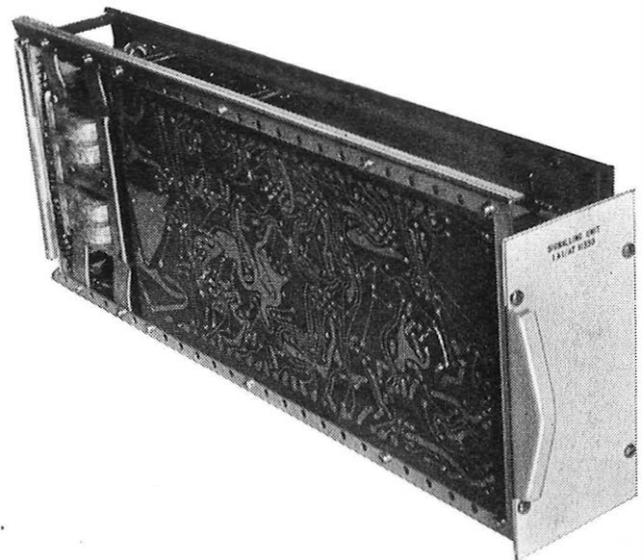
verted to loop-disconnect signals on the 2-wire side of the incoming signalling unit. Each signalling unit has a buffer-amplifier which may be switched on or off to split the 4-wire receive path at a point following the tone receiver to avoid signals being passed to the next link.

One of the features of the earlier design using the valve-type receiver and buffer-amplifier was that it provided for the inclusion of echo suppressors. This facility has seldom been used in the national trunk network and with the implementation of the new transmission plan the need for echo suppressors has disappeared. In consequence, the facility has been omitted from the miniaturized version of the S.S.A.C. No. 9 system (S.S.A.C. No. 9M.).

## SIGNALLING UNITS

The outgoing and incoming signalling units (shown in Fig. 2) can be broken down into four basic parts, i.e. interface, logic, 2-wire/4-wire termination and a buffer-amplifier and receiver, these are shown in Fig. 3.

Signalling between the switching equipment and the signalling unit consists of loop-disconnect pulses over the negative and positive wires and earth-disconnect pulses on the private-wire (P-wire), traffic recorder leads and trunk maintenance control centre rack-busy lamp. Facilities are provided for either battery or earth testing on the P-wire.



(a) Closed View

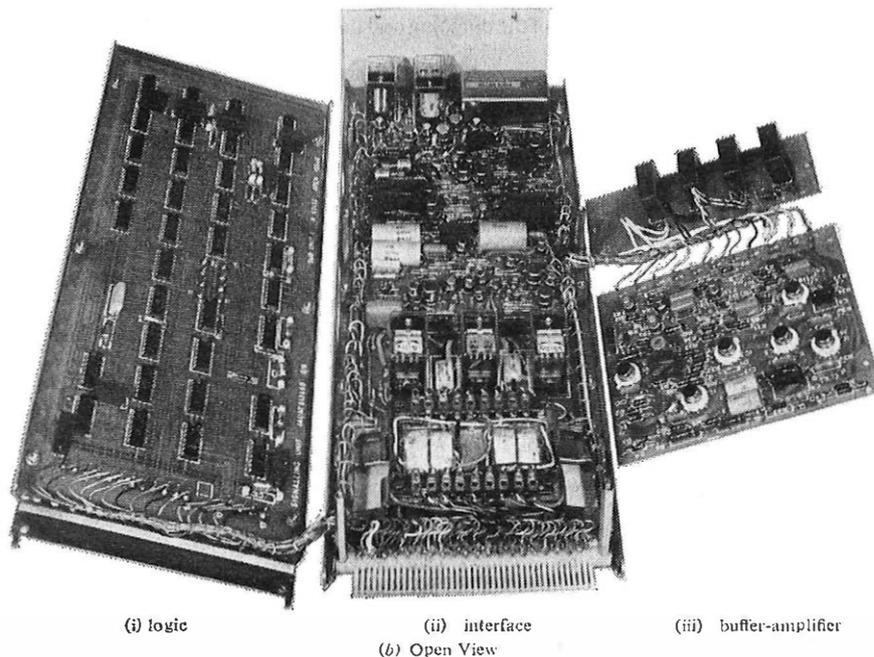


FIG. 2—Outgoing signalling unit

Signals received and transmitted to line on the 4-wire by the signalling unit are in analogue form consisting of 2,280 Hz tone for a given period, the duration being varied to define a particular event. The signals are detected and converted into a d.c. logic form by the receiver.

To protect the logic circuitry, an isolating interface with the exchange equipment is required, where possible, designed with solid-state circuitry to operate from the  $-50$  volt supply. Relays have been used for pulsing, P-wire busying and for switching the circuits to testing equipment.

The 2-wire/4-wire termination is provided by a two-transformer line termination which when, suitably balanced, will give a 3.5 dB loss in the 2-wire/4-wire direction of transmission or vice versa, with a nominal 40 dB loss from the transmit path to the receive path.

The circuits of both the outgoing and incoming signalling units, particularly logic, are complex and it is intended to discuss only the salient features of the design.

## RECEIVER AND BUFFER-AMPLIFIER

The requirements for a signal receiver have been discussed in earlier articles.<sup>2,3</sup> Since the introduction of the S.S.A.C. No. 9 valve receiver<sup>3</sup>, the B.P.O. Research Department has developed a transistorized version, its specification of performance requirements closely following that of the valve design.

The design criteria and philosophy of the transistorized receiver has already been proved. In this earlier design, the signal/guard ratio of approximately six gives the required compromise between a low ratio to avoid signal interference and a high ratio to provide voice immunity. The ratio is obtained by feeding the received voltages, via a resistance, to a series-tuned circuit resonant at 2,280 Hz. The signal voltage is developed across the inductor and the guard voltage is developed across the tuned circuit. These voltages are compared before the receiver relay is operated. By preceding the tuned circuit by a limiter, the received voltages in the working

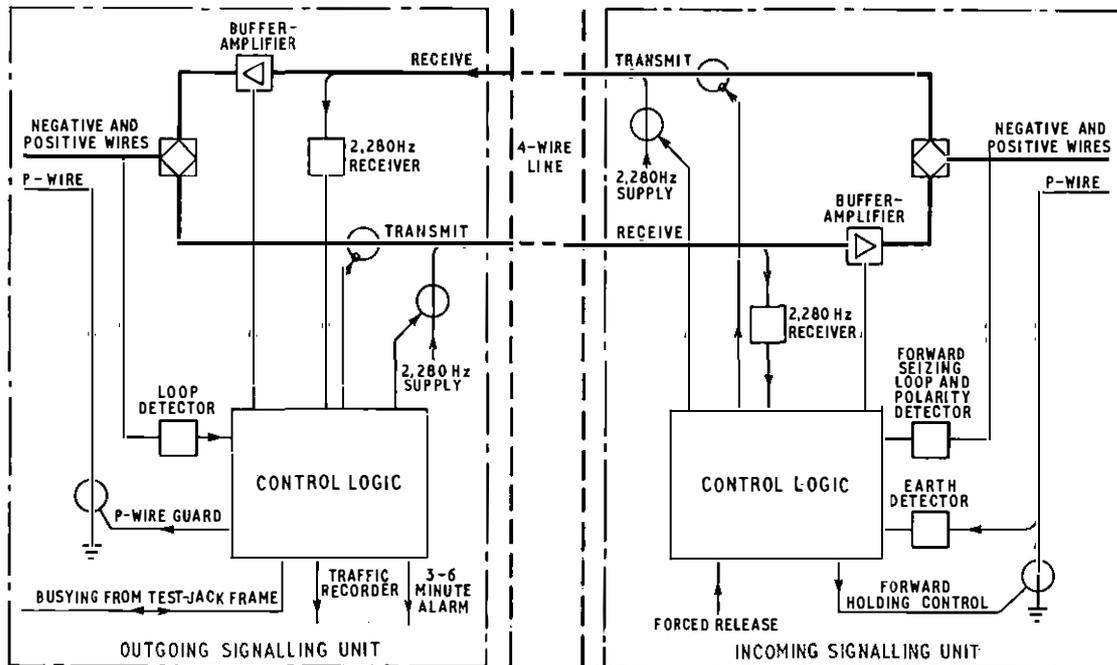


FIG. 3—Block diagram of the outgoing and incoming signalling units

range are brought to a constant level before connexion to the tuned circuit, thus simplifying the design of the comparator. The limiter, however, introduces complications by producing harmonics that could give a false guard and by its property of reducing a low-level signal in the face of a high-level signal requires a parallel tuned circuit to provide de-emphasis of the 2,280 Hz signal.

The new design of receiver and buffer-amplifier was required to be smaller, dissipate less power and be cheaper than the present transistorized version. The size and power considerations were met by the use of integrated-circuit operational-amplifiers with which it was possible to eliminate transformers, inductors and large capacitors and yet still follow the same design philosophy by replacing the series tuned circuit with an active resistor/capacitor circuit using a gyrator (see Appendix 1). By utilizing a sensitive comparator it was possible to eliminate the limiter and de-emphasis networks.

Whereas the transistor receiver was tuned during manufacture by adjusting the slugs within the ferrite core assemblies of both tuned circuits for resonance at 2,280 Hz, the new design simplifies the tuning to the adjustment of one resistor.

### Operational Amplifiers

Operational amplifiers are integrated circuits of some 10 to 25 transistors and associated resistors, used primarily to save weight and space with a bonus of reduced power consumption. The improvements that have been made in manufacturing techniques give increased reliability over a similar circuit of discrete components and at a reduced cost. Operational amplifiers are, in effect, high-gain broad-band amplifiers provided with inverting and non-inverting high-impedance inputs. External feed-back components are required to determine the amplifier characteristic.

These devices require both positive and negative voltages, in this case  $\pm 15$  volts are used. It is possible, by circuit arrangement, to use a single battery but, for simplicity, separate suppliers have been provided. Some parameters of operational amplifiers are given in Appendix 2.

### Simulated Inductance

Simulating inductors in filters and tuned circuits by active resistor/capacitor networks overcomes the problem of using large coils in miniature applications and thus permits maximum miniaturization. Additional benefits very often accrue in reducing a circuit sensitivity to tolerance of component values, with simplified manufacturing and tuning procedures. By producing the same current/voltage relationship, an inductor may be simulated by acting upon an impedance, either resistive or capacitive, with active circuits of either transistors or operational amplifiers used as impedance converters in the form of a gyrator. The use of operational amplifiers instead of transistors greatly reduces the number of individual components required and the properties of an operational amplifier make it eminently suitable for this application. The design of simulated inductors is simplified when one end of the inductor is earthed, as for the S.S.A.C. No. 9M. receiver, which utilizes a simple series-tuned circuit.

In describing the action of a gyrator one must first consider the property of an inductance. Current is proportional to the integral of the voltage.

$$i = \frac{1}{L} \int v \, dt. \quad \dots \dots (1)$$

To meet the requirements of equation (1), a gyrator must have the basic equations (2) and (3), where  $g_1$  and  $g_2$  are the forward and backward transconductances, respectively.

$$\text{From Fig. 4,} \quad V_1 = -\frac{1}{g_1} I_2, \quad \dots \dots (2)$$

$$\text{and, } V_2 = \frac{1}{g_2} I_1. \quad \dots \dots (3)$$

i.e. the input and output impedances are zero and the forward and backward transconductances are finite and opposite in sign.

$$\text{Now, } Z_{in} = \frac{V_1}{I_1} = -\frac{I_2}{V_2 g_1 g_2}.$$



FIG. 4—Termination of a gyrator

Stating the condition that  $V_2 = -I_2 Z_L$ ,

$$\text{then, } Z_{in} = \frac{1}{g_1 g_2 Z_L} \text{ since } Z_L = \frac{-V_2}{I_2}$$

$$\text{If, } Z_L = \frac{1}{j\omega C},$$

$$\text{then, } Z_{in} = j \frac{\omega C}{g_1 g_2},$$

which is equivalent to an inductive impedance where the inductance  $L = \frac{C}{g_1 g_2}$ . In practice,  $g_1$ , and  $g_2$  may be defined by passive resistances, giving at the input terminals of the gyrator an inductance,  $L = C R_1 R_2$ .

A fuller analysis of the simulated inductance circuit assuming ideal operational amplifiers is given in Appendix 1.

### Circuit description of the Buffer-Amplifier

The buffer-amplifier circuit is shown in Fig. 5. The line is terminated in 600 ohms by resistors R6 and R13 and is then d.c. connected to the inverting inputs of two operational amplifiers arranged in a symmetrical balanced circuit that readily provides for noiseless line splitting. The operational amplifiers are used in the single-ended inverting-amplifier fixed-gain mode. With the non-inverting input at earth potential, the inverting input is a virtual earth, therefore, diode clamps can conveniently be used at this point to provide protection to the amplifiers from line surges and impulsive noise.

The amplifier bandwidth has been restricted to 20 kHz at the 3dB point by capacitors C13 and C14 which shunt the feedback resistors R2 and R16 respectively.

The 600 ohm characteristic line-impedance termination is given by resistors R1 and R14. The output impedance of operational amplifiers in this circuit configuration is negligible and may be ignored.

Silent line-splitting is achieved by the applied earth switching on transistor TR4 which in turn switches on transistor TR5, the positive potential developed across resistor R11 being sufficient to bias the non-inverting input to cut-off the amplifiers giving a forward loss in excess of 70dB.

### Circuit Description of the Receiver

The circuit for the receiver is shown in Fig. 5. The receiver pre-amplifier, transistors TR3 and TR2, is d.c. connected to the line via a balanced high-impedance tap. This amplifier has three functions

- (a) to isolate the receiver from the speech path,
- (b) to provide the correct driving resistance for the tuned circuit, and
- (c) to adjust the level of received signals to the optimum for the subsequent circuits.

The series-tuned circuit, comprises the capacitor C6 and simulated inductance formed by the gyrator integrated circuits IC5 and IC6. This is driven from the parallel combination of resistors R18 and R24. The guard voltage is derived across the tuned circuit and amplified by the integrated circuit IC4 and then rectified by diodes D6 and D7. The signal voltage is derived across the simulated inductance, a

convenient point for signal extraction is the output of the integrated circuit IC5, this avoids loading the gyrator by the rectifying circuit of diodes D12 and D13.

Two factors influenced the design of the guard rectifier circuit, the first is that the rise and decay of a signal pulse produces transients in the tuned circuit which are amplified in the guard circuit producing a guard voltage that delays and distorts the receiver output-pulse, the rectifier circuit time-constants were kept to a minimum to reduce this effect. The second is that pulses of a frequency outside the signalling frequency band may cause transient operation of the receiver as the production of a guard voltage lags the signal circuit response. To prevent this misoperation the guard rectifier circuit connects one half cycle to the inverting input and the other to the non-inverting input of integrated circuit IC3, this is, in effect, a full-wave rectifier and voltage-doubler circuit, IC3 summing the inputs.

The comparator is an operational amplifier whose output changes from +13 to -13 volts on the reception of a valid 2,280 Hz signal. To ensure that the comparator remains off when the line is silent or when a signal of less than -28dBm is present, a bias voltage is connected to the non-inverting input.

Transistors TR1 and TR6 form a Schmitt-trigger circuit to interface between the operational amplifiers of the receiver and the low-power t.t.l. The Schmitt-trigger circuit was chosen for its fast operating time and wide voltage differential between its stable states to minimize transients from causing false operation of the logic. The network driving the trigger circuit optimizes the delay and distortion of the output pulse and it is possible, at the expense of delay, to produce zero distortion.

### INTERFACE

It was concluded from a study of the conditions to be expected on the connexions to and from the switching equipment, that it would be desirable to use relay switching for the functions listed in the table. General purpose miniature comb-operated relays are used except for a mercury-wetted reed relay used for the pulsing contacts in the pulsing-out loop of the incoming signalling unit and tone switching on the outgoing signalling unit.

The decision to use a relay for tone switching was influenced by the requirement of having a minimum tone leak to line, better than -80dBm0, to ensure that there are no wideband coaxial amplifier over-load problems. To reduce complexity and types of components, the same circuit elements are repeated wherever possible. This applies particularly to the logic output interface. It was not possible to apply the same constraints to the logic in the input circuits since design is dependent on the external influences. Typical examples of these circuits are as follows.

### Relay Driver (shown in Fig. 6)

In the idle condition, transistor TR1 is turned off by the -5 volts potential at the input. Transistor TR2 is also turned off since its base is at earth potential. A command from the logic is a change from 0 to 1 given by a change in potential from -5 volts to earth, switching transistor TR1 on and causing the junction of resistors R2 and R3 to go negative, thus switching the transistor TR2 and operating the relay.

### P-Wire Detector

The conditions of the P-wire, earth or disconnect, are detected by a high-impedance input circuit (Fig. 7). An earth on the P-wire will turn transistor TR1 on, causing transistor TR2 to turn off, so changing the input to the logic from 0 to 1 and thus commanding the logic to inhibit signalling.

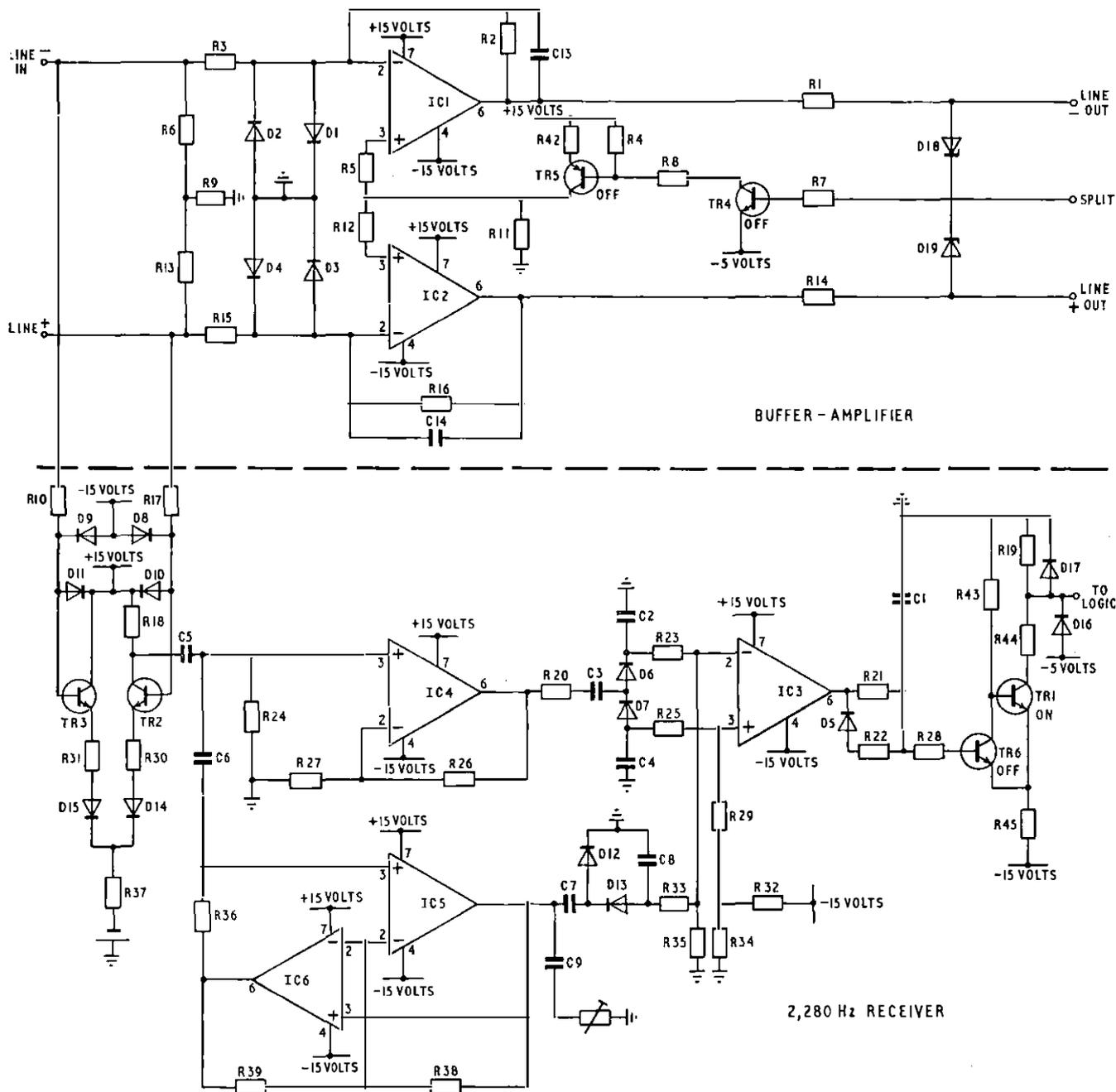


FIG. 5—Circuit diagram of the buffer-amplifier and receiver

The filter circuit consisting of resistors R1 and R2 and capacitor C2 was found necessary to reduce the noise found on the P-wire and so render the detector immune from this type of interference.

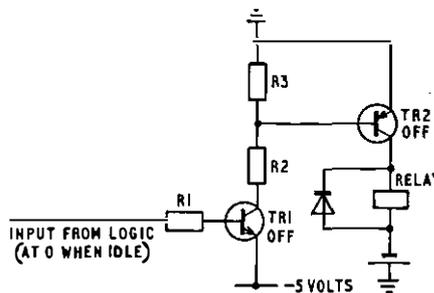
**Reset Circuit**

When a signalling unit is plugged into the rack, the initial surge on connecting power can cause various toggles to be set to an incorrect state. To prevent the first call from being lost the logic is reset by a circuit in the interface, this clears all unwanted information from the logic. The logic is subsequently reset on the initiation of every call.

**D-Relay Function and Loop Detector Outgoing Signalling Unit**

The polarity of the 2-wire, negative and positive wires, is controlled by the state of the switching network made up of transistors TR3-10 and resistors R6-11 (Fig. 8). The circuit

is arranged to take the place of the more conventional D-relay contacts, the function of which is to reverse the polarity of the positive and negative wires upon receipt of the called-subscriber answer condition.



(Note: Shown in the idle condition)

FIG. 6—Circuit diagram of the relay driver

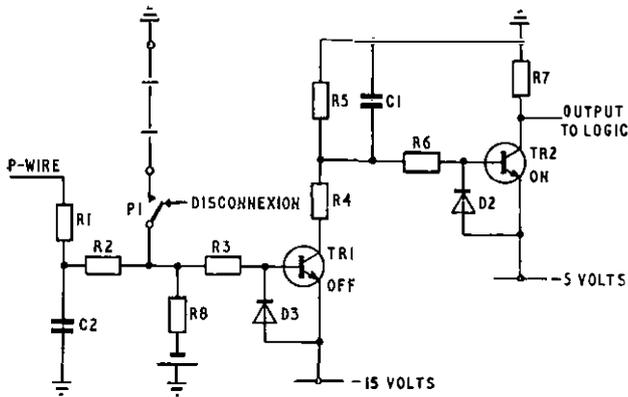
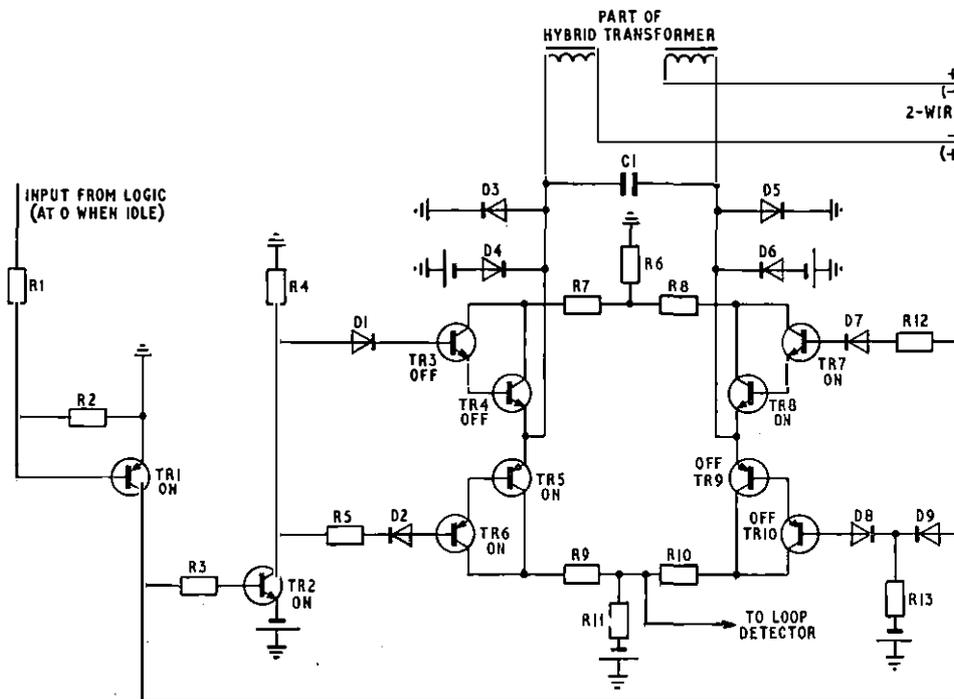


FIG. 7—Circuit diagram of the P-wire detector

In the idle condition, transistor TR1 is on, so the bases of transistors TR9 and TR10 are more positive than their emitter collector circuits and are, therefore, off. Transistors TR7 and TR8 are in the on condition since their bases are less positive than their emitter-collector junctions and so the positive wire of the 2-wire is directed to earth via resistors R8 and R6. With transistor TR1 in the on condition, transistor TR2 is also on causing transistors TR3 and TR4 to be off, and transistors TR5 and TR6 on and so the negative wire of the 2-wire is connected to battery via resistors R9 and R11.

Since the circuit is symmetrical, when called-subscriber answer conditions are detected by the logic, a change of state at the input to transistor TR1 from logic 0 to logic 1 will cause transistors TR1 and TR2 to be turned off, this in turn changes the state of transistors TR 3-10 and in so doing changes over the polarity of the negative and positive wires of the 2-wire.

The transistors in this part of the circuit are arranged in a high gain configuration to decrease the switching time between conduction and cut-off and to provide the necessary current gain from the driving stages, transistors TR1 and TR2.



(Note: Shown in idle condition)

FIG. 8—Circuit diagram of the D-relay function

TABLE

Relays used in the outgoing and incoming Signalling Units

Signalling unit	Relay	Function	Type of relay
Outgoing	P	P-wire busy	23 (NOTE 1)
	XS	Split the transmit circuit	23 (NOTE 1)
	TT	Send tone	Mercury-wetted reed
	RTA RTB RTC	Test highway switching	350 (NOTE 2)
Incoming	P	P-wire busy	23 (NOTE 1)
	A	Complete calling loop	Mercury-wetted reed
	DE	Remove terminating network under called subscriber answer conditions	23 (NOTE 1)
	AS RTA RTB RTC	Complete pulsing loop Test highway switching	23 (NOTE 1) 350 (NOTE 2)

NOTE 1 A type-23 relay<sup>4</sup> is a general purpose miniature comb-operated relay with alloy contacts consisting of 40 per cent silver and 60 per cent palladium.

NOTE 2 A relay 32 is similar to the type-23 relay but with alloy contacts consisting of 5 per cent nickel and 95 per cent gold.

The loop detector circuit is arranged to detect the change of potential across resistor R11, this signal is passed via a 50 Hz filter into a drive amplifier. The output of this amplifier drives a Schmitt-trigger circuit to interface between the loop detector and the logic. The schmitt-trigger circuit was chosen, as in the receiver circuit, to minimize interference with the logic from noise spikes in the 50-volt supply.

### Logic

The basic time-pulse for the logic circuitry is derived from the 2,280 Hz supply. The signal is passed via a buffer-amplifier and pulse shaper to provide a square wave of nominally

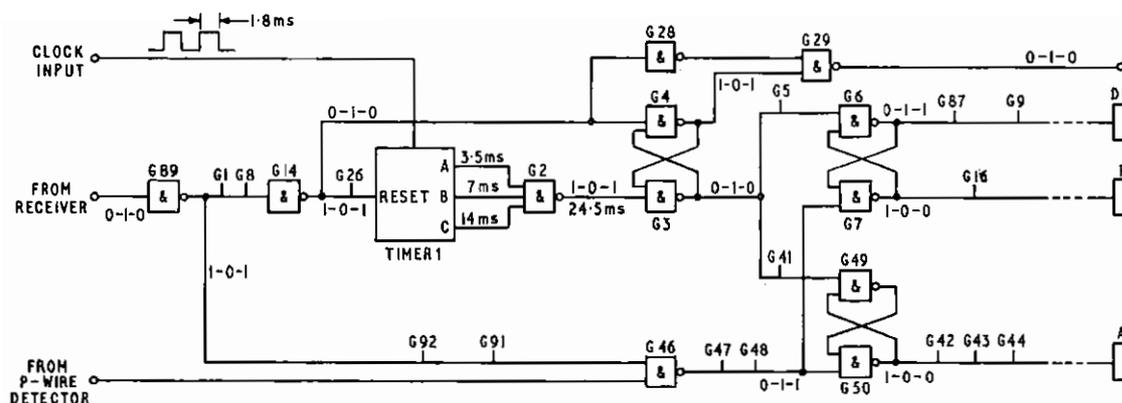


FIG. 9—Part of the incoming signalling unit logic circuitry: initiation of seizure

0.4 ms. This pulse is connected to the logic circuitry and all other required times are derived by the use of four-bit divide-by-16 binary counters in the logic circuit.

The control and timing functions are obtained by the use of NAND gates and counters, of low power t.t.l. packages mounted in dual-in-line 14 lead units.<sup>5</sup> Typically the logic for the outgoing signalling unit consists of eight packages of 4-bit binary divide-by-16 counters and 26 packages of NAND gates made up of a variety of two, three, four and eight input units and inverters. The constraints imposed on the circuit designer with this type of logic circuitry and the need for economic reasons to use the minimum of packages makes these circuits appear complex, but diagram notes are provided to aid understanding.

The logic controls the functions of the signalling unit, and to start a train of events it requires a change of state from the interface circuit. This change of state is referred to as a change from logic 0 to logic 1 or vice versa, logic 1 being at earth and logic 0 being at -5 volts with respect to earth.

To prevent unwanted noise spikes from various sources setting the logic circuitry during an idle period, causing first-call failure, the design has been arranged so that a reset off-condition is applied to all the toggles upon seizure of the signalling unit.

### Logic Circuitry

To give an appreciation of the techniques used, Fig. 9 is a simplified diagram of part of the logic circuitry for the incoming unit and shows the sequence of events on initiating a seizure of the signalling unit. Gates that are not directly concerned in this event are not shown in full but the gate number is shown together with its state, i.e. logic 0 or logic 1, in brackets.

Four-bit binary-counters are used to perform all timing functions. These consist of chains of divide-by-two elements, the outputs of which are available for external gating. An input clock wave-form is divided by two, four, eight etc., through one or more of these counters. If an external gate is used to combine several of these outputs, the gate output will remain at logic 1 until all its inputs are at logic 1 together. The counters will only perform their dividing function when the reset input is held at logic 0. If the reset input is taken to logic 1 the counter will stop and all its outputs will be reset to 0.

The objective in seizing the incoming signalling unit is

- (a) to extend a loop via the negative and positive wires to operate the A-relay of the incoming selector,
- (b) to busy the P-wire, and

(c) to provide a compromise terminating impedance to improve the stability of the line during the time that the signalling unit is seized but in an unanswered state.

The seizing signal is a burst of 2,280 Hz tone, on the received pair of the 4-wire circuit. The receiver responds to this tone and its output changes from logic 0 to logic 1. The output from gate G89 goes from logic 1 to logic 0, and this change, via gates G92, G91, G46, G47 and G48, removes the reset condition to the toggles. A second path from gate G89 via gates G1 and G8 causes gate G14 to change to logic 1.

Gate G14 has three output paths, path one causes gate G28 to go to logic 0 inhibiting gate G29. The output of this gate, going to logic 1, provides a signal to inhibit the buffer-amplifier which splits the line to prevent local interference with the receiver. Path two provides a signal to prime toggle G3/4 which will be used later. Path three causes the reset input of timer 1 to go to logic 1 and enable it to run. After 25.5 ms, outputs A, B and C of timer 1 will be at logic 1 (shown in Fig. 10) and the output of gate G2 will go to logic 0 thus setting toggle G3/4. The output of gate G3 has two similar paths, one via gate G5 causing toggle G6/7 to be set and the other path, via gate G41, causing toggle G49/50 to be set.

The output of gate G7 via gate G16 provides a signal to operate relay P. The output of gate G6, via gates G87 and G9, causes relay DE to operate and the output of gate G50, via gate G42, G43 and G44, causes the operation of relay A.

At the end of the seizing signal, the output from the receiver reverts to logic 0 and the reset input to timer 1 goes to logic 1 via gates G89, G1, G8, G14 and G26 causing it to reset all its outputs to logic 0.

Toggle G3/4 is reset via gates G89, G1, G8 and G14 and the output of gate G29 goes to logic 0 owing to the output of gates G14 and G4 going to logic 1. This removes the inhibit signal to the buffer-amplifier leaving relays A, P, and DE operated. The circuit is now primed for the next event which is to receive the pulse train.

### POWER SUPPLIES

Each signalling unit requires the following supplies

- (a) -50 ± 2 volts d.c. at 65 mA for the interface,
- (b) -5 volts ± 50 mV d.c. at 40 mA for the logic circuitry,
- (c) +15 ± 1 volt d.c. at 12 mA for the buffer-amplifier and receiver, and
- (d) -15 ± 1 volt d.c. at 12 mA for the buffer-amplifier and receiver.

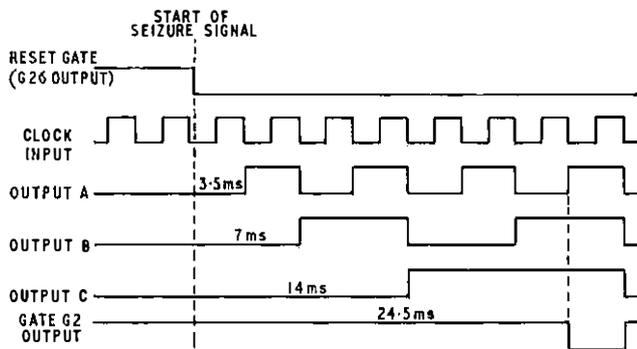


FIG. 10—Timing sequence of timer 1 (Fig. 9)

The  $-50$  volt supply is obtained direct from the exchange battery and the remaining supplies are derived from the same source by using a d.c. to d.c. converter, referred to as the power unit (p.u.).

For security reasons, one p.u. is provided for every 22 signalling units, this basis of provision permitting full utilization of the rack by modules of three shelves. Two of the shelves are fully equipped with signalling units and the third shelf accommodates a p.u. and six signalling units. The same layout is used for both the outgoing and incoming racks.

The constraints on the  $-5$  volt supply require regulation to deal with the variation that can be encountered on the  $-50$  volt exchange battery and also to deal with changes in load for the active and idle states and when a signalling unit is removed from the rack.

The choice of technology to derive the additional supplies was made after considering the following points

- (a) minimum radiated noise,
- (b) minimum air-borne noise specially in the audio band, and
- (c) a requirement not to exceed  $0.2$  mV noise peak-to-peak, rated via a C.C.I.T.T.† network No. 5, being fed back into the exchange battery supply.

The principle used is shown in the block diagram (Fig. 11). A multi-vibrator running at approximately  $20$  kHz is used with a complementary-output feeding into a monostable circuit and, hence, via drive amplifiers, to drive the power transistors in a push-pull mode. This provides an a.c. supply at  $20$  kHz to the windings of a multi-output transformer.

Regulation of the  $-5$  volt supply is obtained by comparing the output with a zener-diode reference circuit to derive a d.c. potential which varies as the  $-5$  volt supply swings about the reference point. This potential is applied to the monostable circuit in such a way as to vary the pulse width and so control

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

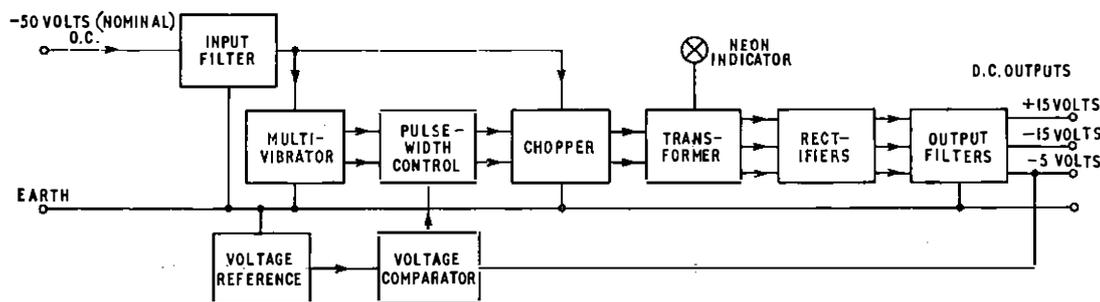


FIG. 11—Block diagram of the d.c.—d.c. converter

the power into the transformer, maximum power being supplied with a 50 per cent duty cycle. The output windings of the transformer are connected in conventional rectifier and smoothing filter techniques.

Overload protection is provided by means of a circuit breaker arranged to trip if the input current is excessive. To protect against short duration surges on the  $-50$  volt supply, a zener diode is provided.

The only fuses are a slow-acting type, rated at 3 amps, connected in the  $-50$  volt feed to the power unit, and a  $1.5$  amp fuse on the front plate of the power unit to protect the  $-50$  volt distribution to the signalling-unit interface circuits.

## Alarms

The output of all supplies, including the  $-50$  volt to the interface circuits, are continuously monitored via an alarm circuit provided in the power unit (shown in Fig. 12). An alarm is given if one of the supplies fail or if, for any reason, the  $-50$  volt supply is disconnected. In addition the alarm is given if the  $-5$  volt supply ranges outside  $\pm 0.25$  volts.

Operational amplifiers are used as comparators and the circuits incorporate hysteresis to reduce the sensitivity to noise close to their operating points. The output of the alarm circuits are common and under alarm conditions a supervisory lamp is lit and an earth is applied to the exchange alarm system.

## TEST ACCESS

During the development, it was realized that wiring every one of the 132 signalling units on a rack to the existing rack-access of a routiner could present cabling problems, the solution was to change the break contacts of the usual form of relay RT into change-over contacts wired to a common highway providing access to any one of the signalling units on the rack. These now become access-relays controlled from the cross-points of a matrix using type-23 relays, contained within the access equipment located on the centre shelf of the rack (Fig. 13), the existing routiner rack access is then redundant for this type of equipment.

By means of a dial and test-lead socket on the access-shelf the access equipment can be used with a portable tester. A 3-digit code locates any signalling unit which is then switched to the test-lead socket for test purposes. The first digit is given by the initial position of the shelf, 0 for the upper-half and 1 for the lower-half of the rack, with nine shelves on each half the second digit is given by the shelf location 0-9, the third digit is given by the position of the signalling unit along the shelf.

This philosophy is followed through to the test desk, where by its dial and a selector to access a particular rack, the rack access equipment is used to provide 2-wire and 4-wire appearances direct on the test desk for testing either a signalling

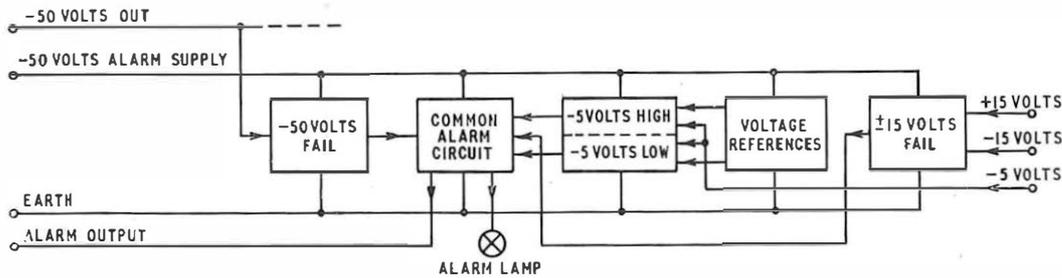


FIG. 12—Block diagram of the alarm circuit

unit or the line without the need for patching on the test jack frame (t.j.f.). This has produced savings in cabling and accommodation in the trunk maintenance control centre by eliminating the 2-wire and 4-wire t.j.f. To avoid blocking the access highway to maintenance for test purposes, during circuit line-up, the existing 2-wire access is retained.

Normal power t.t.l. is used in the design of the logic circuitry to control the matrix, primarily because not all the required functions are produced in the low-power series.

The plug in units have been made compatible for both outgoing and incoming racks by selection of the connecting U-points and redundancy of a few components.

### PROTECTION

A telephone exchange generates a hostile environment for equipment designed with semiconductors and integrated circuits. Spikes of electrical energy on the power supply and junctions can cause damage to these devices resulting in malfunctioning of the equipment. Before protection can be provided on the power and the external leads to dissipate this energy in a controlled manner, some knowledge of its source, magnitude and duration must be known. Some of the biggest difficulties arise in devising networks which simulate these forms of interference.

A continuous 50 Hz voltage may be longitudinally induced into a junction circuit running parallel to a faulty power-cable and, under severe conditions, could rise above 20 volts, this requires a 50 Hz filter in the loop detector element to avoid interference. Short duration, but large amplitude, 50 Hz spikes may be longitudinally induced into junctions close to high-voltage power-cables when the 50 Hz supplies are switched. The voltages induced may be in the order of 800 volts for a duration of 100 ms and protection is given by gas-discharge tubes that strike at approximately 90 volts. The same tubes provide protection against lightning as, although the cable sheathes and protectors reduce the strike effect, a large

current in the sheath induces a voltage in the conductors. A circuit has been devised with low source impedance in which a capacitor charged to 5 k volts is discharged into the signalling unit to simulate the effect of lightning.

Another connexion likely to be affected by interference is the P-wire. Here the back e.m.f. from monitoring relays can be as high as 1,400 volts, requiring a filter within the interface to absorb the energy.

Finally, there are interference pulses on the -50 volt battery supply of various magnitudes and duration caused by switching of electro-magnetic equipment and the rupture of fuses. The interference from switches can be as high as 2 kvolts of 1  $\mu$ s duration while that from fuses rupturing can be 250 volts of 500  $\mu$ s duration. The power contained in the 250 volt 500  $\mu$ s pulse is in the order of 1 to 2 kW and results from a change in current in the inductive element of the busbar when a sub-section fuse is blown. Protection from this interference is given by a surge-suppressor diode, continuously rated at 1,000 watts, connected to the -50 volt supply to each rack, the action clamps the busbar voltage to the equipment at a nominal 58 volts.

### PHYSICAL REALIZATION

B.P.O. 62-type mounting practice was chosen because, by design, it provides a measure of screening for each individual unit, it is fully documented by the B.P.O. for transmission equipment and is available from a number of suppliers. The practice has been proven in the transmission field over a long period and is acceptable for use in telephone exchanges. A view of the equipment provided at Salisbury for field trial is shown in Fig. 14. The signalling units have been developed on a 2.4 in wide module 13.5 in long and 5 in high (shown in Fig. 12). All components, except the hybrid transformer, are mounted on printed circuit boards (p.c.b.) of glass cloth bonded with an epoxy resin. Both sides of the boards are used for

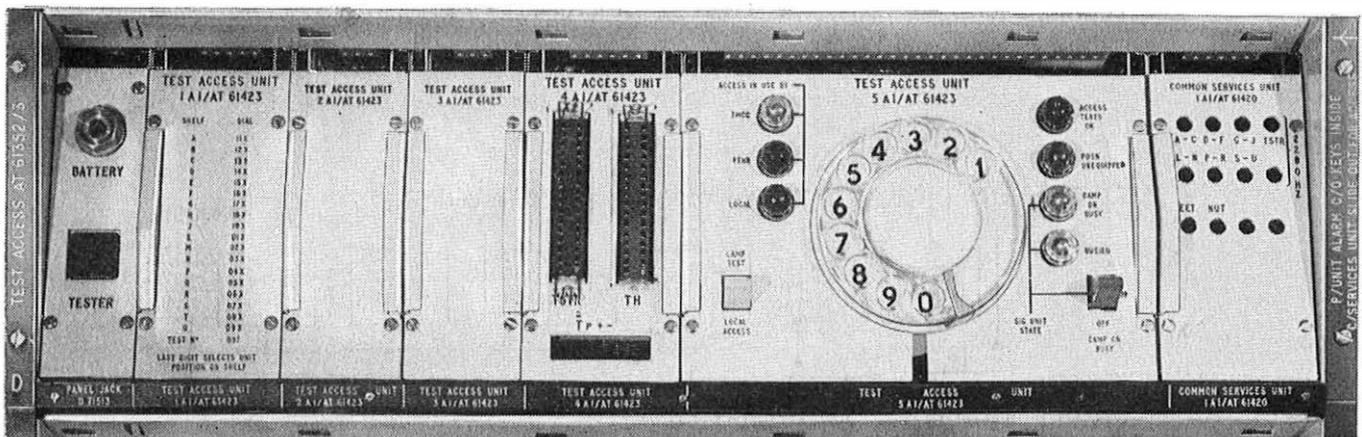


FIG. 13—Photograph of the test-access shelf

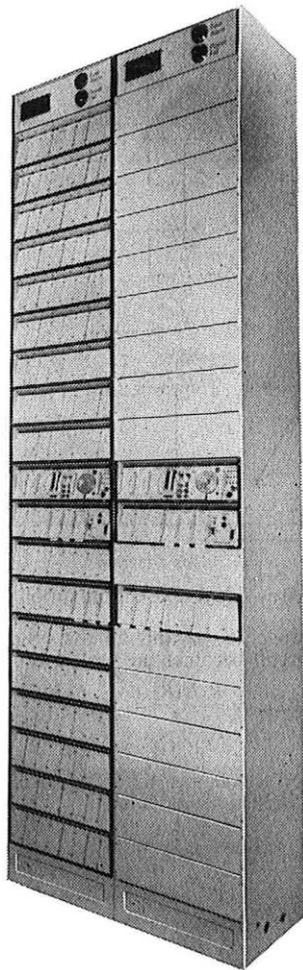


FIG. 14—Photograph of the field-trial equipment in Salisbury Exchange

printed track with plated-through holes, the design is suitable for flow soldering techniques to reduce labour costs.

Computer-aided design was used in the layout of the logic p.c.b. The program of the computer provides for a number of constraints and the system is further enhanced by the graphics loop which, with the aid of a light-pen, gives the operator control over the placing of particular components. Other advantages of the system are the high degree of accuracy that can be obtained with maximum packing density, the ease with which modifications can be made to the p.c.b. design and the speed of completing the work compared with usual draughting techniques.

The design is stored for a period of time on punched paper-tape ready for re-introduction to the computer should a change be necessary.

The final artwork is produced by a plotter,<sup>6</sup> on film which is used direct for the production of the printed board. The plotter also provides a drilling master and component identification drawing.

### CHOICE OF COMPONENTS

Special account was taken of reliability and availability of components in order to keep maintenance costs to a minimum and avoid single sources of supply and premature obsolescence. The mean-time-between-failures of the existing relay-set is 1.5 years, it is hoped that the new design, utilizing as far as possible electronic techniques, would increase this figure to 13 years.

The packing density for the signalling units ultimately depended on the power dissipation of the unit. To design for the minimum power dissipation meant that integrated circuitry had to be used, either in the form of large-scale-

integration (l.s.i.) metal oxide silicon (m.o.s.) where the logic circuitry would be processed onto a single chip, or small-scale-integration (s.s.i.) using standard packages. The decision was made to use s.s.i. in the form of low power t.t.l. which have the lowest power requirements of the standard packages and is readily available from several manufacturers.

The operational amplifier chosen for the buffer-amplifier/receiver circuit required discrete components to obtain the gain/bandwidth product. Although more costly than operational amplifiers with inherent control, it results in a more stable filter-characteristic.

The mercury-wetted reed-relay used in both the outgoing and incoming signalling units has a life expectancy of at least  $10^9$  operations. The relays used for routine and certain interface functions are the type-23 with silver/palladium contacts or where circuit conditions require the use of precious metal contacts, the type-350, a new relay similar in all respects to the type-23 but with nickel/gold alloy contacts.

### DOCUMENTATION

This development has been fully documented and it is possible for any electronic equipment manufacturer to produce the equipment. The documents, therefore, include such items as printed circuit masters and composite drawings to show the component assembly. The components are tabulated in the schedules as part of the drawings. The 62-type mounting chosen for the equipment practice has minimized the documentation by using existing drawings for transmission equipment but drawings of new parts have been included where necessary.

### FIELD TRIAL

The trial was arranged over links between Cambridge-Salisbury and Salisbury-Swindon with the facility to complete a tandem link between Cambridge and Swindon. It was necessary to show

- (a) compatibility with existing designs of relay-sets,
- (b) the performance in face of the exchange environment, and
- (c) expected fault rate in service.

Test calls were sent over the routes and, wherever possible, the reasons for failures determined and recorded. The trial was invaluable in indicating problems associated with practical operating conditions and several small modifications were required to overcome the difficulties encountered. Initially the overall fault rate was in the order of 0.275 per cent, this was reduced to 0.086 per cent then further reduced to 0.03 per cent. In the final analysis faults attributable to the miniaturized equipment was 0.008 per cent. This compared with a fault rate of 0.3 per cent for correctly-adjusted relay-sets of the existing design.

For statistical accuracy the test-call sample under any specific condition was adjusted to meet a confidence level of 95 per cent. However, as the faults directly attributable to the signalling units were reduced, the sample size required became impracticable. Typically for the one error recorded in the final sequence a sample in the order of 30,000 calls would be required to establish accuracy at 95 per cent confidence, there were in fact 15,000 test calls in this series.

The trial was too short to produce data for component life assessment, but by continuing the trial with live traffic it is hoped to assess component reliability.

### MAINTENANCE

The mean-time-between-failure of signalling units is assessed to be in the order of 13 years compared with 1.5 years for the equipment it is designed to supersede. This factor, and the need for relatively complex diagnostic and repair equipment, indicates that centralized repair would prove to be economic. With this objective in view, provision has been made for the

portable tester, designed as part of the development, to be modified by the addition of a plug-in unit, to display the point of failure in the test cycle as an aid to the repair centre.

At the exchange, a faulty unit will be replaced by a spare and the faulty unit sent away for repair. To coincide with this procedure the diagram notes are in two sections, the first giving a description of the unit with details of U-point connexions and associated conditions within the unit for use mainly in the exchange, and the second consisting of logic charts with diagrams showing the action within the unit on the application of a signal, for use at the repair point.

## CONCLUSIONS

The concentration of S.S.A.C. No 9 equipment has been improved by more than 5 : 1 compared with the transistorized equipment, at the same time remaining within the power dissipation requirements for the exchange environment.

By the use of t.t.l. for the logic circuitry, timing functions are controlled within close limits and any failure is most likely to be catastrophic. This together with the small number of contacts in the design of the signalling unit should considerably increase the overall reliability of the equipment.

The design of test-access circuits has saved accommodation and cabling costs and, it is hoped, will be an asset to maintenance staff.

## ACKNOWLEDGEMENT

Acknowledgement is due to members of the team in Telecommunications Headquarters Exchange Systems Division and Research Department who designed and manufactured the field trial equipment, to Telecommunications Headquarters Service Division and to Regional and Telephone Area staff at Cambridge, Salisbury and Swindon who were responsible for conducting the field trial.

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## APPENDIX 1

### Analysis of simulated inductance assuming ideal operational amplifiers in the form of a gyrator

For an ideal operational amplifier, the gain approaches infinity, therefore, for output voltages within the working range, the input voltage  $v = 0$ .

Also, as the input impedance approaches infinity, then the input currents become zero.

Assuming ideal operational amplifiers in Fig. 15(b), then both the input voltages and currents are regarded as zero.

$$\text{Hence, } V_1 = V_3 = V_5.$$

$$I_2 = I_3.$$

$$I_4 = I_5.$$

$$\text{Now, } I_5 = \frac{V_5}{Z_5} = \frac{V_1}{Z_5}.$$

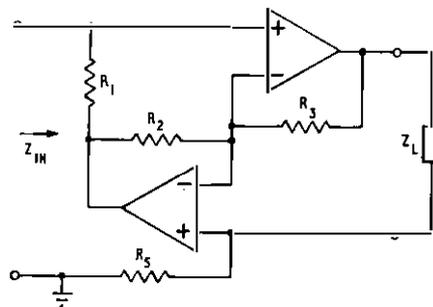
$$\therefore V_4 = I_5(Z_4 + Z_5) = \frac{V_1}{Z_5}(Z_5 + Z_4) \dots \dots (1)$$

$$\text{Now, } I_3 = \frac{V_3 - V_4}{Z_3} = \frac{1}{Z_3} \left[ V_1 - \frac{V_1}{Z_5}(Z_4 + Z_5) \right] = -V_1 \frac{Z_4}{Z_3 Z_5}.$$

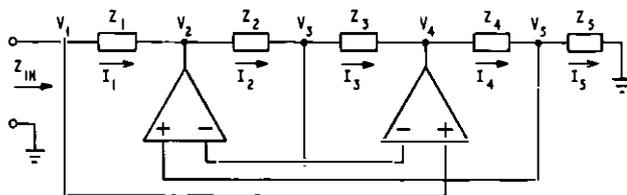
$$\text{Since, } I_2 = I_3, V_2 = V_3 + I_2 Z_2 = V_1 - V_1 \frac{Z_2 Z_4}{Z_3 Z_5}.$$

$$I_1 = \frac{V_1 - V_2}{Z_1} = V_1 \frac{Z_2 Z_4}{Z_1 Z_3 Z_5}.$$

$$Z_{in} = \frac{V_1}{I_1} = \frac{Z_1 Z_3 Z_5}{Z_2 Z_4}.$$



(a) Preferred circuit



(b) Block Diagram

FIG. 15—Ideal operational amplifier

If  $Z_4$  is made a capacitor  $C_4$  and all the other impedances are resistors then the preferred circuit of Fig. 15(a)

$$\text{and } Z_{in} = \frac{R_1 R_3 R_5}{R_2 \frac{1}{j\omega C_4}} = j\omega \frac{R_1 R_3 R_5 C_4}{R_2}.$$

Therefore, a gyrator terminated by a capacitor simulates, at its input terminals, an inductance of value

$$L = \frac{R_1 R_3 R_5 C_4}{R_2}.$$

In the S.S.A.C. No. 9 miniaturized receiver, all the resistors have the same resistance  $R$ .

$$\therefore L = R^2 C_4.$$

Connecting a capacitor of capacitance  $C$  in series with the gyrator input forms a series resonant circuit of frequency

$$f_0 = \frac{1}{2\pi R \sqrt{C_4 C}}.$$

Frequency adjustment is made by varying the value of the earthed resistor  $R_5$ .

As described in the text, the receiver guard-voltage is developed across the tuned circuit and the signal voltage is developed across the inductance. It is convenient to derive the signal voltage from an operational-amplifier output terminal as a low-impedance source.

$$\text{From equation (1), } V_4 = V_1 \left( 1 + \frac{Z_4}{Z_5} \right) = V_1 \left( 1 + \frac{1}{j\omega C_4 R_5} \right).$$

Thus, if  $\frac{1}{\omega C_4 R_5} \ll 1$  the output voltage is very nearly equal to  $V_1$ , the voltage across the simulated inductance.

The Q-factor for this type of circuit is dependent upon its physical configuration, stray capacity should be kept to a minimum. The effect of stray capacity is worse when the values of resistance are high, with the values used the Q-factor is about 600 and is not too sensitive to stray capacitance.

## APPENDIX 2

### Operational Amplifiers

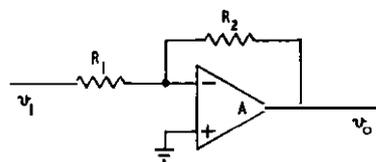
Inverting Amplifier (single ended).

For a typical operational amplifier:

Input impedance  $Z_i$  is high — nominally 2 M ohms.

Output impedance  $Z_0$  is low — nominally 75 ohms.

Open loop gain  $A$  is high — nominally 200,000.



(a) Typical feedback configuration

FIG. 16(a)

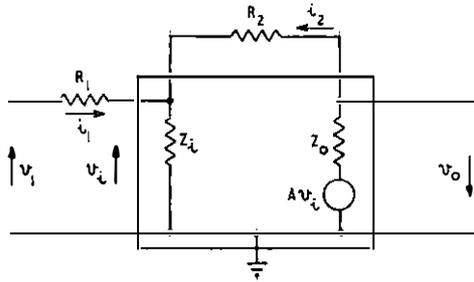


FIG. 16—Single ended inverting amplifier

**Stage-gain and virtual-earth input**

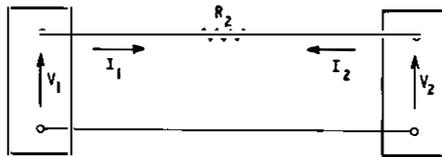
Connecting networks each with two terminals as in Fig. 17(a) and knowing the voltage ratio  $A = \frac{V_2}{V_1}$ , it can be shown that the currents  $I_1$  and  $I_2$  can be obtained by disconnecting resistor  $R_2$  and replacing it by impedances  $Z_1$  and  $Z_2$  as in Fig. 17(b), (Miller's theorem).

Let  $A = \frac{V_2}{V_1}$ .

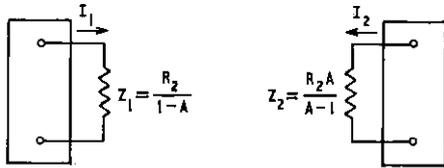
Then,  $i_1 = \frac{V_1 - V_2}{R_2} = \frac{V_1(1 - A)}{R_2} = \frac{V_1}{\frac{R_2}{1 - A}} = \frac{V_1}{Z_1}$ .

$\therefore Z_1 = \frac{R_2}{(1 - A)}$ .

Similarly,  $Z_2 = \frac{R_2}{1 - \frac{1}{A}} = \frac{R_2 A}{A - 1}$ .



(a) Basic diagram



(b) Miller's equivalent diagram

FIG. 17—Connecting two-terminal networks

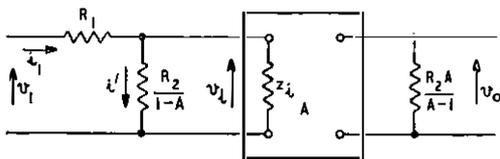


FIG. 18—An operational amplifier connected as in Fig. 17

An operational amplifier connected as in Fig. 16 may be represented by Fig. 18. In practice, both  $A$  and  $Z_i$  are very large.

$\therefore \frac{R_2}{1 - A} \ll Z_i$ ,

and  $i_1 \approx i'$ .

$\therefore v_i = i_1 \frac{R_2}{1 - A}$ .

The output voltage  $v_0 = Av_i$ ,

$= Ai_1 \frac{R_2}{1 - A}$  ..... (1)

As  $A \rightarrow \infty$ ,

then,  $\frac{R_2}{1 - A} \rightarrow 0$  (a short circuit),

and,  $i_1 \approx \frac{v_1}{R_1}$ .

From equation (1),  $v_0 \approx -i_1 R_2 = -\frac{R_2}{R_1} v_1$ ,

and the overall voltage gain  $AS = \frac{v_0}{v_1} = -\frac{R_2}{R_1}$ .

At the actual amplifier input there is, therefore, a virtual short-circuit and because the non-inverting input is at earth potential the inverting input is a virtual earth. It is virtual in that while the feedback through resistor  $R_2$  keeps the voltage  $v_i$  at zero, no current actually flows through the short circuit, current  $i_1$  produced by voltage  $v_1$  flows past this virtual short-circuit through resistor  $R_2$  so that,

$v_0 = -i_1 R_2$ .

**Input Impedance**

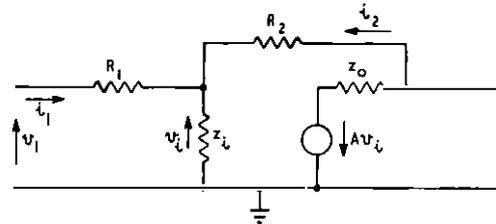


FIG. 19—Input impedance equivalent network

Acting upon the equivalent network Fig. 19,

Let  $R_2' = R_2 + z_0$ .

Then,  $v_1 - (i_1 + i_2)z_i - i_1 R_1 = 0$  ..... (1)

$v_1 - i_1 R_1 + i_2 R_2' + A(i_1 + i_2)z_i = 0$  ..... (2)

$(i_1 + i_2)z_i + i_2 R_2 + A(i_1 + i_2)z_i = 0$  ..... (3)

Hence, it can be shown that the input impedance

$\frac{v_1}{i_1} = R_1 + \frac{z_i}{1 + (1 + A)\frac{z_i}{R_2 + z_0}}$

which, with  $A$  very large, the stage input-impedance approximates very closely to  $\frac{v_1}{i_1} = R_1$ .

**Output Impedance**

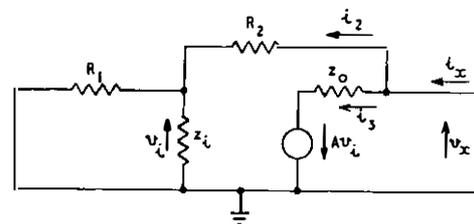


FIG. 20—Output impedance equivalent network

Acting upon the equivalent network Fig. 20,

Let  $R_1' = R_1$  in parallel with  $z_i$ .

Then,  $v_i = v_x \frac{R_1'}{R_1' + R_2}$ .

Now,  $i_2 \ll i_3 \therefore i_3$  approximates to  $i_x$ .

$v_x + Av_i - i_x z_0 = 0$ .

Hence,  $v_x + \frac{A v_x R_1'}{R_1' + R_2} - i_x z_0 = 0$ .

$\therefore \frac{v_x}{i_x} = \frac{z_0}{1 + A \frac{R_1'}{R_1' + R_2}}$ .

If, as is usual,  $z_i \gg R_1$  and  $A$  is very large then, the output impedance approximates to  $\frac{v_x}{i_x} = \frac{z_0}{A \frac{R_1}{R_2}}$ .

# The BS 9000 System for Electronic Components of Assessed Quality

K. H. CLARKSTONE†

U.D.C. 621.38-772:389.6(42)

*The BS 9000 scheme provides a nationally-recognized system for the specification and quality assessment of electronic components. The scheme is now beginning to be applied in the semiconductor and resistor industries, and in the near future, to other components as well. Its national use should lead to a useful reduction in the variety of specifications and inspection arrangements that component manufacturers have hitherto been required to meet. The accompanying benefits of more economic production and more consistent quality are of value to both equipment manufacturers and to the British Post Office.*

## INTRODUCTION

Many of the electronic components commonly used in telecommunications equipment are also widely used in industrial and defence equipment as well as in domestic electrical, radio and television equipment. In the past, where agreement to use common specifications for such components has been attempted, it has been largely on the basis of the requirements of specific sectors of industry, each usually having different views as to what constitutes a good specification. In some instances, the same component is covered by several specifications each requiring minor variations in the necessary tests, test methods and inspection procedures, but all having the same object of ensuring a good-quality component.

In the mid-1960s, a government-sponsored committee\*, on which the British Post Office (B.P.O.) was represented, made recommendations for a system of common standards for military and industrial use. This was the beginning of the BS 9000<sup>1</sup> scheme. This article outlines these recommendations and the present position in the realization of the committee's aims and intentions in providing a system for the assessment of the quality of electronic components.

The committee issued a report, known as the *Burghard report*, in which the following recommendations were made.

(a) The British Standards Institution (B.S.I.) should be charged with the responsibility of controlling standards suitable for both military and industrial applications.

(b) The technical committees of the B.S.I. should prepare specifications for components to meet user requirements, and wherever possible, these should be in line with the International Electrotechnical Commission (I.E.C.) recommendations.

(c) In addition to the technical committees of the B.S.I., approved manufacturers should be permitted to write specifications for those components for which there is no appropriate specification in the series. These specifications should conform to the general rules laid down by the technical committee for components of that particular family to facilitate comparison of one manufacturer's product with that of another.

(d) The specifications for components, in addition to defining physical and electrical properties and tests for initial approval purposes, should include sampling procedures for

tests to be applied to production items to ensure that a satisfactory level of quality is maintained in production. The information derived from these batch and periodic tests should be available to customers as an indication of the quality and reliability of that manufacturer's product.

(e) Manufacturers should be subject to approval in respect of the adequacy of their inspection and quality-control arrangements and the competence of the inspector who would be fully responsible for the inspection and release of products to customers. Each manufacturer's procedures and operations would be subject to supervision by an independent inspection authority.

(f) This authority, acting as agents for B.S.I., should be appointed to ensure that specifications issued by manufacturers conform to the rules, to administer the inspection system and to certify test reports prepared by manufacturers' inspectors.

(g) Components which have been produced under the scheme should be accompanied by release notes certifying conformity with the relevant specifications when they are delivered to the customer.

## B.S.I. COMMITTEES

In 1966, following government acceptance of the *Burghard report*, the Minister of Technology asked the B.S.I. to proceed with the scheme. Three new committees were appointed whose functions are described below. The B.P.O. has had representation on these committees from the outset.

*Management Committee for Components of Assessed Quality (OC33)*. This committee has general responsibility for implementing the scheme envisaged in the *Burghard report* and for settling overall policy matters.

*Inspection Committee (OC33/1)*. This committee is responsible for organizing the inspection and approval arrangements required by the scheme.

*Co-ordinating Committee (OC33/2)*. This committee is responsible for preparing the basic specifications applicable to all types of components, and for co-ordinating the activities of all the technical committees to ensure that specifications for components are correctly prepared and edited.

## Technical Committees

The technical committees already existed within the B.S.I. and consisted of representatives from the component-manu-

† Telecommunications Development Department, Telecommunications Headquarters.

\* Known as the *Burghard committee* after its chairman, Rear-Admiral G. F. Burghard, C.B., D.S.O.

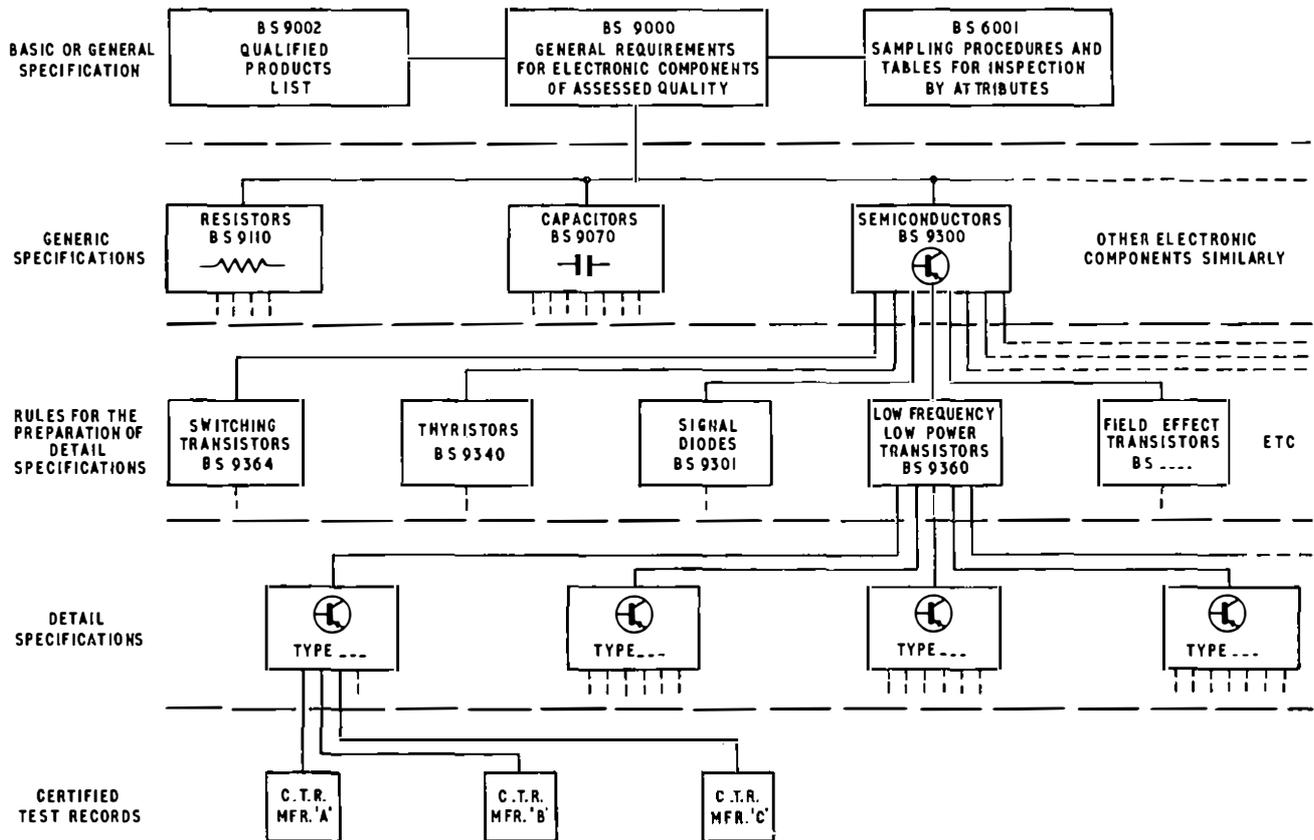


Fig. 1—The BS 9000 system of specifications

facturing industry, the equipment-manufacturing industry and the ultimate users including the B.P.O., Ministry of Defence, industrial organizations and various professional institutions.

Hitherto, the activities of these committees had been concerned with establishing the precise meaning of terms used, standardizing methods of measurement and test, and safety aspects.

The assessment of the quality of components was left entirely to separate agreements between purchaser and supplier.

Under the BS 9000 scheme, the responsibility for translating the general requirements of the scheme for quality-assessed components, as laid down by the Co-ordinating Committee (OC33/2) for each section of the component industry, was given to the technical committee covering that industry.

### SPECIFICATIONS AND DOCUMENTS USED IN THE BS 9000 SCHEME

To avoid the repetition in each component specification of procedures common to all, the *Burgard report* recommended adoption of the specification structure shown in Fig. 1. Organizations large enough to have their own specification writing, inspecting and testing departments, typically the B.P.O. and the Ministry of Defence, have operated somewhat similar schemes to this for many years. It is, of course, an aim of the BS 9000 scheme to eliminate progressively the need for these individual schemes.

#### Basic or General Specifications

BS 9000, entitled *General Requirements for Electronic Components of Assessed Quality*, is a document prepared by

Sub-committee OC33/2. It gives a general explanation of the scheme and the procedure to be used by manufacturers for component approval, inspection, testing, quality assessment and preparation of certified test records. In its 1971 version it incorporates the first steps to harmonisation with a comparable European scheme for components of assessed quality described in document CENEL 1<sup>2</sup>.

BS 6001<sup>3</sup>, entitled *Sampling Procedures and Tables for Inspection by Attributes*, is a document which lays down the sampling procedures to be used for production components prior to their release.

#### Generic Specifications

These specifications give the general requirements applicable to a family or part of a family of components such as resistors, capacitors, semiconductors, electronic valves, and connectors. Included in the generic specifications are terminology, letter symbols, marking of parts, test methods and preferred combinations of test severities.

#### Rule Documents

Rule documents are supplementary to the generic specification and lay down the rules to be followed in preparing detail specifications. The more important items dealt with are as follows:

- (a) standard sequences of testing,
- (b) the minimum test requirements that components in each application category shall fulfil, and
- (c) the test information that is to be entered by the manufacturer in the certified test record (c.t.r.) for the information of customers.

## Detail Specifications

These specifications relate a particular component or range of components to the generic specification for components of that type. They contain the following information.

(a) *Application category of the component.* To meet the varying needs of customers, three application categories of components were envisaged. These are the *general application category*, intended to meet the bulk (80 per cent) of industrial and military applications, the *S-application category*, intended to have a performance meeting the special requirements of the more sophisticated users (e.g. certain military and aviation requirements), and the *C-application category* intended for use where either lower stress levels or a lower degree of quality assessment is appropriate.

Recent proposals still under discussion aim to give more flexibility to the scheme by making provision for components in any application category to be available at 3 different levels of assessed quality.

(b) *Dimensions.* A simple outline drawing or reference to a standard outline drawing is given, dimensioned to cover interchangeability requirements and showing details of external connexions.

(c) *Ratings and characteristics.* These are presented in a standard way for each family of components. In some cases, design data over and above that provided by the ratings and characteristics are included. The design data may be in the form of characteristic curves.

(d) *Inspection test requirements.* These are divided into four groups of tests, each test or sequence of tests has a specified inspection level which fixes the number of specimens to be extracted for testing from any given size of production batch, and an acceptable-quality level (a.q.l.) which gives the maximum number of failures that the randomly-selected sample of specimens is allowed to contain.

Group A tests are conducted on a lot-by-lot basis and cover the more important electrical or mechanical performance characteristics.

Group B tests are also conducted on a lot-by-lot basis and include inspection requirements for mechanical interchangeability and the component's ability to withstand such environmental stresses and short-term endurance tests as can be completed in one week.

When qualification approval has been granted, components from an approved production line are normally released to the customer on the satisfactory completion of the Groups A and B tests.

Group C tests include longer-duration environmental and endurance tests, and those electrical and mechanical tests appropriate for check at intervals of three months.

Group D tests are similar to Group C tests but are concerned with characteristics which are appropriate for inspection at intervals of one, two or three years, and are usually of a design-proving character.

## PREPARATION OF DETAIL SPECIFICATIONS

The detail specifications can be prepared by either the appropriate B.S.I. technical committee, or by a manufacturer.

The normal evolutionary process is for a component to start its life to a manufacturer's specification (known as an F specification). As the market grows and other manufacturers become interested in making it, its status is changed to that of a committee (or N) specification by manufacturers' or users' representatives submitting proposals to a B.S.I. technical committee. Initially, however, a number of detail specifications have been issued by the B.S.I. technical committees to cover existing components which are also covered by Ministry of Defence specifications for passive devices (DEF), active devices (CV) and integrated circuits (CN).

When a user wishes to specify a new component in the BS 9000 system, he has to negotiate with a manufacturer who will issue an agreed specification or, possibly, by submitting proposals for a specification to an appropriate B.S.I. technical committee for the issue of a N specification.

## CERTIFIED TEST RECORDS

Included in the terms of reference for the *Burghard committee* was the consideration of the reliability of electronic components. Typical of the problems that reliability assessment involves is that to assure a failure rate of 0.1 per cent/1,000 hours with 90 per cent confidence by means of normal operating tests requires nearly 4,000 components to be tested for 1,000 hours, with no more than one failure. Most B.P.O. applications need a much better assurance-of-failure rate, but to include specification requirements for this is not economically worthwhile. The committee considered various methods of reliability assurance and recommended a system of certified test records (c.t.r.). The c.t.r.s contain the more important test results that the manufacturer obtains when testing components to the detail specification. These results are accumulated over a six-month period and are presented as number of components tested and number of failures. The cumulative results are also recorded for periods up to three years.

Certified test records are mandatory in the BS 9000 system for components supplied to the *general* and *S-application categories* and must, as a minimum, include the test results for the longer-term endurance tests (2,000 hours, 8,000 hours) and overstress tests. Test results obtained from other tests e.g., solderability, strength of terminations and vibration, may also be required in terms of number tested and number failed. The c.t.r. may also contain information about spreads of characteristics, and these are usually presented in the form of a group/frequency table. This information is mandatory for the more important characteristics but additional spread information on other characteristics may also be required.

The test results to be entered in the c.t.r.s are specified in the rules documents and hence in the detail specifications. The c.t.r.s are published and made available by the manufacturer to customers on request.

Purchasers of components thus have some information available, on an historical basis, of the quality and reliability of a particular manufacturer's product, and thus an additional factor that could be taken into account when ordering components.

## INDEPENDENT INSPECTION AUTHORITY

B.S.I. Committee OC33/1 is the component approval authority, and it has appointed as its agent to implement the requirements of BS 9000, the Electrical Quality-Assurance Directorate (E.Q.D.) of the Ministry of Defence. The E.Q.D. has a nationwide organisation of inspectors and, of course, has responsibilities outside the BS 9000 scheme, but within the BS 9000 scheme<sup>1</sup> is the supervising inspection authority, answerable to B.S.I. Committee OC33/1.

The inspection authority is concerned with the approval of manufacturers, with the verification of manufacturer's detail specifications, with qualification approval of components, with routine quality-assessment tests and with the authentication of certified test records. In addition, it has its own test laboratories.

## APPROVAL OF MANUFACTURERS, TEST HOUSES, AND STOCKISTS

A component manufacturer wishing to take part in the BS 9000 scheme must meet certain general requirements in respect of test equipment and facilities, quarantine and bonded stores, inspection records, etc.

The manufacturer's chief inspector is responsible for ensuring a well-ordered inspection department and is the principal link between the manufacturer and the B.S.I. He is also responsible for ensuring that released products meet the appropriate specification, that a manufacturer's F specification conforms to the requirements of the generic specification, and that the c.t.r.s are accurate.

Manufacturers are approved for the supply of a particular family of components as described in a generic specification, and are expected to have test equipment required by the specification and adequate means of calibration. Where a manufacturer lacks facilities for certain tests, arrangements can be made for these to be carried out by an approved test-house. The approval of a test house follows a similar pattern to that of a manufacturer.

A stockist who wishes to supply components meeting the BS 9000 requirements has to meet similar standards.

The B.S.I. publishes lists (BS 9002)<sup>4</sup> of approved manufacturers, test houses, and stockists, and the ranges of electronic components for which they are approved.

### **QUALIFICATION APPROVAL OF ELECTRONIC COMPONENTS**

Qualification approval is the status given to a component or range of components which meets all the requirements of the relevant specifications. Components supplied against the BS 9000 system must first have qualification approval. To obtain approval to release components, a manufacturer demonstrates by means of qualification-approval tests that he can meet the detail specification for all Group A, B, C and D tests that can be accomplished in 1,000 hours. Where longer-duration tests are specified, full approval awaits the satisfactory completion of these tests. Components with qualification approval cannot, therefore, be available until about three months after the publication by the B.S.I. of the relevant generic specification and rules documents.

The only components eligible for qualification approval to BS 9000 are those made by an approved manufacturer, and each generic specification defines the first stage of manufacture necessary for eligibility. Components imported into the United Kingdom (U.K.), and tested to the BS 9000 specification, are not eligible for supply against the BS 9000 system. Partly-processed imports are only eligible under the conditions stated in the generic specification.

### **RELEASE INSPECTION**

After the completion of a successful qualification-approval test, an approved manufacturer may supply against orders for BS 9000 components only those that meet the full requirements of the relevant detail specification. To do this, he collects the manufactured components into identifiable lots, and on every lot carries out the tests specified in Groups A and B of the specification. The inspection level (i.l.) given for each clause of the specification determines the sample size, and the lot is acceptable for this clause if the number of rejects in the sample is not more than a particular number, the acceptance number, which is a function of the acceptance quality level (a.q.l.). For example, if the i.l. is 1.0, the a.q.l. is 1.5 per cent, and the lot size is 5,000, the tables of sampling plans in BS 6001 indicate that 80 specimens from the batch are taken at random. The test is carried out to the limits specified, and the batch is acceptable if not more than 3 rejects are obtained. This operation is repeated for all the clauses in Groups A and B of the lot, and the lot can only be released for delivery if all the tests are satisfactory.

Every three months, Group C tests are carried out. At intervals of one, two, or three years (as specified), Group D tests are applied.

Testing can be reduced if the product is good enough to meet the requirements in BS 6001 for reduced inspection (i.e.

after 10 consecutive good batches), and a further reduction in testing is possible for components of structurally similar design.

Some manufacturers have operated similar disciplines for their industrial products for many years, but the chief inspector has used his discretion, usually in agreement with the customer, when a particular lot does not meet all the requirements. No discretion is given to the chief inspector in the BS 9000 system.

### **CERTIFICATES OF CONFORMITY**

The certificate of conformity, which accompanies all deliveries to customers, certifies that the components supplied meet all the requirements of the relevant BS 9000 specifications, and includes information whereby the delivered batch can be traced back to the manufacturer's test records.

### **EXTENSION OF THE USE OF THE BS 9000 PRINCIPLE OUTSIDE THE U.K.**

The extension of the BS 9000 concept to European countries has been the subject of much discussion with members of the European Economic Community. Agreement has recently been reached on the general requirements that national schemes shall fulfil, and these are given in Document CENEL 1. Reference to CENEL 1 is made in the 1971 edition of BS 9000, the documents serving parallel functions.

In addition, mutual recognition of the inspection and approval authorities has also been agreed between France, Germany, Italy and the U.K.; other countries, notably Belgium, Holland, Denmark and Sweden, are likely to participate in due course.

The bringing in to line (or harmonization) of component generic specifications is already under discussion and components released to harmonized specifications could be available within 1-2 years.

Extension of the principle beyond Europe is under discussion by members of the I.E.C.

### **COMMENTS ON THE BS 9000 SYSTEM**

A Government White Paper was issued in May 1967, entitled Public Purchasing and Industrial Efficiency. The paper contains several very favourable comments on the B.S.I. activities in this field.

The following extracts from the paper are relevant:

"It is the Government's policy to help to make British industry more efficient and competitive".

"Reduction in the number of similar varieties of products purchased is a powerful method of promoting efficiency in production."

"Standardisation is indispensable to schemes which objectively measure product quality including performance, safety and reliability. Such schemes can be extended to provide quality control, which ensures that the whole production of a particular article conforms to minimum requirements, and so tend to reduce their unit cost".

These statements represent the benefits that stand to be gained by the adoption of the BS 9000 system on a wide scale. However, so far only a limited number of specifications have been issued covering components used in large quantities in telecommunications equipment and some effort has necessarily been spent by the B.S.I. technical committees in producing specifications for other users needs.

In addition, the technical committees' instruction to see that specifications reflect the latest I.E.C. thinking has tended to slow the pace of progress to that of I.E.C.

Some difficulties have arisen as a consequence of the testing philosophy, which requires that the assessment of quality be made by performance tests on the finished item. This is a

sound policy provided that these detect failure mechanisms likely to cause widescale premature failures in service.

Accelerated testing which is truly representative of real-life usage may take too long and thus not be an economic proposition. Long-term reliability and life expectancy is then best covered by specifying materials or methods of construction known by research or experience to be satisfactory, or by barring those materials or methods of construction known to give rise to failures in the long term. The incorporation of such requirements to cover long-term B.P.O. needs has proved difficult, but nevertheless in certain critical areas is becoming accepted within the BS 9000 system.

Typical phenomena which need guarding against by this type of approach are silver migration, tin whisker growth, poor connexions within electrolytic capacitors and contamination or corrosion of integrated circuits by unsuitable plastic materials.

Should economic performance tests become practicable, then these materials requirements will be dispensed with.

The present position with respect to the generic and rules documents of the BS 9000 system is summarized in the appendix.

Components of a specific type and design can only be available under the BS 9000 scheme when the generic specification, the rules document and the detail specification are published, and a manufacturer has obtained qualification approval.

#### B.P.O. POLICY

The B.P.O., through its representatives on the various management and technical committees, has helped to formulate the BS 9000 scheme, and in those areas where suitable BS 9000 components are available in sufficient quantity, the general requirement is that they shall be used in preference

to non-BS 9000 items unless there is obvious reason to question their overall advantage to the B.P.O. The onus of providing the evidence rests with the proposer of the alternative item.

To open up to the BS 9000 system the large-scale component market that equipment in current production represents, B.P.O. component specifications are being amended to indicate suitable BS 9000 items when they become available. This will avoid the necessity for any major changes to existing equipment drawings.

To further promote the use of the BS 9000 scheme, a committee of representatives has been formed from the B.P.O. the Telephone Equipment Manufacturers Association and the Electronic Components Board. Its main purpose is to consider all policy matters associated with the implementation of the scheme and to make appropriate recommendations to the constituent bodies where required.

#### ACKNOWLEDGEMENTS

The author wishes to place on record the valuable comment and guidance received when preparing this article from members of the Purchasing and Supplies, Telecommunications Development and Research Departments of the B.P.O.

#### References

- <sup>1</sup> BS 9000. General Requirements for Electronic Components of Assessed Quality, Part 1 (1971) General Description and Basic Rules and Part 2 (1972) Data on generic and detail specifications. B.S.I.
- <sup>2</sup> CENEL 1. Harmonized System of quality assessment for electronic components. European Electrical Standards Co-ordinating Committee.
- <sup>3</sup> BS 6001. (1972). Specification for Sampling Procedures and tables for Inspection by Attributes. B.S.I.
- <sup>4</sup> BS 9002. (1972). Qualified Products list for Electronic Components of Assessed Quality. B.S.I.

#### APPENDIX

##### BS 9000 Component Specifications, May 1972 position

Component family	Component type	Generic specification	Rules documents	Detail specifications issued
Resistors (fixed)	Type 1 (film) Type 2 (composition) Precision wire-wound Wire-wound	BS 9110	BS 9111 BS 9112 BS 9113 BS 9114	N-001, N-002 N-001 { F.001 N.002
Potentiometers		BS 9130		
Capacitors	Ta. electrolytic Polystyrene Ceramic Polyester Mica Al. electrolytic	BS 9070 Section 1, 2 BS 9070 Section 3 BS 9070 Section 4 BS 9070 Section 5 BS 9070 Section 6 BS 9070 Section 7 BS 9070 Section 8		N.001  N.002-N.005
Semiconductors (discrete)	Signal diodes Switching diodes Voltage reference diodes Voltage regulator diodes Microwave mixer diodes Microwave mixer diodes (pulse) Microwave detector diodes Rectifier diodes low-current Rectifier diodes (medium-current) Rectifier diodes (high-current) Controlled-avalanche rectifier diodes Thyristors (low-current)	BS 9300	BS 9301 BS 9302 BS 9304  BS 9305  BS 9320 BS 9321 BS 9322 BS 9330 BS 9331 BS 9332 BS 9333 BS 9340	N.001 F.002  { F.001—F.004 F.039—F.040

**APPENDIX—continued**

Component family	Component type	Generic specification	Rules documents	Detail specifications issued
Semiconductors (discrete)	Thyristors (medium-current) Low-frequency low-power transistors High-frequency low-power transistors Transistors (general) CV types (Many CV specifications have been transferred to the BS 9000 scheme).	BS 9300 app. C	BS 9341 BS 9360 BS 9361 BS 9365	F.001—F.009  { F.009—F.012 F.040—F.044
Semiconductor integrated circuits	Transistor-transistor-logic gates	BS 9400	BS 9401	
Electron tubes	Transmitter Counter and indicator Indicator Corona stabilizer Corona stabilizer Travelling-wave (t.w.) T.W. amplifiers T.W. power amplifiers Magnetrons Pulsed fixed-frequency Gas-filled microwave switching Tunable T-R cells A.T.R. cells Pre-TR cells Passive protection Cathode ray Precision oscilloscope General-purpose oscilloscope Radar display Camera Vidicons	BS 9010 BS 9015 BS 9020 BS 9025 BS 9030 BS 9040 BS 9050 BS 9060	BS 9011 BS 9016 BS 9021 BS 9026 BS 9027 BS 9031 BS 9041 BS 9042 BS 9043 BS 9044 BS 9051 BS 9052 BS 9054 BS 9061	
Relays		BS 9150		
R.F. connectors		BS 9210		
Rigid waveguide	2: 1 rectangular Medium flat (M) Flat rectangular (F) Circular (C)	BS 9220		N.001 N.002 N.003 N.004
Sockets for plug-in devices	B7G and B9A tube sockets	BS 9500		N.001—N.006
Connectors below 3MHz		BS 9520		
Lever switches		BS 9561		
Micro switches		BS 9562		
Rotary switches		BS 9563		
Quartz crystals		BS 9610		

# Electrical Contacts in Telephone Exchanges: Contact Opening and Closing Phenomena and Quenching Techniques

## Part 3—Practical Quenching, Laboratory Tests and Investigations into Service Failures

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U.D.C. 621.316.933.8:621.3.066.6

*Part 1 of this article discussed general principles of contact switching and quenching. Part 2 dealt with the practical approach to the design of circuits for British Post Office exchange equipment. Part 3 covers practical quenching and devices, laboratory testing of switching apparatus and equipment models, and investigations into service failures.*

### INTRODUCTION

Parts 1<sup>1</sup> and 2<sup>2</sup> of this article described the fundamental phenomena involved in contact switching, the general principles of quenching and the identification and elimination of potential contact failures. This was taken to the stage at which the basic circuit configurations had been completed, the types of switching devices allocated and contact materials selected appropriate to the load current and the estimated number of operations in the working life of the equipment. This part gives the design approach to the provision of quenches shown necessary by circuit analysis and describes the progressive development of British Post Office (B.P.O.) standard types. Adequate quenching is essential; any shortcomings result in service hazards and may involve costly detection and remedial action.

An outline is given of laboratory tests carried out on switching devices and equipment models to check and supplement the designers' theoretical work. Design and production are inevitably subject to constraints, and decisions often involve compromising between conflicting factors. Service investigations are described to give some indication of the difficulties which face the designer, the manufacturer and the field engineer in resolving what may appear to be relatively simple failures.

### AIMS AND ECONOMICS OF QUENCHING

The aim in providing a quench is to divert and dissipate energy which might cause malfunctioning owing to contact damage, surge-voltage breakdown or electrical interference. The principles already described enable the designer to identify contacts likely to fail, or cause trouble, in the short-term, for which a quench is essential. Examples are selector magnets, pulsing-relays, heavy current loads, chattering or bouncing contacts and circuit elements likely to develop high-surge voltages or cause electrical interference. The more common case is where the short-term effects appear likely to be small and the designer has to decide whether the long-term cumulative contact damage will cause failures in the lifetime of the equipment.

Long-term erosion damage can be reduced to small proportions by quenches, but it is not economical to provide them universally. A quench to extend contact life is justified where the cost is less than the charges which would otherwise arise in the lifetime of the equipment. Direct cost-comparison is difficult as imponderables are involved, such as the hidden cost of intermittent service failures. Maintenance charges for fault-location, springset-renewal, rewiring and overheads, are high. Quench cost has been reduced by improvements in design, materials and production, and quenching has become economic on an increasingly wide range of applications. For some years the non-linear resistor has been particularly attractive; it is cheap, small and easily fitted. Reductions in the size and cost of capacitor-resistor units have extended the use of this very efficient quench.

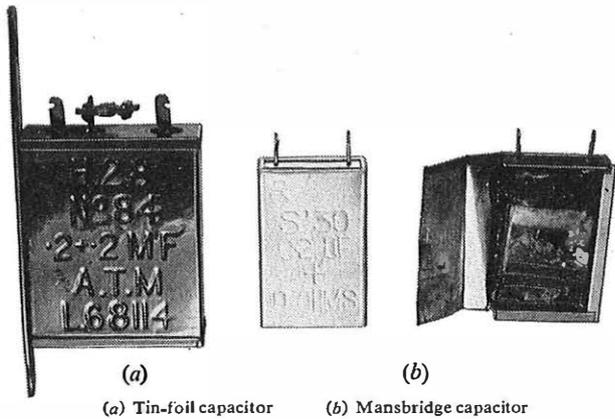
### B.P.O. STANDARD QUENCHES

The principles of the four main types of exchange equipment quench are described in Part I of this article. By co-ordinating laboratory investigations of basic phenomena, feedback of information from the field and advances in materials and production, B.P.O. development engineers, in co-operation with the telecommunication industry, have standardized effective, and economic, techniques and quenches. This has necessitated reconciling the functions of the quenched device, the physical and electrical properties of the controlling contacts, mounting requirements, and costs. A firm policy of rationalizing types for a range of applications has been followed, individual designs being developed only where the quantities required are large. Specifications have been framed so that essential features are controlled, but allowing manufacturers to exercise their expertise and offer variations in the basic design.

### Capacitor-Resistor Networks

Developments in B.P.O. capacitor-resistor quenches are illustrated by a number of practical examples. While there is some scope for variation in the design capacitance value, the aim is to provide the capacitance in as small a space as possible, in a convenient shape, which will withstand repeated current surges from the quenched load. Capacitors in early equipment had electrodes of tin-foil, with paper dielectric (Fig. 1(a)), or

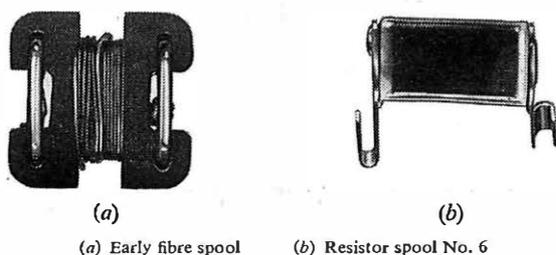
† Telecommunications Development Department, Telecommunications Headquarters.



(a) Tin-foil capacitor (b) Mansbridge capacitor  
FIG. 1—Early uniselector quenches

of Mansbridge foil, made up by applying a slurry of finely-divided tin and binding materials to dielectric paper (Fig. 1(b)). Mansbridge capacitors<sup>3,4</sup>, the forerunners of present-day metallized types, were favoured by the B.P.O., as it was established that there was no significant probability of a permanent short-circuit between electrodes in the dielectric, owing to the property of self-healing, whereby part of the stored energy destroys the surrounding metallized coating, and isolates the fault.<sup>5</sup> This avoided fire-risks in the quench and load coil, possible with short-circuits between tin-foil electrodes. Tin-foil and paper dielectric have been superseded by aluminium foil and plastic film,<sup>6</sup> but B.P.O. specifications for metal-foil quench capacitors now call for a voltage-proof test against the possibility of electrode short-circuit. Modern metallized capacitors use aluminium or zinc metallizing deposited on plastic film, and are smaller than Mansbridge equivalents.

The resistive element in capacitor-resistor quenches dissipates energy from the load during quenching, and must also withstand cumulative heating, should a short-circuit occur in the capacitive element. It is suitable for easy connexion to the capacitive element without damage to either. Early porcelain bobbins, separately mounted, were soon replaced by fibre spools directly-wired to the capacitor (Fig. 2(a)). Progressive developments, aimed particularly at fire-risks with fibre spools, produced the present standard, Resistor Spool No. 6, which safely dissipates nine watts in free air, is mechanically and electrically robust, and is suitable for connexion to single or composite capacitors (Fig. 2(b)). A



(a) Early fibre spool (b) Resistor spool No. 6  
FIG. 2—Quench resistors

rationalized range of six values from 10 ohms to 1 kohm caters for all practical applications, including some relay quenches.

The convolutions of both tin-foil and Mansbridge electrodes have appreciable inherent resistance and this was exploited as the resistive element in capacitor-resistor quenches, particularly Mansbridge. The resistance was specified in terms of a.c. measurement. The thinness of modern metallized coatings necessitates bunching the edges of the convolutions for lead-out purposes, largely eliminating the inherent resistance. However, metallized capacitors have been developed having inherent resistance formed by constricting the current paths in the electrodes.<sup>7</sup>

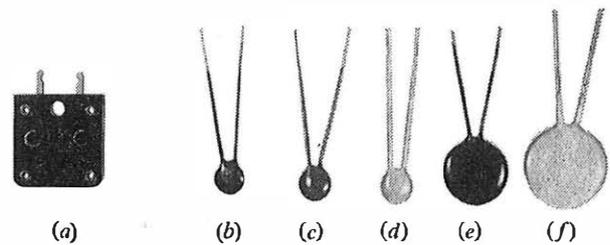
Capacitor-resistor quench development has been considerably influenced by the characteristics of contemporary contact materials. P.G.S. alloy, 7 per cent platinum, 67 per cent gold and 26 per cent silver, used initially, had a low minimum-arcing current, requiring efficient quenching. The resistive element was, therefore, not allowed to exceed 10 ohms.<sup>8</sup> Although low resistance increased the inrush current on contact closure, the softness of P.G.S. alloy prevented welding-adhesion. P.G.S. alloy was superseded by platinum and tungsten for contacts controlling magnets, the latter material being used for some heavier-duty applications. A 10-ohm quench resistance could be used with tungsten which is not prone to welding but a 200-ohm minimum resistance was desirable for platinum.

### Shunt Resistors

Shunt resistor quenches are used in only a limited number of cases and the resistance is provided in a suitable form to meet the application requirements.

### Non-Linear Resistors

Standard non-linear resistors are shown in Fig. 3. Voltage-limiting units, No. 3A, Fig. 3(a), used in house exchange



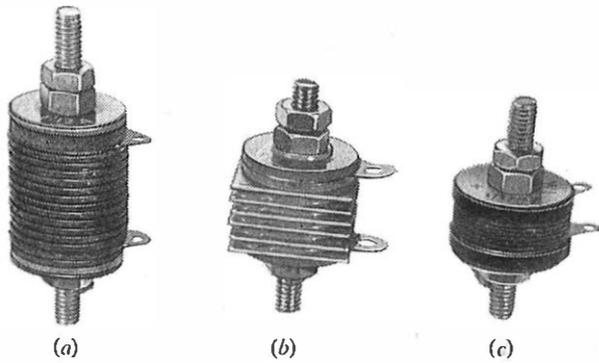
(a) Unit Voltage Limiter 3A  
(b) Non-linear resistor No. 1 (Brown)  
(c) Non-linear resistor No. 2 (Red)  
(d) Non-linear resistor No. 4 (Yellow)  
(e) Non-linear resistor No. 6 (Blue)  
(f) Non-linear resistor No. 9 (White)

FIG. 3—Standard non-linear resistor quenches

systems since 1939, were introduced as a quench for surge-voltages causing insulant breakdown in the cables between stations. The silicon-carbide disk is contained in a moulded case having studs and holes allowing the units to be assembled in groups. The later, direct-wiring type, was evolved to ensure satisfactory quenching with a minimum-size disk and a plastic coating of minimal material content, to avoid fire-hazards. Non-linear resistors Nos. 1, 2 and 6 are general purpose quenches for 50-volt equipment. Non-linear resistor No. 1 (Fig. 3(b)), is used where it is essential to avoid unduly delaying armature release. Non-linear resistor No. 2 (Fig. 3(c)), is preferred for light and medium current loads and non-linear resistor No. 6 (Fig. 3(e)), is used for heavier loads such as magnets and paralleled coils, where the use of a capacitor-resistor network is precluded. Non-linear resistor No. 4 (Fig. 3(d)), is used in 80-volt telegraph switching equipment and non-linear resistor No. 9 (Fig. 3(f)), in 24-volt private automatic branch exchanges to suppress surges causing bell-tinkling.

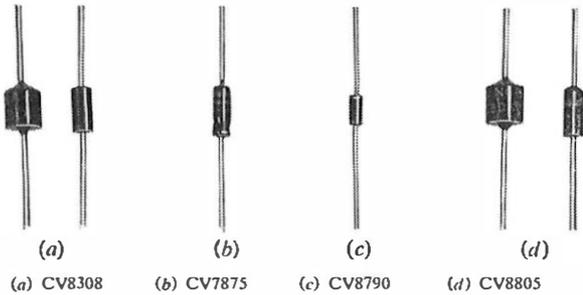
### Metal Rectifiers and Diodes

Standard metal rectifiers and diodes are shown in Figs. 4 and 5. Rectifier Element 1/12A (Fig. 4(a)), a copper-oxide device, and the superseding item Rectifier Element 1/12AZ are used as surge-suppressors.<sup>9</sup> The latter design is smaller, has improved characteristics and is available in selenium disk form (Fig. 4(b)) as well as copper-oxide (Fig. 4(c)). Silicon diodes are now preferred for B.P.O. applications; they are highly effective, very small and cheap. Diodes widely used in standard equipment are shown in Fig. 5. In selecting diodes for the quench configurations shown in Part 1 of this article (Fig. 8), the principal design criteria are



(a) Rectifier 1/12A (Copper-oxide)  
 (b) Rectifier 1/12AZ (Selenium)  
 (c) Rectifier 1/12AZ (Copper-oxide)

FIG. 4—Standard metal-rectifier elements



(a) CV8308 (b) CV7875 (c) CV8790 (d) CV8805

FIG. 5—Standard diode quenches

(a) Peak reverse voltage: rated maximum at least twice the supply voltage, to provide a margin against transient surges on the supply leads.

(b) Forward current: rated maximum at least equal to the steady-state current via the quenched coil.

(c) Peak reverse power: When the avalanche characteristic is used, the diode must safely dissipate, in the reverse direction, the energy discharged from the quenched coil.

In prototype-testing of circuit applications, care has to be taken to avoid misleading results from rectifiers and diodes whose parameters are substantially better than specification, as others of more normal quality may fail in service.

## SELECTOR QUENCHES

Selectors function under onerous conditions with critical time-margins and the quench cost must be small as quantities are large. Selector magnets have to cope with heavy mechanical loads at high repetition rates, and energizing ampere-turns are large. Unless the quenches are very efficient, the life of the controlling contacts will be short. Characteristics required are

(a) maximum contact protection,

(b) small size, allowing mounting adjacent to the magnet, to form an integral part of the selector without impeding maintenance access and without susceptibility to vibration failure,

(c) capability for absorbing energy from the magnet at the highest working rate, without fire-hazard, and

(d) failure by open-circuit, rather than short-circuit.

With adequate contact protection the level of interference is low and is unlikely to degrade nearby radio and television reception. Interference from wiring and contacts may still cause malfunctioning of adjacent electronic equipment, thereby requiring the precautionary measures described in Part 2 of this article. The capacitor-resistor quench is preferred for B.P.O. selectors. The capacitance and resistance values are chosen to influence favourably armature release-time and stepping. Shunt resistors and non-linear resistors

have some areas of use but reduce stepping-speed. They must be connected across the coil, rather than the contact, and they limit the induced coil voltage but do not reduce the high-frequency oscillations at the contacts, a common source of interference. Although non-linear resistors can be directly wired to the coil, supported by their lead-out wires, they are then prone to vibration-failure.

## Uniselectors

The progressive changes in uniselector quenches illustrate the way in which the component development engineer has to adapt his designs to take account of improvements in component manufacture and the requirements of changing equipment practice. Early subscribers' uniselectors had 75-ohm magnets and  $0.2 + 0.2 \mu\text{F} + 10\text{-ohm}$  quenches. The type shown in Fig. 1(a) used two tin-foil capacitive elements and a common 10-ohm resistor, to quench two adjacent uniselectors. Judged by the criteria given in Part 1 of this article, this capacitance value is too low to effectively limit the voltage across the capacitive element. Short-circuits between electrodes occurred in service, and to protect the magnets and quenches against fire-hazards, disconnect heat-coils were provided in the common earth-wire to each group of 100 uniselectors. A shunt capacitor across the heat-coil afforded partial protection until the heat-coil was replaced. Some of these quenches are still in use. A later type is used for fault-replacement.

The type shown in Fig. 1(b) clipped into position immediately above the uniselector magnet. The electrodes were Mansbridge foil, and the 10-ohm spool lay alongside the capacitor roll inside the case. Owing to the small capacitance, the peak-voltage caused frequent self-healing discharges through the Mansbridge foil, progressively reducing capacitance and quenching efficiency. The increased arcing accelerated the formation of tungsten-oxide film on the contacts and conduction became intermittent, drawing attention to the quench failure.

The capacitor No. MC 94, utilizing a  $0.5 + 0.5 \mu\text{F}$  Mansbridge unit, with inherent resistance of 9–70 ohms at 1 kHz, was a compromise between the need to increase capacitance and to keep the size small. The quench was mounted separately from the uniselector.

The development of an improved subscribers' uniselector, B.P.O. uniselector type 3<sup>10</sup>,<sup>11</sup> with a 50 per cent increase in rack capacity, meant that the quench had to be redesigned for direct mounting to save space. This cylindrical quench (capacitor No. 7720, Fig. 6(a)) fitted into spring clips in front of the mechanism, requiring only local wiring to the interrupters. The capacitance was  $0.45 \mu\text{F}$ , Mansbridge, with inherent resistance 20–80 ohms at 800 Hz, a convenient manufacturing value.

To meet recurrent shortages of Mansbridge foil, and rising demand, the specifications for these quenches were widened to allow discrete resistors and alternative electrode materials. Metallized-paper and 47-ohm carbon resistors, enclosed in the case, were acceptable for the capacitors No. MC 94. Occasionally these exuded black filling-compound, illustrating the hazards which accompany internal energy-dissipation. Metallized paper and metal foil with 47-ohm resistors, were acceptable for the capacitors No. 7720. The resistors could be provided inside or outside the cases, but were required to be of specific types to withstand heavy current surges and avoid fire-risks. Wire-wound, uncoated tin-oxide or carbon composition resistors were allowed with metallized paper, which does not develop sustained short-circuits.

Carbon composition resistors were not allowed for metal-foil electrodes, because of the risk of ignition with overload owing to electrode short-circuits.

Capacitors No. 7720 were a good design leaving little scope for the development engineer until smaller metallized capacitors became available. To exploit these, a new quench specifica-

tion was issued. The common aims for type-2 and type-3 uniselectors were

- (a) improved quenching, preferred quench  $1 \mu\text{F} + 220\text{-ohm}$ ,
- (b) small size and cost,
- (c) direct mounting, eliminating separate mounting bars and long wiring runs for type-2 uniselectors, and separate mounting clips for type-3 uniselectors, and
- (d) scope for manufacturers' variants to increase competitive procurement.

Essential requirements were limited to basic dimensions, avoidance of fire-hazards, and the provision of two wiring tags instead of one tag and a flexible lead for connexion to the adjacent interrupter. This, apparently attractive feature, was not acceptable as flexible leads are prone to vibration failure at the point of exit from the body of the unit. Rigorous type-approval tests ensure that reduction in size is not achieved with a penalty of reduced reliability.

Figs. 6(b) and 6(c) show two design variants of capacitors No. 7731 approved for type-3 uniselectors. The capacitive element of Fig. 6(b) is encapsulated in a moulded nylon case

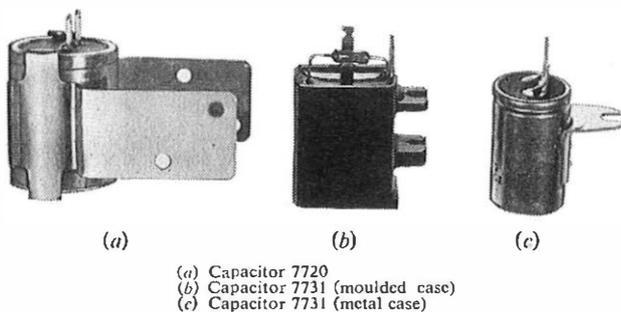


FIG. 6—Type-3 unselector quenches

having a friction clip which fits onto the mechanism knife-edge adjusting screw. The clip design ensures that vibration does not loosen the grip by abrading the material. The 220-ohm metal-oxide resistor is located outside the case to avoid internal heat stresses, and the lengths of the terminating wires are such that the points of exit from the body are at nodal vibration-points, to avoid fatigue and disconnexion failures. Fig. 6(c) is a steel-can unit with enclosed resistor. A wax-filling locates and separates the elements and aids heat-conduction from the resistor. The fixing lug fits under a lock-nut on the mechanism.

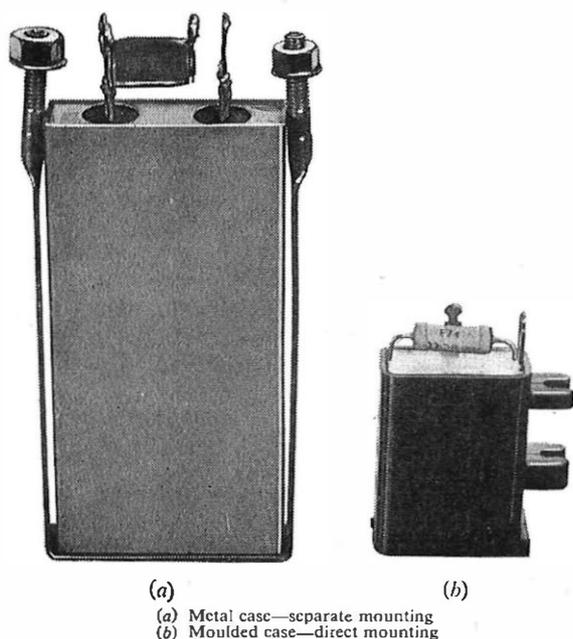


FIG. 7—Type-2 unselector quenches

Uniselectors, other than those in subscribers' circuits, require very efficient quenching, as conditions are onerous. After some early use of a  $0.2 \mu\text{F} + 10\text{-ohm}$  quench, a  $1 \mu\text{F} + 200\text{-ohm}$  quench was widely adopted and when the B.P.O. type-2 unselector was introduced for heavy duty applications this became the standard quench (Fig. 7(a)). An approved  $1 \mu\text{F} + 220\text{-ohm}$  quench design, meeting the latest specification, is shown alongside in Fig. 7(b). It is similar to the nylon-cased quench for type-3 uniselectors, but incorporates a resistor of higher-rating.

### Motor Driven Uniselectors

The B.P.O. Unselector Motor Drive No. 2<sup>12</sup> is a high-speed switch, its average stepping speed being 200 bank-contacts per second, compared with 65 for type-2 uniselectors. Operating time-margins are critically short and conflicting factors had to be carefully weighed in deciding quenching arrangements. The unselector is driven by a small motor comprising an unwound armature and two stator coils (Fig. 8). To start the drive, latch magnet LM is operated, actuating tungsten contacts LM1 which energize the stator coils via two tungsten interrupter contacts GHdm, operated alternately by the revolving armature-spindle cam. The drive is cut by the operation of a platinum high-speed relay-contact, K1, which releases the latch magnet, allowing the latch to re-engage with the gear wheel. During homing of the switch, the latch magnet is operated and held via platinum contacts GHS1 until the home position is reached. For test purposes the latch magnet is energized via base-metal contact GHk, which is manually operated. The stator-coil resistance is 45 ohms, representing a steady-state inductive load of 1 amp at each GHdm contact and contact LM1; 0.5 amp when the unselector is stepping. The latch-coil-resistance is 100 ohms, giving an inductive load of 0.5 amp at the cut-drive relay contact, the GHS1 homing contact, and the GHk test contact. The stator-coil quench protects the GHdm contacts during the drive condition and the LM1 contacts when the latch-magnet releases to stop the drive. The latch-magnet quench protects the relay contacts which cuts the drive on operation and the GHS1 and GHk test contacts on release. Conditions are onerous and the quenches must be of the capacitor-resistor type. The rapid flux-changes in the stator coils, corresponding to some 100 energizations per second, require the capacitance to be small; the resistance must also be small to avoid reducing quenching efficiency. The standard is  $1.0 \mu\text{F} + 10$  ohms. Capacitive inrush currents can be tolerated in view of the durability of tungsten contacts.

For the latch-magnet, quench capacitance and resistance should both be small to avoid delaying the release of the latch detail to stop the wipers on the required contacts.

However, a large capacitance is desirable to protect the relay contact which cuts the drive and to avoid arcing which might prolong the magnet current and delay the release of the detail. A minimum resistance of 200 ohms is desirable to protect the platinum controlling contacts against inrush currents and welding. An early quench was  $0.5 \mu\text{F} + 200$  ohms but the present standard quench is  $0.3 \mu\text{F} + 20$  ohms. This keeps the latch detail release-time within the critical range of 1.4 ms to 2.0 ms, ensuring accurate engagement with the gear-wheel. Unavoidably, part of the quench resistance margin for platinum contacts has had to be traded for essential improvements in latch performance. The three motor unselector quenches are assembled to form a single composite unit.

### Two-Motion Selectors

Magnet quenching in two-motion selectors protects the controlling contacts, which may be relay contacts, self-interrupted-drive contacts associated with the magnet, or contacts operated mechanically by other parts of the mechanism.

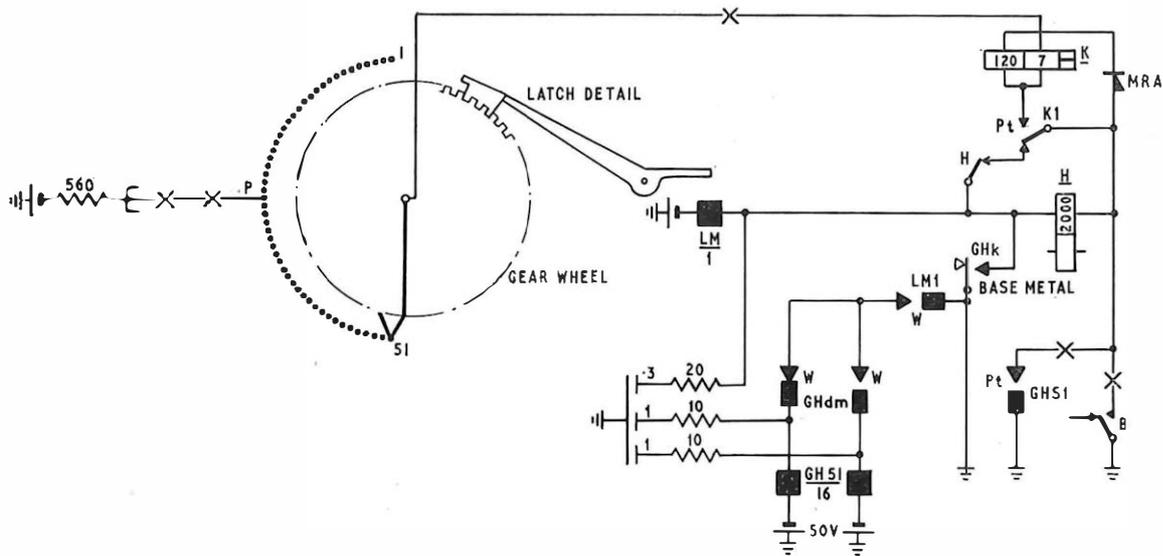


FIG. 8—Quenching of motor uniselector magnet coils

Quenches affect the performance of the vertical and rotary magnets and the hunting and switching functions of the selector. Following an early phase of  $0.5 \mu\text{F} + 10\text{-ohm}$  quenches and P.G.S. contacts, a  $1 \mu\text{F} + 1 \mu\text{F} +$  common  $200\text{-ohm}$  resistor quench was introduced to improve performance and cater for platinum contacts (Fig. 9(a)). A notable reduction in size is achieved with the corresponding B.P.O. design (Fig. 9(b)), which is still standard. Composite capacitors with a common resistor are an economical way of quenching two adjacent magnets, provided there is no unwanted interaction between the two capacitive elements.

Fig. 10 illustrates the need for careful checking. During slow release of relay B, armature-hesitation and inherent contact-sequencing caused contact B2 to release relay CC and complete the rotary-magnet circuit before contact B1 had disconnected the vertical-magnet. Chatter at contact B1, owing to armature-hesitation, caused current pulses via the two quench-capacitors with only small limiting series resistance, resulting in welding of the contacts.

Release magnets, in B.P.O. 4,000-type selectors and earlier designs, include a shunt-resistor quench to protect contacts opening the magnet circuit.

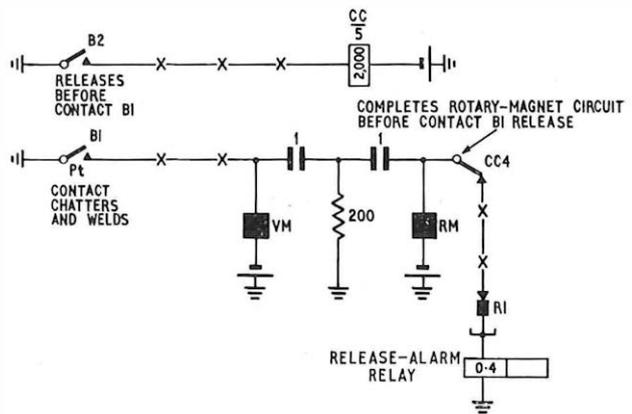
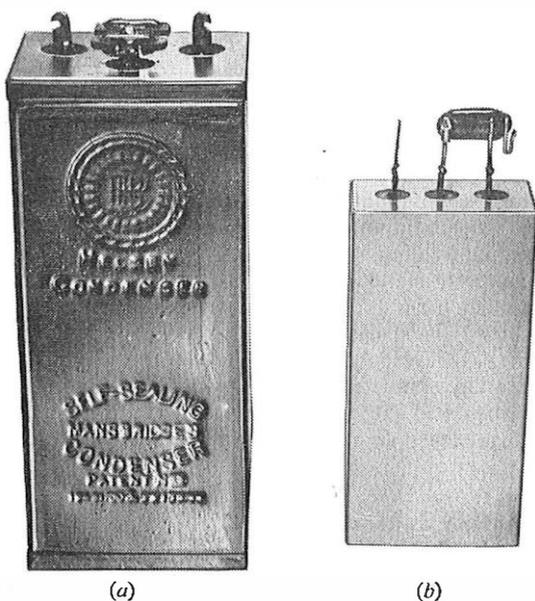


FIG. 10—Contact failure with coupled quenches

### PULSING RELAYS

A variety of circuits involve pulse-operated relays; many are heavily worked and their coils require quenching to protect the controlling contacts. Similarly the contacts of pulsing relays have to be protected. Quenching practices are based on the most common application, in which the pulse characteristics are similar to those of the signals from a subscriber's dial, i.e. 10 p.p.s., break-to-make ratio 2:1. Other pulse-operated relays are dealt with in practice by analogy. With pulsing-relays, the designer is in the fortunate position of being able to use the interplay between the quench and the relay-coil to advantage. The quench may be designed to change the characteristics of pulses repeated by the relay, to suit operational requirements. It follows that pulsing relays and quenches often form standard circuit configurations, whose performance limits are determined in detail for network design purposes. Other benefits from quenching, often overlooked, are the suppression of line surges and interference-clicks.

A pulsing-relay may have one or more windings, forming part of a transmission bridge, Fig. 11(a), or of a separate circuit-element, Figs. 11(b) and 11(c). The quench may be at remote controlling contacts, Fig. 11(a) and Fig. 11(b) or at the coil Fig. 11(c). In some junction switching equipments, with capacitor-type transmission bridges, the bridge capacitors are arranged to act as a quench for outgoing pulsing contacts. Pulsing contacts may be part of a subscriber's installation, or of the exchange equipment. Quenching is almost invariably by capacitor-resistor network, which allows



(a) Early Mansbridge (b) Capacitor MC 101

FIG. 9—Two-motion selector quenches

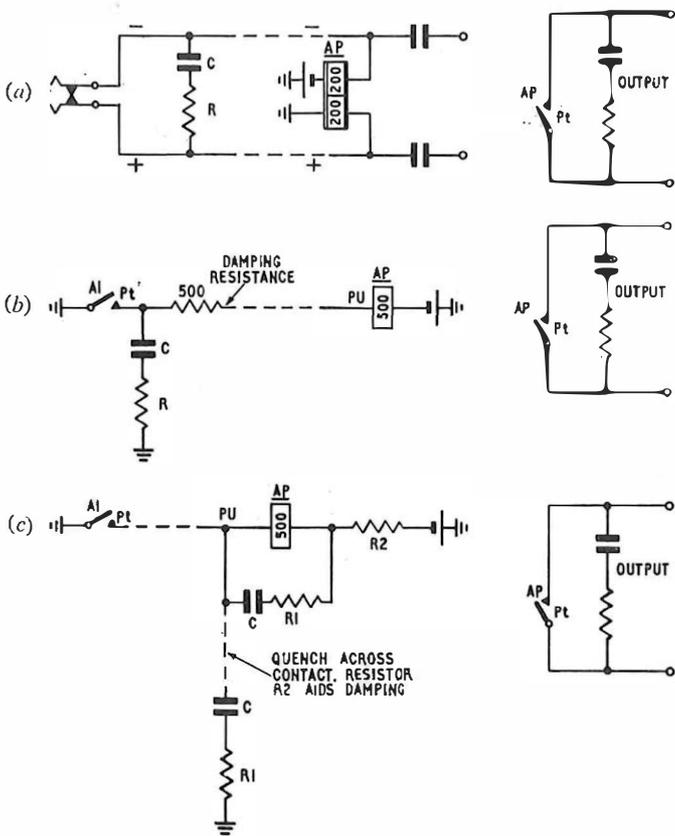


FIG. 11—Quenching of pulsing relays

the relay armature to be critically controlled, particularly during release. With appropriate capacitor and resistor values the quench can give optimum pulsing output from the relay. For example, an increase in the make-contact-closed period of the quenched relay, may be used to compensate for a decrease in make-contact-closed period at the input, or in succeeding pulse-repetition stages. Where the total circuit resistance is low, capacitor-resistor quenches may, however, set up oscillatory currents and, if the reverse-surge is of sufficient magnitude and duration, re-operation of the armature can occur during the output break-period, producing a spurious pulse (Fig. 11(d)). It is often possible to increase the resistance sufficiently to damp the oscillation and avoid spurious pulses. In Fig. 11(b) damping resistance in the PU lead has the additional advantage of reducing the contact load current. Modification of the connexions in Fig. 11(c) so that the quench is across the contact instead of across the coil, includes resistor R2 in the oscillatory circuit and eliminates spurious pulses.

### SUPPRESSION OF SURGE VOLTAGES AND INTERFERENCE

Standard quenches, in order of preference on cost grounds, are the non-linear resistor, the diode, and small capacitor-

resistor units. In light-load applications, a non-linear resistor No. 1 or 2 (Figs. 3(b) and 3(c)), across the coil, is adequate, being easy to fit and having only small effect on armature release. Diodes, Fig. 5, are easily fitted and are more effective than non-linear resistors but notably increase armature release time. Small  $1\ \mu\text{F}$  + 220-ohm quenches, such as capacitors No. 7805 or 7809, Figs. 12(a) and 12(b) are very

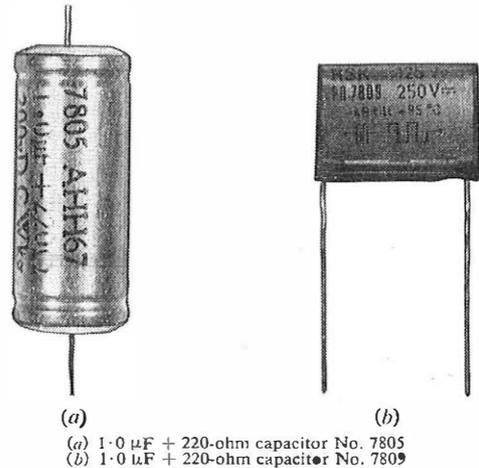


FIG. 12—Composite capacitor-resistor quenches

effective when connected across contacts to suppress interference from arcing and sparking. Fig. 13 illustrates an interesting application of shunt-resistor quenches, to inhibit the effect of direct interference surges between relays.

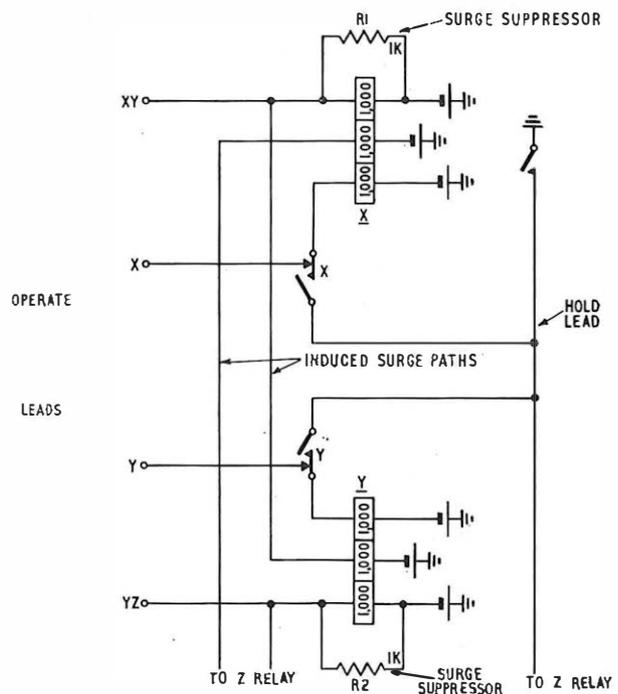


FIG. 13—Suppression of interference surges by shunt resistors

X, Y and Z were prone to false operation by induced surges via interconnected windings, for example, operation of relay X over the X lead was accompanied by operation of relay Y. Resistors R1, R2 and R3 for relay Z, limit the interference currents without unduly affecting relay performance.

### BOUNCING AND CHATTERING CONTACTS

When bounce or chatter of contacts cannot be eliminated by design, and quenching is essential to deal with arcing and sparking, the quench type must be carefully chosen, to avoid harmful effects. For light loads, the resistor non-linear No. 2,

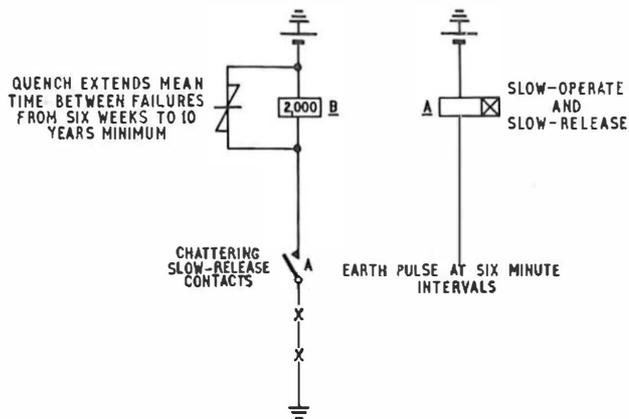
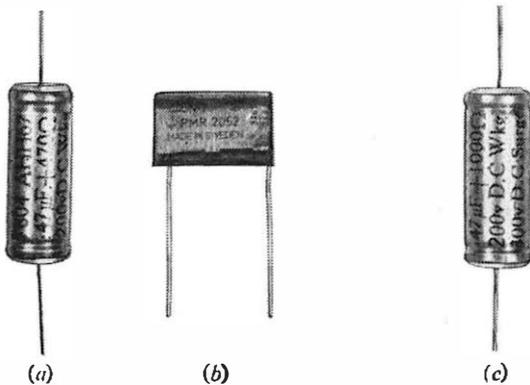


FIG. 14—Protection of chattering contacts

Fig. 3(c), or a diode, Fig. 5, are used. A non-linear resistor-quench added to the chattering slow-release contacts shown in Fig. 14, which were prone to interlocking, extended the mean-time-between-failure from six weeks to an estimated 10 years minimum. Capacitor-resistor units are necessary for heavier loads; the preferred types are capacitors No. 7804 and 7808,  $0.47 \mu\text{F} + 470$  ohms, Figs. 15(a) and 15(b), for silver or palladium contacts, and capacitor No. 7803,  $0.47 \mu\text{F} + 1,000$  ohms, Fig. 15(c), for platinum contacts.



(a)  $0.47 \mu\text{F} + 470$ -ohm capacitor No. 7804  
 (b)  $0.47 \mu\text{F} + 470$ -ohm capacitor No. 7808  
 (c)  $0.47 \mu\text{F} + 1,000$ -ohm capacitor No. 7803

FIG. 15—Composite capacitor-resistor quenches

Capacitance is low to reduce erosion by inrush quench currents and avoid welding on closure. A higher resistance for platinum takes account of its greater tendency to weld.

### HEAVY CURRENT LOADS

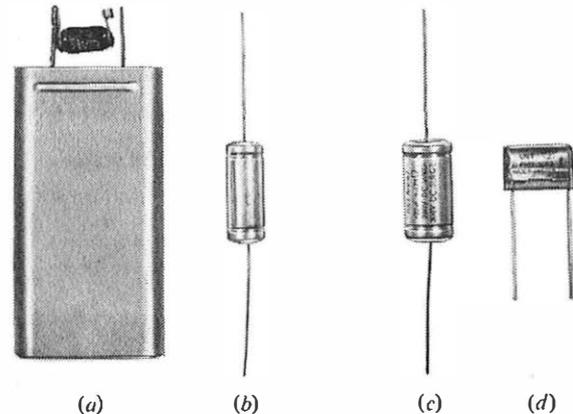
Quenching is essential in applications where the load conditions are considered to be sufficiently onerous to cause short-term contact damage and failures. An accurate assessment of load magnitude must take into account the nature of the load, i.e. resistive or inductive, the current and voltage, the contact material and the estimated number of operations required in the equipment life. For resistive loads, the maximum rated current for the contact material may be exceeded provided the reduced contact life still meets requirements. Accurate prediction of the extent to which contact life with resistive loads is reduced by overload is not possible, but the penalty is severe. With silver contacts a 50 per cent current overload reduced contact life by a factor of 100. Performance can be improved to some extent by a capacitor-resistor quench, see Part 1 of this article. Present B.P.O. practice for resistive loads is, as far as possible, to keep within rated maximum values and avoid the use of quenches.

Heavy inductive loads in exchange equipment are easy to recognise, being mainly magnets, individual low-resistance

relay-coils, or groups of paralleled relay-coils. Currents are kept well below the rated resistive maxima shown in Part 1 of this article, Table 1, and not more than eight relay-coils are paralleled, to limit the stored energy. For the standard B.P.O. contact materials in 50-volt equipment, quenching is considered essential, regardless of the number of operations, with the following inductive load-currents

Contact Material	Current
silver	0.2 amp
palladium and platinum	0.3 amp
tungsten	0.5 amp

These values are based on consideration of the minimum-arcing currents of the materials and field experience. Preferred  $1 \mu\text{F} + 220$ -ohm quenches are shown in Figs 12(a) and 12(b). A non-linear resistor No. 6 quench, Fig. 3(e), is used in situations where capacitor-resistor units cannot be fitted. For contacts used to interrupt very heavy inductive load-currents, the quench capacitance is appropriately increased and the resistance decreased. Metal-case capacitors and external resistors of the types shown in Fig. 16(a) are used, in view of the high peak-voltages involved.



(a)  $0.1 \mu\text{F} + 1,000$ -ohm capacitor No. 119 and resistor-spool No. 6  
 (b)  $0.1 \mu\text{F} + 1,000$ -ohm capacitor No. 7801  
 (c)  $0.22 \mu\text{F} + 470$ -ohm capacitor No. 7802  
 (d)  $0.22 \mu\text{F} + 470$ -ohm capacitor No. 7807

FIG. 16—Capacitor-resistor quenches

### REDUCTION OF LONG-TERM CONTACT EROSION

Quenches to reduce long-term contact erosion are provided with the object of extending contact life to cover the full working lifetime of the equipment. The load is almost invariably a single relay-coil or a number of relay-coils in parallel. As the coil resistances may range fairly widely, there is a great variety of possible combinations of load-coils and contact currents. The life required of the contacts may similarly range widely from less than  $10^4$  to more than  $10^8$  operations. While a corresponding variety of ideal quenches could be determined for these combinations, in practice, the design approach is based on a high degree of rationalization, giving all-round cost savings. For small currents, where the number of contact operations required is small, no quench is provided. As the load and life requirements increase, the cheapest quench, a non-linear resistor, is used. As conditions become more onerous, capacitor-resistor networks are used, the capacitance increasing and the resistance decreasing as the load current becomes greater in accordance with the principles described in Part 1 of this article. The full range of long-term conditions of this kind are met by three preferred

standard quenches, the non-linear Resistor No. 2, Fig. 3(c); capacitor No. 7801,  $0.1 \mu\text{F} + 1,000\text{-ohms}$ , Fig. 16(b); and capacitors No. 7802 and No. 7807, both  $0.22 \mu\text{F} + 470\text{-ohms}$ , Figs. 16(c) and 16(d). Conditions more onerous than these fall within the heavy-current category and are quenched appropriately. A comparison of Figs. 16(a) and 16(b) indicates the size reduction which can be achieved with modern components.

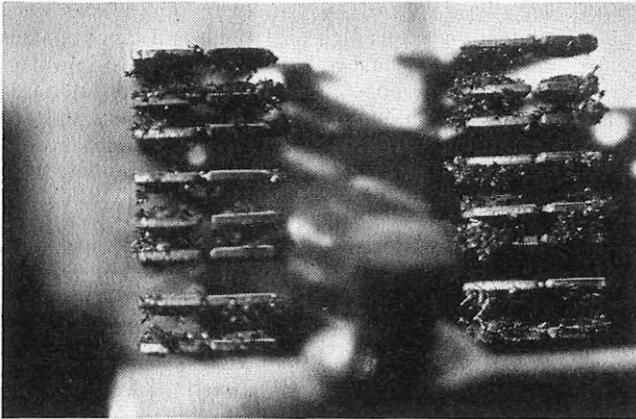


FIG. 17—Whiskers on silver contacts caused by sulphur contamination

## LABORATORY TESTING

Facilities are provided in Telecommunications headquarters laboratories for the investigation of contact problems and the evaluation of switching devices. B.P.O. Research Department deals with basic phenomena, Purchasing and Supply Department with materials, and Development Department with mechanical and electrical testing.<sup>13</sup>

### Materials

The B.P.O. has considerable experience of the principal contact materials, silver, platinum, palladium and tungsten. Proposed new materials require careful testing; for example, a silver-palladium alloy must be resistant to tarnishing which affects silver, and resistant to the formation of non-conducting frictional polymers which occurs with palladium. Laboratory tests are followed by trials on working equipment.

Materials for other parts of switching devices must be checked with equal care; they may affect contacts directly, by surface contamination, or indirectly, by influencing actuation. Materials which give off vapour constitute great hazards. Silicones and hydrocarbons have already been mentioned. Organic plastics, which have advantages for production, must be fully stable, over the full working temperature range; thus, ultra-violet stabilization of polyvinylchloride inhibits release of hydrochloric acid gas. Shedding of particles by the materials should be minimal, particularly for parts moved during actuation. Materials which touch should be compatible, to avoid chemical reaction and frictional damage. The springset combs of B.P.O. type-12 relays, which are in sliding contact during actuation, are of glass-filled nylon and acetal resin, ensuring less wear and debris than if they were of the same material. Vapours, wear-debris and dust are carried to other parts of switching equipment by air movements. Covers for relays and groups of equipment afford some protection for the contacts, but may increase local vapour concentration by slowing air circulation. Correct choice of cover materials is vital. Fig. 17 shows whisker-like growths on silver contacts, caused by sulphur-vapour contamination from rubber sealant material in the edges of equipment covers. Sulphur-bearing materials also accelerate tarnish formation on silver contacts and their use is avoided as far as possible for B.P.O. equipment.

Vapour from the plasticizer in polyvinylchloride sealant-foam used in equipment covers has reacted with copper wear particles on phosphor-bronze relay residuals to form a tacky paste, causing relay armatures to stick in the operated position, after a short period in service. In the longer term, the contacts themselves could have been contaminated.

## Electrical performance

Test programs are planned to provide comprehensive performance information over the full range of operating conditions, including contact-load capability and contact life. Checks are made for inherent contact bounce or chatter, using the oscilloscope and high speed cinematograph.<sup>14</sup> Appropriate limitations are then imposed on circuit applications of the device. Contact life is determined for a range of resistive loads of practical importance, including a 100 per cent overload, and also for inductive loads, quenched and unquenched. These tests are conducted under simulated working conditions and the following precautions are taken to ensure that extraneous factors do not cause misleading results at the contacts under test

(a) unless their coils have identical characteristics, devices under test are not controlled from common contacts, avoiding mutual interference when the energizing fluxes collapse,

(b) the test-rig contacts controlling the devices are carefully maintained and quenched. Where timing requirements are critical and quenching is not possible, two contact-units are connected in series to increase the total rate of contact separation and reduce sparking and arcing,

(c) wiring-runs avoid other leads likely to be propagating interference. Experience has shown that interference surges in the wiring of test-rigs can change contact discharges into more harmful forms, for example from glow to arc, giving misleading results,

(d) similarly, battery and earth supplies are kept free from interference by segregation and decoupling,

(e) contacts are kept free from vibration unless it forms part of the working environment, and

(f) the atmospheric environment is made comparable with the conditions of use. Usually, dust, fumes from volatile floor-polishes or paints, and overforced ventilation are avoided.

## Circuits

Laboratory tests on switching circuits are carried out on prototype models under simulated worst-case conditions. Relays and uniselectors occupy their design positions on the mountings, to check for magnetic cross-fire between adjacent items, which can affect contact actuation, and for mechanical vibration, which causes contact chatter. To take into account the possibility of interference, wiring forms occupy the relative positions they will have in the manufactured equipment. Interconnecting cables are of length and type comparable with those to be used in service, so that wiring discharges are simulated. A visual check is made for sparking and arcing contacts to locate any which are liable to suffer damage and which require consideration for quenching. This is supplementary to the analysis carried out at the design stage and each sparking/arcing contact is dealt with on its merits. However, damage is not always in proportion to the visual effects. Pronounced blue-glow discharge may cause only slight damage but may indicate a need to limit the induced voltage to avoid insulant breakdown. On the other hand, the effect of a hardly perceptible white-hot arc may be severe. Likewise, welding on closure usually occurs without apparent sparking. Invisible oscillatory discharges in the ultra-violet range, may cause severe erosion or interference. Discharges occur in a random manner, dependent on complex factors. A spark may occur once in a dozen operations, then on several successive operations, followed by an apparent complete absence of discharges. If visual inspection reveals

incipient spike and crater formation, accelerated life-tests are carried out to determine whether cumulative effects are sufficiently severe to justify circuit modification, or quenching.

### SERVICE INVESTIGATIONS

Feedback of performance information from the service engineer in the field to the designer is vital to the improvement of design and reliability. B.P.O. maintenance procedures for exchange equipment ensure that fault data are systematically recorded and analysed and that cases of circuit malfunctioning are investigated and reported to Service Department at Telecommunications Headquarters. The success of these arrangements largely depends on the skill and enthusiasm of the man on the spot. Failures owing to switching contacts often involve intermittent or obscure factors; detection and fault location require keen observation and detailed knowledge of the equipment. Where necessary, specialists are called in for advice and the investigation widened to obtain the maximum amount of information.

### Surge-Voltage Breakdown and Interference

When the primary cause of a breakdown has been identified, a check is made for secondary factors such as poor coil-winding practices, defective or unsuitable materials or, exceptionally, damp environment. Comparisons are made to see whether defects are confined to a particular batch of equipment.

The interference sources in working equipment are difficult to locate owing to the erratic nature of contact discharges. Observation over a period is usually required to associate the trouble with the circuit element concerned. Suspect coils are temporarily quenched with non-linear resistors or diodes, to narrow the field of search. A wire propagating interference in a wiring-form may be located by an oscilloscope search-probe or pick-up coil.

### Conduction Failures

Conduction failures of single contact units are not usually investigated unless the repercussions are severe, such as faulty contacts in tone distribution feeds for signalling systems. Investigations are more commonly made where reports indicate patterns of recurrent failure for which no normal explanation can be found. Many cases of this kind involve circuit elements and devices which, judged by the criteria described in Part 2 of this article, would be considered to have

only a small margin for correct functioning. The aims are to identify abnormal factors which have taken up the margin, to determine remedial measures and to eliminate the trouble from future supplies. These aims are not always easy to achieve. The discussion is confined to silver contacts, as conduction problems on B.P.O. equipment mainly arise with this material.

### Surface appearance and interface-resistance of silver contacts

Poor conduction means high or variable resistance contact points, and the maintenance engineer attempts to correlate performance, surface appearance and measured interface-resistance. The results are examined comparatively and are generally confusing and inconclusive. Under practical conditions conduction efficiency of silver contacts cannot, with any certainty, be directly related to their colour. This can be affected by the process used to fix the contacts to their bearer-springs, by the storage environment, by the length of time in service and by the working environment. Contacts may be rivetted or welded to their bearers. After manufacture they are mostly of clean, silvery colour, but a small number of welded contacts may have a bright blued-steel appearance. In service, the changes in colour progressively follow those exhibited by silver exposed to the atmosphere, viz.: silver, yellow, blue and black. Fig. 18 illustrates colour changes observed on 1,120 contact points at a working exchange, over 600 days of its early period of service, and shows how the proportion of black contacts progressively increases with time. In practice, not all the contacts at a location undergo the complete change to black; a small proportion seem to retain the silver colour, or an intermediate colour, almost indefinitely. The discolouration is largely silver-sulphide, a substance of low conductivity, which exhibits the characteristic colour changes shown, as its thickness increases. The sulphide film, which finally takes the form of a black patina or incrustation, responds to the mechanical pressure of the contact force, deforming and flaking from the surface, after which the growth is repeated. The existence of many millions of 'black' silver contacts, apparently functioning satisfactorily, with millions more new silver contacts being brought into service each year, seems at variance with the known poor conductivity of silver sulphide. A number of effects combine to improve conduction; the relative softness of the black patina results in it being displaced by the impact, wipe and pressure of the contacts, and penetrated by metallic high-spots on the contact surfaces. It is also decomposed by

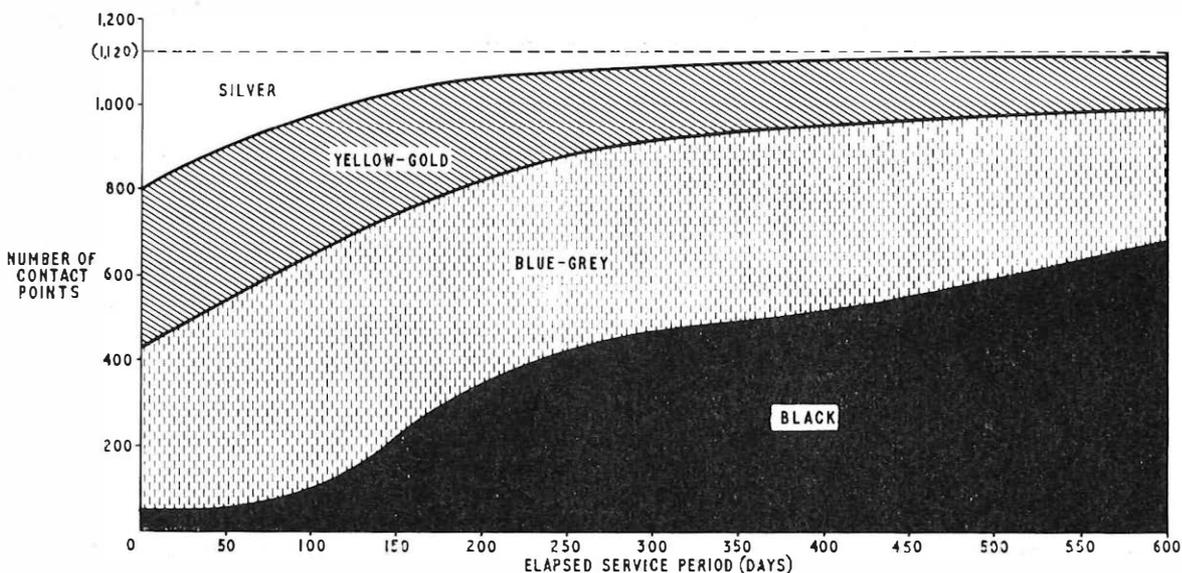


FIG. 18—Colour changes of silver contacts

heating arising from passage of current through the interface resistance.

Other contaminants are often present at the interface: thin layers of organic substances, possibly deposited from vapours in the environment, inorganic salts, fungi, oils, dust, grit, lint, human perspiration acids, skin and hair, have all been identified. Powerful techniques are available for their detection: chemical analysis, X-ray diffraction analysis, and the scanning electron-microscope. Imprints, or plastic replicas, of the contact surface have been taken in thermoplastic material<sup>15</sup> which lifts off all surface deposits for further examination.

Unfortunately, experience has shown that even after all surface contaminants have been identified, it is more often than not impossible to decide whether the failures can be basically attributed to any particular one of them. Even in the laboratory, contact resistance measurement can be a slow process and unless the conditions are carefully controlled the results are of little value. For circuit investigations it is essential to know the voltage and current at which measurements are to be made; whether single or repeat tests are to be carried out and the extent to which the contacts may be pre-conditioned, or disturbed, such as by switching their normal loads.

Significant results to detect a general pattern or trend are more likely to be obtained if the test voltage and current are kept small; the low-level-duty conditions of 10 mV and 10mA described in Part 2 of this article are a useful compromise. In considering the results, it has to be borne in mind that arbitrary test conditions, applied in a static test, represent a departure from normal circuit operation. Anomalous results may be obtained owing to the absence of dynamic factors such as contact wipe, bounce, and limitations on the time available to build-up the circuit current (see Part 2 of this article). Thus, contacts functioning correctly under circuit conditions may appear poor in terms of measured static resistance. Local vibrations may also cause the interface resistance to be unstable. Pulse techniques have been successfully used to investigate cases where the time margin for current build-up is short. Pulses of pre-determined characteristics in terms of voltage, source-impedance and width were applied to the circuit path and contacts under test, and the current build-up observed with an oscilloscope. As it has not been B.P.O. practice to lay down absolute standards for contact resistance of switching devices, the value of all these tests lies largely in the extent to which the results can be relied upon for comparison with other good contacts which, throughout their working life, have been subjected to exactly the same conditions. Requirements which cannot easily be met.

#### Remedial measures

Thorough cleaning of faulty, or suspect contacts is an obvious palliative. The service engineer also aims at elimina-

ting, or reducing, the possibility of trouble, by improving those factors over which he has direct control: removing dust, checking and, if possible, increasing contact-force and buffered spring lift and renewing worn parts likely to affect actuation. In cases of severe recurrent trouble, he may apply a contact lubricant. A specially blended mineral-based oil is used, which is intended to protect cleaned contacts against further tarnishing. The protection is not permanent but generally lasts from nine to 18 months, depending on conditions. The loss of effectiveness is due to the oil receding from the interface, drying-out, and being destroyed by heating caused by the passage of current. Lubricants as a means of improving conduction performance of electrical contacts have been known for many years.<sup>16</sup> The cost of application to large quantities of equipment, the possibility of creepage and of damage to adjacent materials and the tendency to collect dust and other contaminants have made lubrication a last-resort treatment for B.P.O. equipment. Nevertheless, maintenance engineers have recalled the benefit which followed routine polishing of relay and bank contacts with chamois leather, in particular the virtual elimination of microphonic noise for a considerable period. An improvement probably due to the lanolin oil-content of the chamois leather.

#### Influence of production methods on service performance

When investigations of fault patterns provide sufficient data to warrant reference-back to production, intensive checks are made in co-operation with the manufacturer. The quantities involved, the inevitable lapse of time since production, changes in factory personnel and even minor process and materials variations make it difficult to trace trouble to its source. Production for the B.P.O. of bearer springs and contacts is carried out under closely controlled conditions to ensure a high-quality product at economic cost. The theory has been advanced that processing of bearer-springs and contacts with cleaning agents removes the minute amounts of oil and grease normally present during production, leaving the surface extremely active and very susceptible to atmospheric contamination which, for reasons not fully understood, becomes self-perpetuating.<sup>17</sup> There is some evidence that over-cleaning of contacts has contributed towards failures in B.P.O. equipment. It seems anomalous, however, that while an oil or grease film of only monomolecular thickness left after production is claimed to confer lasting benefit, the effect of a fairly liberal application of oil to working contacts is short-lived.

The best way of ensuring high initial reliability and an acceptable mean-time-to-first-failure, is to provide, at the production stage, adequate contact-force, contact-follow and wipe. Substantial lift of correctly adjusted buffered springs is an indication that the design contact force has been achieved with a margin allowing for progressive contact-wear in operational use.

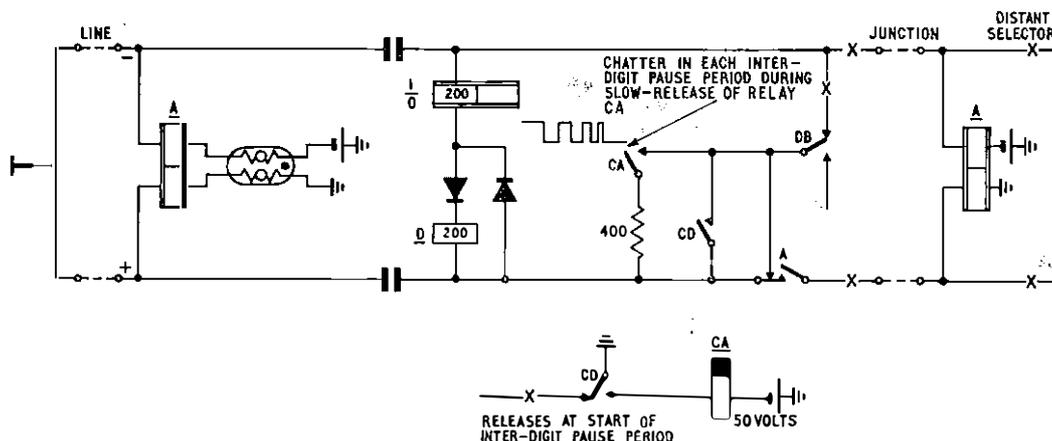


FIG. 19—Contact chatter causing noise in transmission path

### Contact Damage and Irregular Actuation

Many investigations involve short-term failures caused by contact damage or irregular actuation of contacts. The more common forms of damage and their causes, are shown in the Table. While the basic cause may often be fairly easily identified, checks are made for less obvious factors such as bounce, chatter or vibration. Obscure conditions such as short-circuiting of relay coils during release may cause slow-restoration and chatter. Similarly, momentary re-operations of relays by reverse surges during pulsing increase the severity of the working conditions, as do fleeting overloads caused by contact bunching. Fig. 19 shows a circuit element in which contact chatter occurring during slow-restoration of a relay, causes objectionable noises in the transmission path as well as increasing contact wear.

Wear in the springset lifting studs of B.P.O. 3,000-type relays can be a hidden cause of erratic contact action and

**TABLE**  
**Causes of Common Forms of Contact Damage**

Form of Contact Damage	Probable Causes
Severe erosion and burning	Excessive current.
Severe erosion without burning	Excessive number of operations. Contact surface activated by hydrocarbon vapours, possibly from floor polishes or other contaminants.
Welding or freezing	Capacitive loads. Incorrect capacitor-resistor quench. Line discharges. Slugged load coils. NOTE: Each of these conditions is appreciably worsened by contact bounce.
Spike and crater tending to interlock	Contact chatter, usually during slow release.
Spike, whisker or rod of contact material short-circuiting contacts. More likely with platinum	Repetition rate of contact operation, and/or load, too onerous for the switching device.

incorrect contact sequencing, Fig. 20. Where possible, B.P.O. type 10<sup>18</sup> and 19<sup>19</sup> relays, which have long-life comb-actuated springsets are provided in applications likely to be sufficiently onerous to develop this form of trouble.

Some 3,000-type relays exhibit a phenomenon known as armature climbing, which displaces the armature on its knife-edge and causes severe contact malfunctioning. Inherently possible with any 3,000-type relay, the trouble occurs mainly

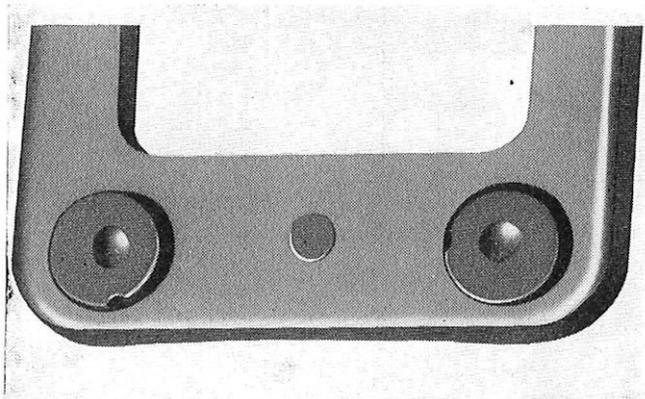
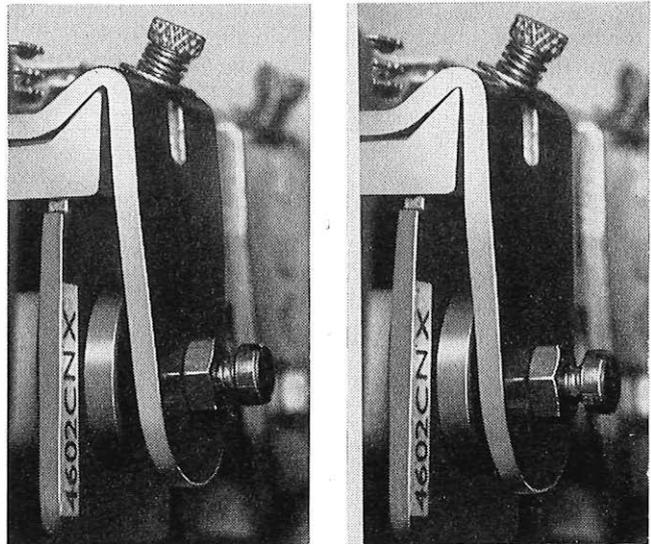


FIG. 20—Worn springset lifting-studs

with pulsing applications. On restoration, the armature overshoots its normal position compressing the retaining screw spring. Two forms of overshoot may then occur: a longitudinal movement, displacing the armature forward along the yoke, Fig. 21(a); a transverse movement pivoting the armature about its back stop, Fig. 22. When the overshoot energy has been dissipated the armature may slide back on to the knife-edge, or may remain displaced, held by the retaining spring pressure; the pressure of the springset pins on the armature lifting studs, and, of considerable importance, tacky wear-debris around the knife-edge, Fig. 23(a). Re-operation of the displaced armature gives abnormally large contact-openings and severe output pulse-distortion.

Repeated forward overshoots can cause the armature to take up permanently an incorrect pivoting position, as in Fig. 21(a).



(a) Incorrect pivoting (b) Correct pivoting  
FIG. 21—Longitudinal overshoot of relay armature

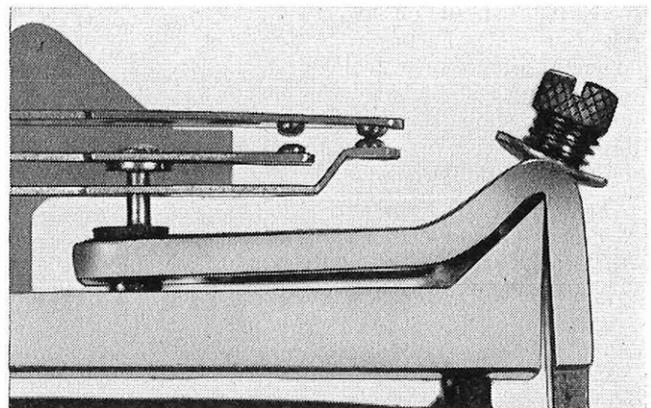
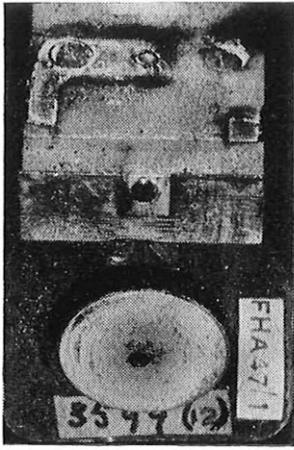


FIG. 22—Transverse overshoot and incorrect pivoting of relay armature

Successive transverse overshoots, as when operated by pulse trains, can progressively increase the armature displacement, until the retaining spring pressure is sufficient to push it back into its correct position. The sequence is repeated with the next train of pulses.

Overshoot effects are worsened by

- (a) downward tilting of the armature, inherent with some springset loadings,
- (b) high usage, increasing knife-edge wear and debris,
- (c) burrs and irregularities on the inside of the armature slot through which the retaining-screw passes. These aid



(a)



(b)

FIG. 23—Wear debris on relay knife edge and worn armature retaining screw

climbing, retard or prevent restoration, and add to the wear debris, Fig. 23(b), by abrading the retaining screw,

(d) rapid current-decay and defluxing, caused by the action of capacitor-resistor quenches, as in Fig. 11(d), accelerating armature release.

Armature-climbing is inhibited by a special retaining-screw fitted to relays susceptible to the trouble as shown in Fig. 24. Armature-slots are specially checked for freedom from burrs.

Short-term erosion is sometimes caused by the contacts being activated by atmospheric vapours such as hydrocarbons as described in Part I of this article.<sup>20</sup> This reduces the contact gap breakdown-voltage and quenches are then only partially

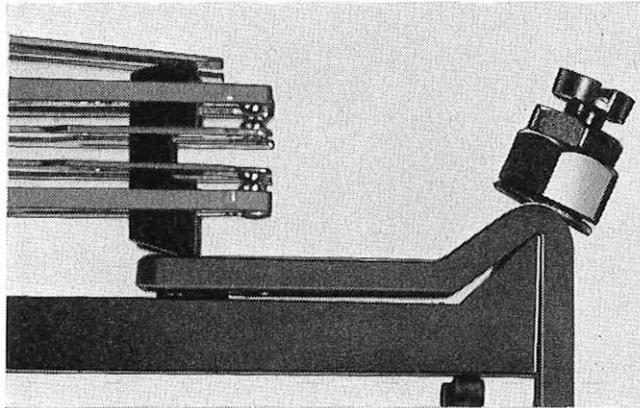


FIG. 24—Special armature retaining screw

effective. The presence of abnormal black films and particles is a sign of contact activation by hydrocarbon vapour. Fig. 25 shows black particles and dust deposited beneath arcing contacts at a working exchange. Fig. 26, photographed on the same equipment, shows black particles which had been produced inside a dust-proof relay-cover, which excluded dust but still permitted the ingress of vapours. Here, the particles together with a characteristic smooth crater on the negative contact were an indication that, due to misplaced zeal, the exchange floor was being polished too frequently with over-liberal applications of polish. The penalty was a serious reduction in the life of platinum and palladium contacts, particularly on pulsing relays. Experience, and a sense of proportion, are essential in interpreting evidence of this kind. It should be mentioned that the characteristics of polishes used in B.P.O. exchanges, and cleaning procedures, are carefully controlled. Hydrocarbon contaminants may be present in the atmosphere in some localities, and may affect performance of exchange switching contacts.

Investigations sometimes reveal that apparent design improvements in contacting systems are themselves the cause of new forms of trouble. Fig. 27 shows an arrangement used for many years in a number of different forms for power control-circuits. Conditions are onerous; the moving-coil system of a meter closes contacts when the measured quantity reaches some pre-set value. The moving bearer-springs and contacts are light, and generally close very slowly, causing discharges, interface heating and contact adherence, as the initial make-contact-force is small. When the measured quantity changes in the reverse direction, the initial retractile force of the moving contact is very small and any adherence will delay, or prevent the control function being carried out. At various times improvements have been made, quenching effectiveness increased, relays operated via the meter contacts have been locked and released from other more robust contacts. It seemed logical that a change to chatter-free platinum contacts would eliminate remaining troubles, ensure high reliability and extend working life (Fig. 28). In service, erratic behaviour of the new contacting system was traced to contact adherence: after closure, opening of the contacts was being delayed until the retractile force due to the moving-coil had built-up to such an extent that when the adherence bond broke, the moving system overshot, and closed the other limit contacts, causing the control system to hunt. The adherence was due to minute strong welds, characteristic of platinum, difficult to avoid with clean surfaces, and requiring large forces to rupture. It is ironical that moving-coil systems were used in classical experiments into contact adherence, because of the fine degree of control they provide over contact pressure and retractile force.<sup>21</sup> The contact system shown in Fig. 29 has buffered springs, and a flexible form of actuation, giving appreciable contact-wipe and follow. The contacts are of silver, which could be considered as introducing a risk of

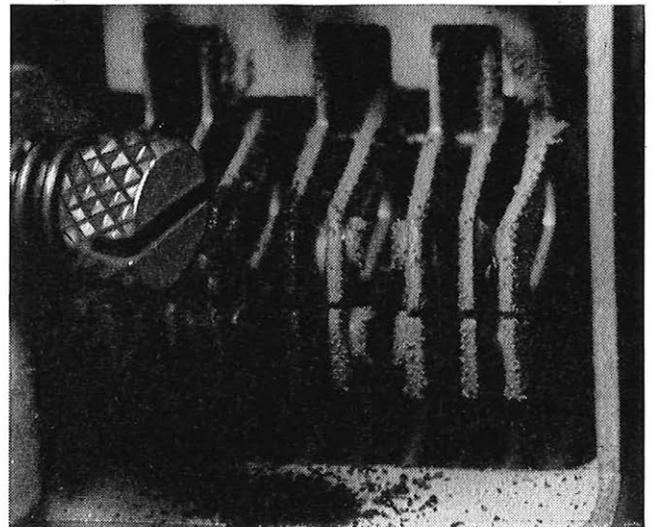


FIG. 25—Carbon particles and dust from arcing contacts

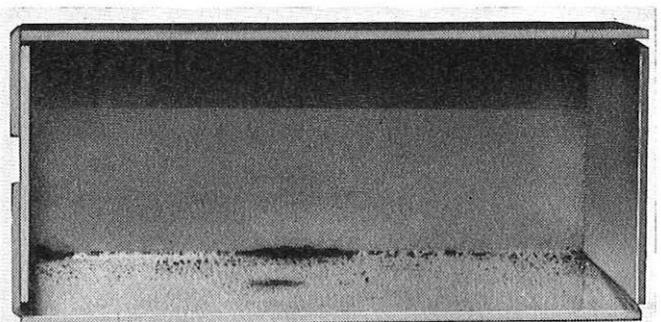


FIG. 26—Carbon particles inside dust-proof relay cover

conduction failure due to surface films. In fact, the system has proved reliable. Surface films on the silver reduce adherence bond formation and any which form are less tough than with platinum and are easily ruptured by wipe and follow, occurring while the buffered-spring contacts are closing and also while they are opening. Solid-state devices are now used for B.P.O. applications of this kind, at least one situation from which the switching-contact engineer is prepared to withdraw in favour of his modern competitor.

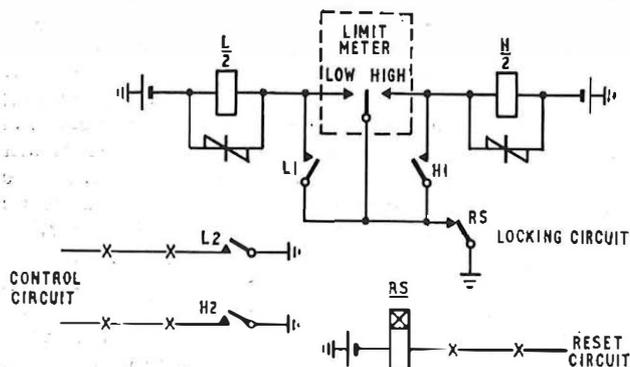


FIG. 27—Protection of limit meter contacts

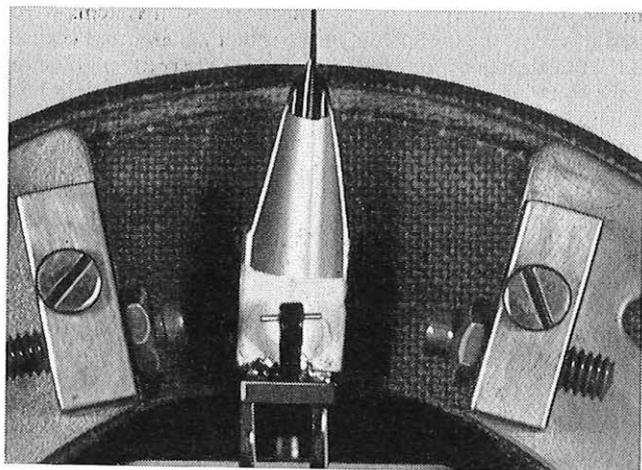


FIG. 28—Platinum contacts—rigid system

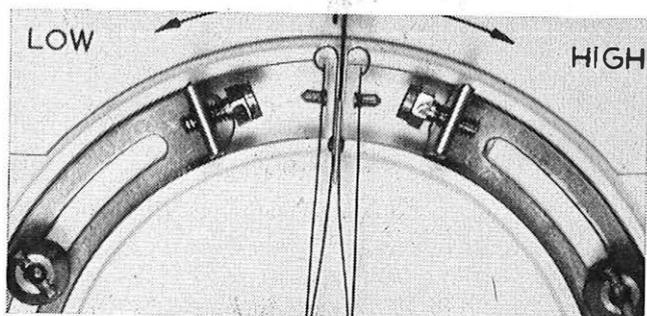


FIG. 29—Silver contacts—flexible system

## CONCLUSION

This article has covered a range of aspects of contact-switching technology in telephone exchange equipment, mainly concerned with relays having contacts open to the atmosphere.

Very large numbers of these open relays and similar devices are still being installed in equipment to existing designs and they offer the best solution for many new circuit applications.

They are also used extensively in the peripheral equipment and signalling circuits of B.P.O. standard reed electronic exchanges.

New forms of relays and switching devices are being designed in step with changes in equipment practice, with consequent possibilities for new kinds of contact hazard.

Knowledge of fundamental contact phenomena is an essential base for sound circuit design practices, leading to enhanced service reliability. Vital, in view of the large quantities involved and the high cost of maintenance effort.

The vast literature on switching contacts and their troubles, extending over 50 years, indicates the difficulties experienced in relating theory to practical design. In this field of design and development, adequate deployment of resources, continuity of effort and systematic recording and updating of experience and codes of practice, are certain to yield ample returns.

## ACKNOWLEDGEMENTS

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# Management of the TXE4 Electronic Exchange Project

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U.D.C. 621.395.345.001.1

*The development for bulk production of the TXE4 electronic system for large local exchanges, and the provision and installation of some £15 million worth of equipment is being carried out by Standard Telephones and Cables Ltd (S.T.C.) under a contract placed in June 1971. The joint British Post Office/S.T.C. project control organization for managing the execution of the contract is described; it is concluded that the careful planning and firm control achieved has resulted so far in the project timetable being closely followed and principal target dates being met without significant slip.*

## INTRODUCTION

The history of the development of electronic exchanges in the United Kingdom was traced in a recent article,<sup>1</sup> which indicated that a contract was placed with Standard Telephones and Cables Ltd in June 1971 to complete a production-engineered version of the TXE4 system for large local exchanges and supply some £15 million worth of equipment for 15 to 20 exchanges.

The drafting, negotiating, and later, management of a development-into-manufacture contract is work that gets little publicity, probably because it has not got the laboratory glamour of initial development or the excitement of early field trials. However, it is crucial to the commercial and operational success of a new development, for it is at this stage that technical, operational, industrial and economic interests merge in a decisive way; large-scale resources start to be committed and management techniques and skills of a high order must be brought to bear if success is to be assured.

The work that has to be done to carry forward a new telephone exchange system such as TXE4 from a feasibility model (Tudor exchange) to successful large-scale production is detailed, meticulous and time consuming. Since it is the foundation of success (or failure) it is worth recording, and this article outlines the principal features of the contract and describes how its execution is being jointly managed by the British Post Office (B.P.O.) and S.T.C.

## THE CONTRACT

The contract defines the system requirements and identifies the remaining development work and production engineering to be undertaken; it covers the various commercial aspects, and defines arrangements for the supply and installation of exchanges to be ordered during a 3-year period. It includes comprehensive costing clauses to provide for detailed verification of S.T.C.'s development and production costs.

Experience in recent years has increasingly demonstrated the importance of full and unequivocal understanding between a supplier and customer of the requirements of a new exchange system. In consequence, the contract was prepared with painstaking care and in great detail to ensure that B.P.O. requirements were explicitly stated and the extent of the contractor's commitment was clearly defined. The commitment of both parties and the system requirements and performance cannot be changed without full consultation and agreement.

The contract is about 2 inches thick and is sup-

ported by a greater volume of *Post Office Requirements* and other detailed specifications.

## System Definition

The TXE4 system is defined by a comprehensive statement of the facilities to be provided and other B.P.O. requirements. The technical requirements include the basic organization and arrangement of a TXE4 exchange, constructional features, the environment in which an exchange must operate, transmission performance and power supplies.

These various facets of the system definition were the concern of many people in various parts of B.P.O. Telecommunications Headquarters and S.T.C. because they involved consideration of technical, operational, service and cost objectives and had to take account of the problems of bulk manufacture, quality assurance, installation and commissioning. Some of the requirements and desirable features conflicted with one another, while others were well known and documented for electro-mechanical exchange systems but needed reconsideration for an electronic system. Some features of the TXE4 system had to be considered in the light of the field-trial experience of the Tudor exchange model and in the context of the latest information on the present-day and likely future needs of the U.K. telephone network.

Detailed and time-consuming studies and negotiations within and between the B.P.O. and S.T.C., occupying a whole year, were necessary before the system requirements could be explicitly defined and the drafting of the contract completed. The need to bring together specialists from engineering and other disciplines in different parts of the B.P.O. and S.T.C., and to control and co-ordinate their efforts, lead naturally to the joint project-control organization described later in this article.

## Development, Type Approval and Quality Assurance

The scope and stages of development are described in the contract, together with a timetable of key dates. The first stage is to complete development work to meet, in an acceptable manner, the latest requirements specified by the B.P.O. for new director and non-director exchanges. The second stage is to provide for extension of existing Strowger exchanges by TXE4 equipment; this is a feature of the TXE4 system which is particularly needed to enable a Strowger exchange to be progressively converted where available accommodation is limited. An optional third stage makes provision for additional features and further applications, if so required by the B.P.O.

The contract lays down the detailed type-approval procedure to be followed to ensure that the TXE4 system meets

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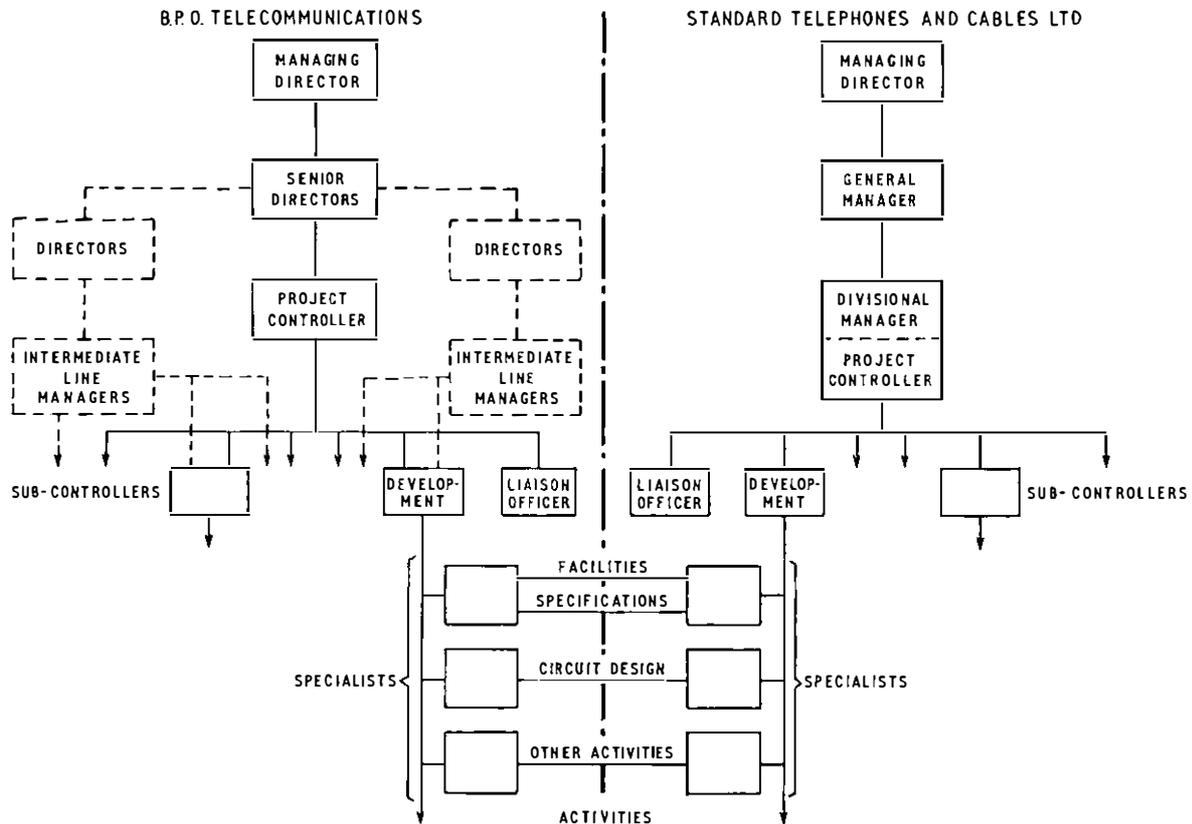


FIG. 1—Project control organization

the requirements specified in the contract. It also defines the quality assurance and acceptance-test principles to be adopted.

### Ordering Program

The B.P.O. undertakes to place works orders during a 3-year period to March 1974 for the supply and installation of TXE4 exchanges to a specified total value. The rate of ordering is defined in the contract and increases progressively over the 3 years to match a planned build-up of the contractor's production and installation capacity. S.T.C. undertakes to provide manufacturing and other resources to complete these orders to an agreed timescale. The B.P.O. is responsible for dimensioning the exchanges, and will thus be able to ensure that the quantities of equipment ordered to meet operational and service requirements are both adequate and economical. The exchange design and dimensioning practice that is being followed has resulted from comprehensive traffic simulation studies.<sup>2</sup>

### Commercial Aspects

The maximum prices to be paid for TXE4 exchanges are clearly delineated in the contract. Firm prices will only be agreed after a detailed investigation of S.T.C.'s costs at an agreed running rate of production has been made by the B.P.O. Both the maximum and firm prices are subject to adjustment to take account of any continuing inflation of material costs and labour rates. The prices to be paid are defined only in terms of TXE4 equipment and are in no way tied to prices being paid for other exchange systems.

### PROJECT CONTROL ORGANIZATION

The execution of the contract is being managed by a joint B.P.O./S.T.C. project-control organization (Fig. 1) headed by two Project Controllers: a Deputy Director at Telecommunications Headquarters for the B.P.O. and the manager in charge of the Electronic Switching Division for S.T.C.

The Project Controllers are both supported by several Sub-controllers, each dealing with an activity or a group of activities; these include such matters as circuit design, component-supplier approval, quality assurance, operational planning, acceptance testing, and commercial matters (e.g. pricing). The Sub-controllers are in turn assisted by Specialists in the various activities. Two Liaison Officers cope with much of the day-to-day contact between the B.P.O. and S.T.C., and draw together the activities of the Sub-controllers.

In the B.P.O. the Sub-controllers and Specialists are in several Departments of Telecommunications Headquarters. The project organization, which is superimposed on the line organization, co-ordinates the various Divisions, etc. that have a part to play in such a complex undertaking as introducing a new telephone exchange system. Regions will also be increasingly drawn into the project activities as work proceeds through development and manufacture to installation in the field.

The S.T.C. project organization corresponds more closely with the line organization because nearly all the Sub-controllers and Specialists are members of the Electronic Switching Division, which is headed by their Project Controller.

The joint organization was set up in mid-1970 (a year before the contract was placed) and dealt initially with the preparation of the contract. The emphasis of the work shifts as the project moves through its various phases, such as system development and engineering for production, equipment manufacture, installation and commissioning.

### CONTROL PROCEDURE

The outline timetable in the contract has been expanded into a number of detailed programs which are used for control and for monitoring progress. Sub-controllers and Specialists are in day-to-day contact with their opposite numbers to ensure that there is a smooth flow of information between the B.P.O. and S.T.C., and that difficulties are



FIG. 2—A corner of the working area showing a few of the progress control charts

resolved without delay; there are also regular discussions to review progress.

At approximately monthly intervals the two Project Controllers hold formal review meetings, attended by all Sub-controllers and Liaison Officers, at which a general review of progress is made, any necessary corrective action is initiated, and plans are approved for forthcoming phases of the project. After each meeting a joint report is made to senior B.P.O. and S.T.C. management.

At less frequent intervals the B.P.O. Senior Directors and Directors concerned meet the S.T.C. Assistant Managing Director, who is head of the Telephone Switching Group, and his senior staff for a review of progress. From time to time the two B.P.O. and S.T.C. Managing Directors meet for a general overview of the project. The two Project Controllers take part in all these meetings.

The joint project control organisation, which has now been in existence for some 2½ years, works well. It ensures that the project moves forward as planned by exercising the necessary controls; in addition, it has led to a close working relationship between supplier and customer and ensures that potential hold-ups and other important problems are quickly referred to whatever management level in the B.P.O. and S.T.C. is necessary to overcome difficulties without delay. It also acts as a continual stimulus, reminding all concerned of the importance of making the TXE4 system a success, technically, operationally and financially.

## SYSTEM DEVELOPMENT AND PREPARATION FOR MANUFACTURE

### Manufacturer's Design Procedure

The design procedure that has been used by S.T.C. for the TXE4 system is in three parts: system, circuit and mechanical design.

System, including logic, design is defined by senior designers in the Technical Department and each stage is checked by these designers on completion. Individual circuits, e.g. amplifiers, electronic gates, are designed and proved in a

laboratory group to meet the requirements of the system designers. All designs are checked and approved by a separate team of engineers who are responsible for carrying out the system testing. Mechanical design is carried out by a team of engineers in the Technical Department in conjunction with industrial engineers in the manufacturing organization, to ensure that manufacturing requirements are considered at an early stage.

### Control of Development Progress

A detailed plan was prepared at the outset by the manufacturer for the 10,000 or so individual activities of the system development using PERT network principles. The plan shows the interlinking of the activities and the manhours needed to complete each of them.

Each week every member of the development staff completes a card showing the activities on which he has worked and estimates the amount of work needed to complete the activities. The information on the cards is analysed by a computer and the results in terms of progress and cost against the plan are available early the following week. The analyses are discussed at weekly progress-meetings and any necessary corrective action is initiated to ensure that key target-dates are met.

Other outputs from the computer enable the forward work-load to be assessed by type of skill, thus allowing changes to the load to be anticipated in sufficient time to plan and achieve revised manpower needs.

A second level of control takes the form of detailed day-to-day progressing of individual design items within the various parts of the Technical Department. Much of this control is expressed by large charts displayed in the working areas (Fig. 2), which are used by people working on the job to establish the progress of any items and give a ready indication of the current problems. Each designer is also continuously aware of the promised dates for completing his own activities, and he can see how these activities fit into the general timetable for the project.

### **B.P.O. Check of Design**

During the design process there are various B.P.O. checks. Firstly, pre-manufacturing drawings covering mechanical, electrical and software design are sent to the B.P.O. for comment. At a later stage of design the B.P.O. registers all "formal" (i.e. manufacturing standard) drawings, including mechanical drawings and amounting in all to about 12,000 sheets. As part of this registration process, a check is made that standards of practice laid down in the contract have been followed and that earlier B.P.O. comments have been taken into account.

Additionally, a sample check has been made of the manufacturer's circuit design practice, involving both theoretical checks and laboratory tests of basic circuits such as gates, amplifiers and highway elements.

### **Testing of Development Model Exchange**

A large model exchange has been assembled in the manufacturer's laboratory, consisting of 36 racks of equipment made by normal manufacturing processes and including all the essential elements of a large public exchange. The model has enabled final checks to be made on individual racks as they were put into bulk production.

The model is now being used for extensive overall checks of the complete TXE4 system.

### **Testing Production Equipment**

Bulk production equipment is being tested as comprehensively as practicable in the factory, particularly to minimize work on site. The plug-in equipment units that are standard throughout the exchange and the extensive use of plug-and-socket connexions for inter-rack cabling facilitate the testing work. Test access to units is easily obtained and they can be quickly tested in bulk using automatic tape-controlled and other testers.

The conventional factory testing of racks and plug-in units is being supplemented for the first exchange by tests on groups of racks. Samples of key racks for this exchange (Birmingham Rectory) are being erected in the factory and temporarily interconnected using plugs and sockets to allow simulated commissioning tests to be made before the equipment is dispatched for installation.

### **Type Approval**

Type approval is taking place in several steps. During the early stages of design and preparation for manufacture, the B.P.O. Development Department approved individual components; provisional approval was given to mechanical design features and mounting practices; and sample circuits were examined in detail to approve the design practices and standards that were being followed.

Development Department are participating in the S.T.C. tests on the model exchange, but final type approval will not be given until the first working exchange has been tested and observed in service.

### **EXCHANGE ORDERS**

By March 1974, the end of the 3-year period, some 15-20 exchanges will have been ordered. They will be mainly replacement director exchanges but will include at least one non-director exchange and two or three extensions of existing Strowger exchanges.

Control and progressing of the installation and commissioning of Rectory exchange is being undertaken by a joint B.P.O./S.T.C. team, which includes representatives from Midland Telecommunications Region as well as from Telecommunications Headquarters. The team is directly responsible to the two Project Controllers and reports progress to them at their monthly review meetings.

The team also maintains a general oversight of the other exchanges in the 3-year ordering program. Very large orders such as Manchester Blackfriars/Deansgate, an exchange of over 18,000 lines, will be handled individually as special projects on lines similar to those already established for certain international telephone exchanges and similar important inland orders; e.g. Sector Switching Centres.

### **CONCLUSIONS**

By the end of 1972 the remaining development work for director exchanges had been completed and the minor additional development for non-director working was nearly finished; the construction and commissioning of the model exchange was almost complete and system tests were in progress; and bulk production was well under way and increasing rapidly.

The detailed timetable for the execution of the project had been closely followed and all the principal target dates had been met without significant slip. Problems will undoubtedly continue to arise but the effective joint project control organisation should ensure that they are identified and their significance determined in time for them to be successfully overcome.

### **ACKNOWLEDGEMENTS**

The Author is grateful to S.T.C. for permission to reproduce Fig. 2.

### **References**

- <sup>1</sup> MAY, C. A. *Electronic Exchanges: The Steps Leading to TXE4*, *P.O.E.E.J.*, Vol. 65, p. 134, Oct. 1972.
- <sup>2</sup> BEASTALL, H. and POVEY, J. A. *Teletraffic Studies of TXE4* (in this issue).

# Teletraffic Studies of TXE4

H. BEASTALL, B.SC.† and J. A. POVEY, B.SC.(ECON.), F.S.S., M.B.C.S., C.ENG., M.I.E.E.†

U.D.C. 621.395.345: 621.395.31

*The British Post Office is increasingly using advanced teletraffic techniques to analyze, in depth, the traffic capabilities of telecommunications systems, to determine the effect of partial failure on traffic handling and to optimize dimensioning rules. This article describes the approach to the problem and the techniques used, with particular reference to the evaluation and improvement of the TXE4 system.*

## INTRODUCTION

The engineering development of the sequence of electronic exchanges culminating in the design of the TXE4 exchange, and the project-control organization and management for the TXE4 development contract have been described by C. A. May<sup>1</sup> and E. Davis<sup>2</sup>. The evaluation of the traffic capabilities of the new design and the derivation of optimum dimensioning rules have been the subject of comprehensive analyses using modern teletraffic techniques. These teletraffic studies, performed during the development phase and in full collaboration with the engineering design teams, have also provided the basis for system improvements.

## AIMS AND TECHNIQUES

The general objectives of the teletraffic studies carried out by the Teletraffic Branch of the Telecommunications Development Department of the British Post Office (B.P.O.) are to aid system evaluation, to derive optimum dimensioning rules i.e. those rules which will result in achieving service aims at minimum total cost, and to identify possible system changes which would lead to improvements in traffic efficiency. Most traffic practitioners tend to restrict their studies to elements of a switching system independently of other elements. It is believed, however, in the B.P.O. that because of the complex inter-relationship between component parts it is necessary, in addition to such studies, to analyse the behaviour of the system as a whole so far as this is possible within the limitations of even very large computers. Without complete system studies, it is not possible properly to evaluate and improve a switching system, and past evidence has demonstrated how profitable this approach can be.

There are two main tools available with which to attack the problems. The first is the purely mathematical approach using probability theory to produce working formulae. This has the great advantage that it elucidates general principles and leads to accurate algebraic solutions that can be applied simply and generally. Unfortunately, for anything but a very simple system, this approach usually leads to very complex and frequently unmanageable mathematics. Nevertheless, by adopting simplifying assumptions, analytical methods can be successfully employed to give a general feel for the problem, to identify the most sensitive variables and, hence, to reduce the overall size of the problem. The second main technique in common use is that of simulation. This involves creating a valid model of the system in logical terms while omitting irrelevant detail—and then using this model for a statistical analysis of the behaviour of the system. Judgement on what is

irrelevant in this context, i.e. what is relatively insensitive to variation or what is outside the range of practical application, can be strongly supported by preliminary mathematical analysis, as already mentioned. The creation of a valid model is usually accomplished by progressive cut-and-try-again methods. For the simulation of other than the very simplest system, powerful computer assistance is essential.

The general process of system evaluation by simulation is illustrated at Fig. 1. Experience has shown that at least 3 man-years of effort are required for the preliminary simulation of a typical modern system (i.e. before system improvements are fully considered), the desirable deployment pattern being illustrated at Fig. 2. The time-scale illustrated cannot be significantly shortened.

## TXE4 SYSTEM STUDIES

It is feasible, given a large enough computer, sufficient manpower and time, to describe in a simulation program every detail of the operation of a system. Fortunately, in practice, it is not necessary to go to such lengths. In the case of the TXE4 system studies, the main parameters included in the analytical and simulation studies have been ten, namely:

- the number of units,
- the numbers of planes,
- the numbers of diagonals on A-switches (concentrating originating calls on to available A-B links),
- the arrangements for marker sharing,
- the provision of transfer circuits between planes,
- the proportion of D-switch links having transmission bridges,
- the provision of partially equipped units,
- the methods of path selection,
- the number of main control units (m.c.u.), and
- the number of registers per m.c.u.

To give some measure of the comparative complexity of the studies of a modern system, it might be mentioned that the number of main parameters to be studied in a Strowger director exchange would be three: the numbers and inter-connection arrangements for A-digit selectors, subsequent switching stages, and directors.

B.P.O. requirements specify the traffic performance of an exchange in terms of grades of service at normal load and at specified degrees of overload. For example, the grades of service for incoming calls (which must include both the switching network and the control and, in fact, determine the dimensioning of the TXE4 exchange main control) are:

- normal load: 0.015,
- 10 per cent overload: 0.030,
- 20 per cent overload: 0.075

† Telecommunications Development Department, Telecommunications Headquarters.

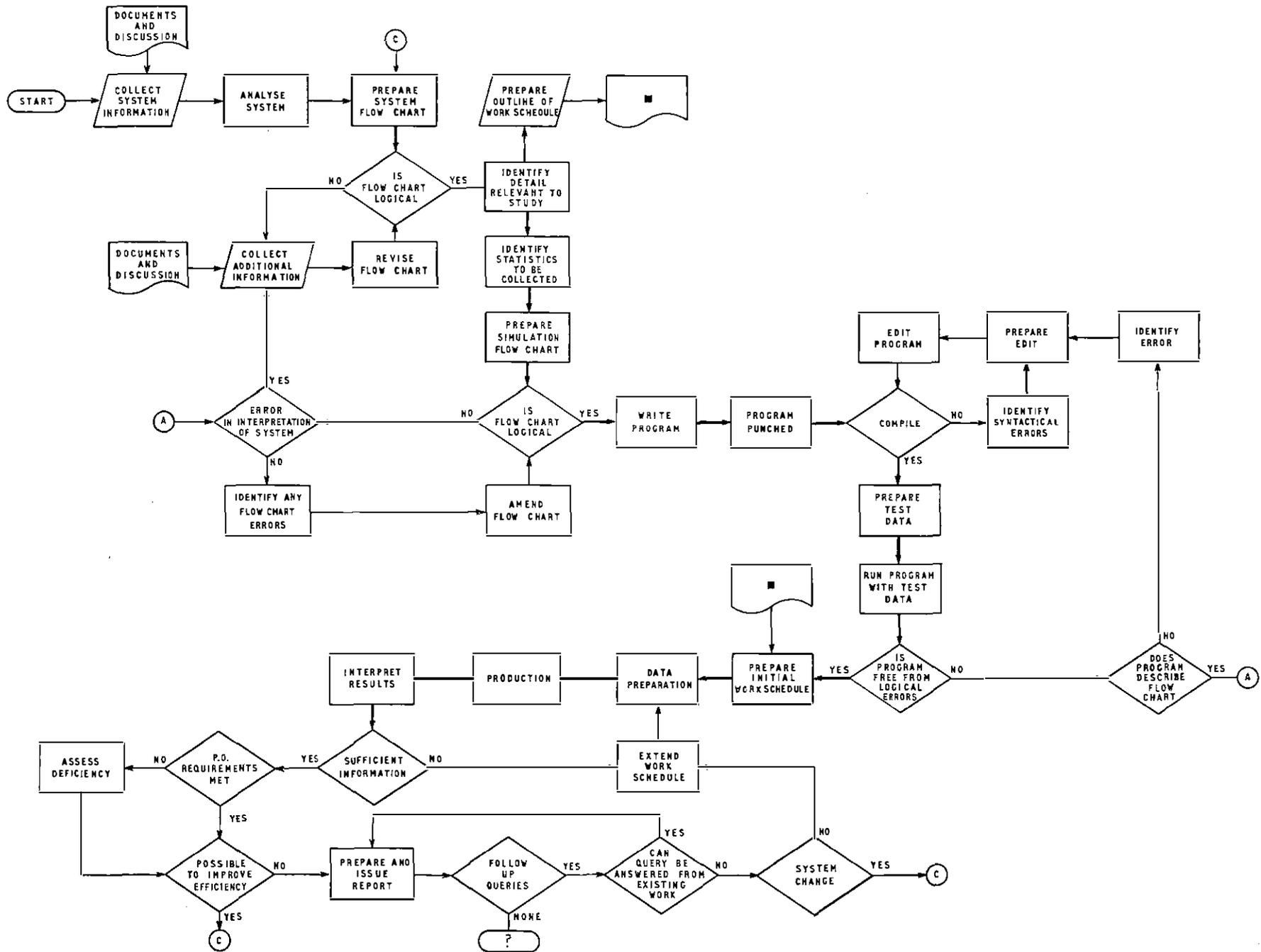


Fig 1—Flow chart of system evaluation by simulation

WEEK	TEAM PERSONNEL		
	A	B	C
1			
2			
3			
4			
5	SYSTEM DESCRIPTION AND SYSTEM FLOW-CHART		
6			
7			
8			
9			
10		PROGRAM FLOW-CHART	
11			
12	OUTLINE WORK SCHEDULE	PROGRAM WRITING	
13			
14			
15			
16		PROGRAM DEVELOPMENT	
17			
18			
19			
20			
21		PROGRAM VALIDATION	
22			
23			
24	PREPARATION FOR ANALYSIS		
25			
26			
27			
28			
29			
30			
31			
32			
33			
34			PRODUCTION
35			
36			
37			
38			
39			
40			
41			
42			
43			
44			
45			
46			
47			
48			
49			
50			
51	REPORT WRITING		
52			

FIG. 2—Optimum resource allocation for system evaluation by simulation

The performance of the system is also required to give acceptable, and stipulated, service in the presence of faults. Our studies have encompassed these various conditions. For each system configuration under study, from 5 to 7 computer runs have been necessary in order to straddle the grade of service criteria and, hence, enable the traffic capacity for each configuration to be determined.

The form of the TXE4 system model is illustrated at Fig. 3 which shows a portion of the flow-chart representing the control of an originating call. This portion represents about one-fortieth of the complete model. It is this flow-chart which provides the basis for the computer simulation program. The TXE4 system studies were broken down into three areas—the preliminary analytical study, the study of the main control system and the study of the switching area.

The allocation of effort to these studies and a brief assessment of the output obtained so far is shown in Table 1. Simulation studies of the TXE4 system are continuing, particularly to study possible improvements to the system.

The risk of an exchange running into congestion trouble when first installed, that is when it has significant spare capacity, is of course very low. Accordingly, the teletraffic studies have been concentrated on the behaviour of the exchange when fully loaded and when overloaded. For the TXE4 systems, tests have been made on the reaction of some 90 switching-network configurations and 80 control configurations to various traffic loadings (including overload).

One very early outcome of these studies was the fact that equipment failures would have had a greater than expected influence on the traffic capacity of the system. As a result of this, design modifications were introduced to improve

TABLE 1  
Summary of Teletraffic Studies of TXE4

Item	Time (Man-Months)	Output
Preliminary analytical study using simple model	5	Indication of sensitive areas Indication of effects of equipment failure Aid to planning, efficiency and validation of simulation
Development of detailed model and simulation of control system	33	Displayed degradation in grade of service caused by failure Firm traffic-capacity tables derived for provision of control equipment
Development of model of switching network and studies including variations in main design parameters	40	Traffic capacities evaluated and optimized using 1-10 switching units Need for planar transfer circuits on outgoing calls demonstrated Rules for marker sharing evolved

reliability. Another interesting characteristic of the TXE4 system is that the dimensioning is largely determined by the overload requirements, rather than the grades of service at normal loads. For the current version of the TXE4 system, traffic studies have also demonstrated, with a high degree of confidence, that the limit to traffic capacity (for example, about 5,000 Erlangs for a 20-unit exchange) is determined by the capacity of the control area. We have therefore directed attention to examining possible ways of increasing the traffic capacity of the system. Traffic studies in this area have been remarkably successful in that they have led to the identification of evolutionary changes which will double the capacity of the control area at relatively little additional capital cost.

All the tests performed have enabled potential traffic bottle-necks to be confidently identified, traffic capacity to be related to configuration and cost, and the effects of failure of elements of the system to be predicted. Hence, dimensioning rules can be optimized in terms of congestion probability and cost. Teletraffic reports conveying these results are used by operational departments as bases for directives for implementation in the field e.g. field dimensioning rules. For the TXE4 system eleven successive teletraffic reports have been compiled on various aspects of structuring and dimensioning.

#### THE VALIDITY OF TELETRAFFIC STUDIES

Once a model is available, validated by the comparison of mathematical analysis with simulation results, and wherever possible progressively refined by comparing its reaction with actual experience, the success of a teletraffic study depends upon the precision of traffic input data, especially the accuracy with which the probabilistic features of originating calls can be described. In computer simulation, a sampling experiment is performed on a set of random variables and, just as in normal telecommunications traffic sampling, the output is subject to the usual statistical errors. Most of the properties of the system under consideration are related to the occurrence of what are expected to be rare events (e.g. call failure due to congestion) so that the samples taken must be large enough to permit the useful interpretation of standard statistical tests. This implies that the accuracy of a computer simulation depends on the length of run. It also depends upon the size of the system being modelled. A great deal of basic theoretical work has been devoted to these aspects of teletraffic studies and the bases of the B.P.O. processes are essentially those which have been adopted throughout the world as a result of prolonged theoretical and practical studies. Work in progress at present

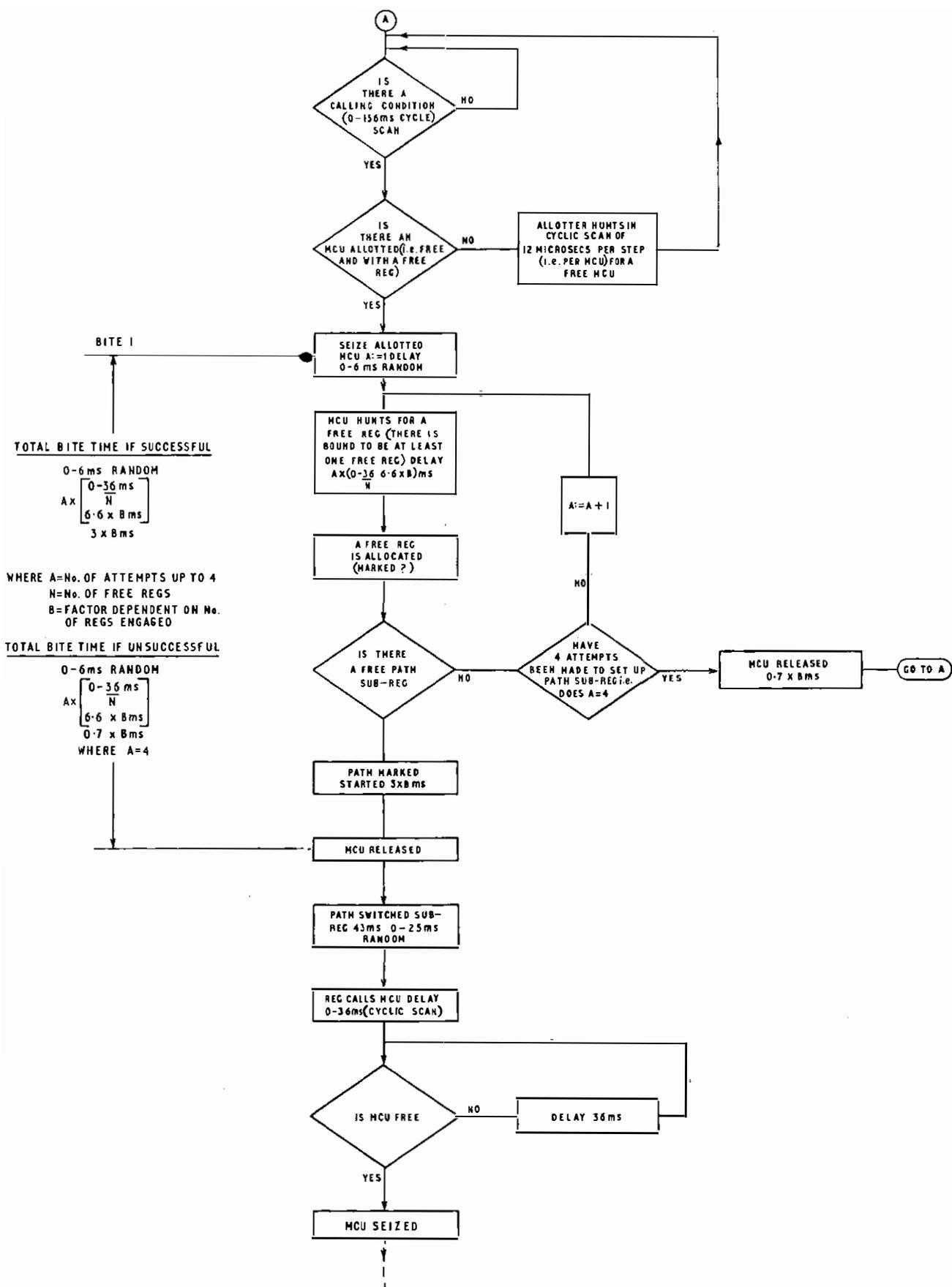


FIG. 3

suggests that the accuracy of an estimate derived from computer simulation is directly proportional to the square root of the run length and inversely proportional to the fourth root of the system size. It is on the basis of considerations such as these that the desirable lengths of computer runs in respect of the TXE4 system have been determined. In all, some 1,000 computer runs have been performed, occupying about 10,000 hours of run time and simulating well over 50 million originating and incoming calls for different classes of customer.

The computer simulation studies of the TXE4 system were carried out on a large Elliott 503 computer, which has a main store of 8,000 words and a backing store of 132,000 words. Although this is a large machine, the store is not big enough to simulate the control and switching areas of large exchanges simultaneously. The programs require 10,000 words for the logical description of the TXE4 control and 11,000 words for the switching area. The rest of the computer store is used for the simulation package, which provides the general framework for the simulation program itself; the list of events (e.g. times of call arrival, release of particular links, etc); the system data and the collection of key statistics. The typical time for a single run of the control simulation program was 6 hours, and that for the switching simulation program 12 hours. These figures demonstrate the careful management required for economic simulation work, and the need for precautions such as the periodical "dumping" of the complete store on to magnetic tape to safeguard against computer failures.

#### RELATIONSHIP OF TELETRAFFIC ANALYSIS WITH OTHER STUDIES

Teletraffic analysis cannot, of course, cover all the aspects of a complete evaluation process. It cannot prove engineering

reliability or technical design validity. These must be the subject of other tests and controls, many of them mentioned in the two articles<sup>1,2</sup> referred to previously. There is no doubt, however, that comprehensive teletraffic studies, preferably carried out as a continuing activity, checking and contributing to system development, form an essential component of whole-system optimization and evaluation. Indeed, no other process is known by which one can seek to ensure, prior to public service, that a system will carry its designed traffic load or to foresee how it will behave in overload and fault conditions.

#### CONCLUSION

As a result of the studies described above the traffic capacity of the TXE4 system in any practical situation and its reaction to overload and failures have been accurately determined. In this sense, more is now known about the traffic capability of the TXE4 system than has been known about any other system prior to its being put into service.

#### ACKNOWLEDGEMENTS

Acknowledgement is due to the many members of the Teletraffic Branch of the Telecommunications Development Department of the B.P.O. who have carried out the work described in this article.

#### References

<sup>1</sup> MAY, C. A. Electronic Exchanges: The Steps Leading to TXE4. *P.O.E.E.J.*, Vol. 65, p. 134. Oct. 1972.

<sup>2</sup> DAVIS, E. Management of the TXE4 Electronic Exchange Project (in this issue).

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## Notes and Comments

### Letters to the Editor

Dear Sir,

As an Internal engineer may I put in your columns a question to my External colleagues? As one looks at the external scene one is struck by the many advances in work methods and materials introduced in recent years, but one thing seems to have remained unchanged since the days of Sir John Gavey or earlier; in fact it seems to have regressed.

I refer to that mainstay of local line work the pole, which, particularly in towns, outrages the elegance of most modern street furniture. Lamp standards, telephone kiosks, even sand bins have clearly been the subject of considerable styling exercises, with beneficial results.

Is it not time we considered the Post Office image and ceased disfiguring the urban landscape with tree trunks, utilitarian and unadorned? Have we ever sought the services of design consultants?

Yours faithfully,

K. S. LAVER

Operational Programming Department,  
Post Office Telecommunications Headquarters,  
2-12 Gresham Street,  
London EC2V 7AG

Dear Sir,

As I understand it, a very large proportion of the magazines circulated by the London Centre fail to get back to the Librarian. Someone keeps them. I wonder how many of the magazine-keepers realize that they are taking the journals from a specific fellow member? At the beginning of the year, one of their colleagues has paid the Institution for a year's circulated copies of his chosen magazine. In practice, few of them get back to him. Last year I paid for 12 copies of *Hi-Fi News*. Two came back.

The Librarian does the best he can, but is helpless in the face of conduct of members. I have some hope that, could the printed circulation label but explain that copies were destined for someone who has paid for them, a few more might get back to the Librarian.

It is disappointing to find that one cannot even consult the previous year's issues in the Institution Library. Not nearly enough copies get back to make a set.

Yours faithfully,

L. F. KEEL

Operational Programming Department,  
Post Office Telecommunications Headquarters,  
Lutycns House,  
Finsbury Circus,  
London EC2M 7LY

Dear Sir,

It was a pleasure to study Charles May's readable article on Electronic Exchange development. I was however surprised to see in the second paragraph that t.d.m. development 'culminated' in the Highgate Wood experiment. (I note that this view is not quite echoed at the top of the next column.) It seems a little unkind to dismiss the work of the development teams on the Low and High Speed t.d.m. exchanges. Both teams produced workable (although perhaps uneconomic) exchanges which were more advanced in many aspects than Highgate Wood and were an essential part of learning about electronic exchange design. It is often forgotten that 'negative' information—finding out what not to do—is as important and as costly as successful developments that proceed into full fruition.

Yours faithfully,  
C. E. CLINCH

Postal Mechanization and Buildings Department,  
Postal Headquarters,  
Leith House,  
47-57 Gresham Street,  
London EC2V 7JL

### Post-Graduate Awards in Engineering and Science 1972

Each year the Post Office makes a number of awards to selected staff to pursue post-graduate courses in engineering and science. This is the first year that the awards has been made open to application and also the first year that selection has been carried out by Telecommunication Headquarters.

The following candidates have been awarded scholarships for post-graduate courses in engineering/science.

The following Officers have all been awarded a one-year M.Sc. course in Telecommunications Systems at the University of Essex:

Mr. A. C. Barnes, Executive Engineer, Network Planning Department, Telecommunications Headquarters.

Mr. H. G. Ambler, Executive Engineer, Telecommunications Development Department, Telecommunications Headquarters.

Mr. M. Berry, Executive Engineer, Research Department, Telecommunications Headquarters.

Mr. M. D. Bexon, Executive Engineer, Telecommunications Development Department, Telecommunications Headquarters.

Mr. T. S. Davidson, Executive Engineer, Telecommunications Management Services Department, Telecommunications Headquarters.

Mr. J. F. Marshall, Executive Engineer, Telecommunications Development Department, Telecommunications Headquarters.

Mr. R. J. Anderson, Assistant Executive Engineer, Telecommunications Development Department, Telecommunications Headquarters, has been awarded a one-year M.Sc. course in Communication Engineering at the University of Manchester Institute of Science and Technology.

Mr. J. F. Buckley, Executive Engineer, Telecommunications Development Department, Telecommunications Headquarters, has been awarded a one-year M.Sc. course in Computing Science at Imperial College, London.

Mr. J. R. Fox, Executive Engineer, Research Department,

Telecommunications Headquarters, has been awarded a three-year Ph.D. course in Computer Diagnostics at Essex University.

Mr. M. Gandy, Executive Engineer, Research Department, Telecommunications Headquarters, has been awarded a one-year M.Sc. course in Telecommunications Technology (Bosworth) at the University of Aston, Birmingham.

Mr. M. S. Maddison, Executive Engineer, Research Department, Telecommunications Headquarters, has been awarded a one-year M.Sc. course in Computing Science at Imperial College, London.

Mr. R. A. J. Smith, Executive Engineer, Telecommunications Development Department, Telecommunications Headquarters, has been awarded a one-year M.Sc. course in Communications and Electronics at Imperial College, London.

Mr. G. A. Jenkins, Executive Engineer, Midlands Telecommunications Region, has been awarded a one-year M.Sc. course in Telecommunications Technology (Bosworth) at the University of Aston, Birmingham.

Mr. R. H. Hill, Assistant Postal Controller II, Development Planning Division, Telecommunications Headquarters, has been awarded a one-year M.Sc. course in Computing Science at the London Institute of Computer Science.

Mr. F. P. Halstead, Assistant Postal Controller II, Development Planning Division, Telecommunications Headquarters, has been awarded a one-year M.Sc. course in Computing Science at Imperial College, London.

### Publication of Correspondence

The Board of Editors would like to publish correspondence on engineering, technical or other aspects of articles published in the *Journal*.

Letters of sufficient interest will be published under "Notes and Comments". Correspondents should note that, as it is necessary to send copy to the printer well before publication date, it will only be possible to consider letters for publication in the April issue if they are received before 23 February 1973.

Letters intended for publication should be sent to the Managing Editor, *P.O.E.E. Journal*, Post Office Factories Headquarters, Bovay Place, London, N7 6PX.

### 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 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.

# Regional Notes

## London Postal Region

### Eastern Telecommunications Region

#### *The "Royal Norfolk Show" Norwich*

Telecommunications engineering using the latest mechanical aids was a highlight at the 1972 Royal Norfolk Show.

This vast two-day occasion is a major event with up to 12 months preparation for two full days of exhibition. Attended by nearly 90,000 people, it offers a superb opportunity to enhance the public image of the local telephone service.

Centrally situated, on a busy corner, and overlooking the Grand Ring, the location of the Telecommunications stand could not be bettered. Pinpointed from afar by bright yellow flags with blue telephone motifs, and flanked by a long red line of the kiosks, the exhibit drew the public in their thousands.

Half of the space was devoted to a colourful display of modern refined subscriber's apparatus, with a hint of the future given by a working experimental vision phone. This was all housed in tented accommodation and supplied by Eastern Telecommunication Region.

The other half of the space was devoted to telephone area activity. The challenge of turning an 80 ft by 40 ft grass plot into an attractive educational display was accepted with enthusiasm and a profusion of ideas. All Divisions were involved in discussions and after considerable analysis of possible rejects, the decision crystalized to a working display of the "Rodding and light cabling unit", complete with all accessories, road safety precaution and gas testing equipment, road breakers, emergency lighting plant and radio control.

To ensure success in a venture such as this calls for meticulous planning and preparation, coupled with widespread enthusiasm by all concerned in the execution. The final presentation to the public was something really worthy of any progressive telecommunications undertaking.

Some 40 ft of clear plastic duct was laid across the grass surface and flanked by a 2 ft wide bank of earth, whilst a jointing box was partially buried at each end. This enabled spectators to view easily the operations in a cross-sectional simulation of what goes on in duct lines beneath pavements and roadways.

With the vehicle at one end, cable drum equipment at the other, and box guards and cones correctly placed, the stage was set to show the public how modern telephone engineers operate.

Members of the Norwich telephone area field staff operated duct motors, introduced artificial blockages, cleared them, and generally demonstrated how they coped with problems. The public flocked to the continuous re-enactment of daily routine that few of them were even remotely aware of. Great interest was shown in a tiny oscillator tucked into the nose of the rods. Members of the public of all ages were watched by very interested spectators as they wore headphones, and listened for the tell tale locating bleeps from the tip of the rods moving along the duct.

From numerous comments and local newspaper reports, widespread admiration of our methods and understanding of our problems was generated. This should help the field force when wayleaves are required or the public are put to inconvenience with emergency road openings.

The guest of honour was Anglia television's Jennifer Cresswell. A previous Miss Anglia, she now appears in a weekly program, "Sale of the Century". Jennifer was welcomed by Mr. J. E. Golothan, The Director of Eastern Telecommunications Region, and Mr. J. C. Saunders, the General Manager of Norwich Telephone Area, and members of the field force explained the technicalities of the display to their charming guest.

Thanks are due to all concerned with the project, however small or large their contribution. It was a good team effort and a credit to all participants.

Ideas for next year's show are already taking general shape, and there are hopes of providing working units of latest exchange switching equipment as part of an overall concept embracing the activities of all Divisions in the area. Naturally, before any specific preparations can be started, basic policy meetings at both regional and area levels must define the main theme and outlines.

F. D. W. EMBLING

#### *Replacement of the Brick Chimney at Post Office Supplies Division, Crayford Depot, Kent.*

The heating plant at the Crayford Depot consists of six Le Mont Boilers with a total heating capacity of  $60 \times 10^6$  BThU/hour. A brick flue-gallery connected to a common chimney which was itself contained in a tower block. The chimney was built in 1952 and was approximately 100 ft high and 7 ft 6 in in diameter.

In September 1971 large cracks appeared in the base of the chimney, the largest being  $\frac{1}{2}$  in wide and running vertically to 15 ft. The cause was thought to be a severe thermal shock occurring when the boilers were lit for the first time after the summer shut-down period. This together with internal corrosion weakened the base of the chimney. A further contributory factor to the failure, which gave added cause for concern, was that this chimney was built entirely of molar bricks instead of the normal structural brick construction with a molar brick liner.

Immediately on finding these defects South Postal Engineering Section constructed and fitted 11 steel bands around the defective part of the chimney to stop any further bursting effect. The Department of the Environment (D.O.E.), filled the cracks, placed glass tell-tales in position and arranged weekly inspections to note and report any further deterioration of the chimney.

Chimney specialists and the D.O.E.'s structural engineers were of the opinion that unless there were any worsening effects with the firing of additional boilers, the measures taken would allow the chimney to operate for the 1971-72 heating season only. However, there was no guarantee that the chimney would operate for the entire period. Planning the replacement was put in hand immediately at Regional Headquarters.

Having regard to the vital importance of the Crayford Depot to the Telecommunications and Postal businesses, it was imperative that uninterrupted heating was provided throughout the heating season. The replacement chimney, which was to be of three-core steel-insulated construction, could not be erected until the summer of 1972, so as an insurance against premature failure of the chimney, it was decided to provide three temporary lightweight uptakes mounted individually on top of three of the boilers as a first priority. These temporary chimneys protruded through the boiler house roof and would allow three boilers to provide sufficient heat for the large storage sheds. Provision was made for the office accommodation to be heated with calor gas heaters if the need arose.

Tenders were invited and a contract for the whole of the



work was awarded to Thomas W. Ward Ltd. The three temporary chimneys were ready for use by January 1972 and had to be brought into operation at the end of April 1972 to allow an early start to the demolition work. The brick chimney was demolished in four weeks and the new chimney and flues were supplied, erected and the plant tested by mid-July.

The new chimney was delivered in 33 ft sections which were lowered one at a time through the top of the tower block by

means of a high lift crane. The photopgraph shows the base section being hoisted.

Thanks to excellent co-operation between the Depot Manager, the resident Post Office maintenance staff, the Post Office Clerk of Works, the D.O.E. (who supervised the builders work) and the Contractor, the whole project ran smoothly from start to finish, and what might have been a serious situation was averted.

J. E. TOUT

## Associate Section Notes

### Dundee Centre

After careful consideration of all the suggestions, the following program has been arranged for the 1972/73 Session.

- 1972
- 11 October A visit to the Department of Civil Engineering—University of Dundee.
- 31 October "North-sea oil" by Shell United Kingdom Exploration and Production Ltd.
- 16 November "Behind the scenes"—A visit to City Museum and Art Galleries.
- 12 December "Post Office statistics" by Mr. W. R. Crook, Telecommunications Headquarters, Scotland.
- 1973
- 20 February "Geology in the Dundee Area" by Mr. I. Spence.
- 20 March "Service in the seventies" by Mr. T. C. Watters, Telecommunications Headquarters, Scotland.
- 6 April Visit to Marconi Space and Defence Systems, Hillend.
- 17 April Annual general meeting.

The Committee make an earnest appeal for all members to "pull up their socks" and make a real effort to attend these meetings.

R. T. LUMSDEN

### Exeter Centre

At a members meeting in March, Norman West and Don Craig presented their papers "The Post Office Radio Service—past, present and future" and "The Wells of Mersa" respectively; Norman giving his experiences throughout 23 years, supported his talk with exhibits of suppressors in many forms, Don, returning to 1935, with his adventures in locating the Wells at Mersamatrué, which dated from the Dynasties of Egypt, was descriptively related. Both these papers were enjoyed with admiration, and proved that talent can be found within the membership.

At the annual general meeting in April, votes of thanks were expressed by the Chairman and Secretary to the retiring President, Mr C. P. Moss, for his dedication to the Centre during his term of office, especially in the formation of winter programmes which had brought greater attractions to the members. The following Officers were then elected:

*President:* Mr. B. L. E. Yeates; *Chairman:* Mr. G. S. Steer; *Assistant-Chairman:* Mr. C. K. Sanders; *Secretary:* Mr. E. Soper; *Assistant-Secretary:* Mr. J. J. F. Anning; *Treasurer:* Mr. W. F. Lambert and *Librarian:* Mr. N. H. B. West. *Committee:* Messrs. T. F. Kinnaird, D. N. Miller, J. L. Petherick, S. G. Page, C. W. Paterson, J. Brown, G. W. W. Abbott and J. Scanes.

In his opening address, the President spoke of our identity within the field of telecommunications, endeavouring to maintain a professional status—to this goal our aim is directed.

A visit to Hinks and Sons, builders of "The Golden Hind" was arranged in April—this replica constructed by using traditional methods, was a fascinating sight, showing the skills of boat building which had continued for over a century in the area of Appledore. We continued our tour through one of the most modern shipyards in Europe, fully automated and totally under cover employing the latest in shipbuilding machinery.

It was with deep sadness to learn of the tragic death of our former Chairman, Mr. Roy Powesland, who I am sure will be remembered by many for his contribution to the success of our Centre.

E. SOPER

### Glasgow Centre

At our annual general meeting, held on 18 May 1972 in the Charing Cross Hotel, Glasgow, the gratitude of the Glasgow Centre, for services rendered, was expressed to Mr. J. McCallum our chairman for the past four years. Mr McCallum was unable to attend the annual general meeting, having only that week been discharged from hospital, and it is with not a little regret that we accept his resignation from the office of chairman.

The following officers have been elected for the coming year:

*President:* Mr. J. L. Sommerville; *Chairman:* Mr. R. E. Johnston; *Vice-Chairman:* Mr. W. Fotheringham; *Secretary:* Mr. R. I. Tomlinson; *Assistant-Secretary:* Mr. R. W. Stevenson; *Treasurer:* Mr. K. Gordon; *Librarian:* Mr. N. Cochran. *Committee:* Messrs. H. McNamara, F. N. Hamilton, P. McBride, C. Faith, T. McAuley, N. Potts, M. Kane, J. Roney, E. J. Jamieson, H. McCaig, J. Blane, J. Bannerman and J. McCallum.

The following program has been arranged for the 1972/73 session.

- 1972
- 19 October "Preparation for Interview" Mr. H. C. Stevenson, Deputy Controller Personnel, Telecommunications Headquarters Scotland.
- 16 November Visit to Charles Frank Ltd, Scientific Instrument Makers, Glasgow.
- 14 December "Holiday '73" Introduced by Bellemdaime Travel Centre Ltd, Giffnock, Glasgow.
- 1973
- 18 January "The work of the Weather Centre, and Meteorological Office in general" by Mr. Watt, Glasgow Weather Centre.
- 15 February Visit to Glasgow College of Nautical Studies, Planetarium, Thistle Street.
- 15 March "A funny thing the Law" Mr. Frank Skerrat of the Evening Citizen Newspaper.
- 19 April "Welfare at Work" Mr. E. V. McQuoid, Welfare Officer, General Manager's Office Glasgow Telephone Area.
- 18 May Annual general meeting.

R. I. TOMLINSON

### Hereford Centre

The annual general meeting was held at the Spread Eagle Hotel, on 15 September 1972, and was followed by a steak supper.

The following officers were elected:

*Chairman:* Mr. K. Lee; *Vice-Chairman:* Mr. S. J. Cound; *Secretary:* Mr. A. J. Charles; *Assistant-Secretary/Librarian:* Mr. N. Innes; *Treasurer:* Mr. L. J. Knight; *Auditors:* Messrs. W. J. Merrick and M. Powell. *Committee:* Messrs. L. Evans, W. J. Lee, H. Holt, N. Deeley, C. J. Brace, M. Parry, D. Knight, D. Till, R. Evans and G. Marpole.

Membership of the section now stands at 124, and in 1972 an interesting visit to Hereford Town Hall was undertaken. There were two talks given: "Telephone Area Organization" by the Telephone Manager, Mr. G. Arnold, and "Submarine Cables" by Dr. P. R. Bray.

Details of the 1973 program have yet to be finalized but it is hoped to include visits to a telephone manufacturer's and a coal mine. Several interesting talks are planned, including the "Weights and Measures" department and the Police Service.

A. J. CHARLES

### London Centre

Last year was very successful in many ways and it is hoped that this year will be as good. The program for this year is as follows:

1972	
3 October	"Work Study in the Modern Post Office", by Mr. K. Grainger.
7 November	"Sector Switching Centres", by Mr. B. F. Yeo.
5 December	"Telegraph exchanges, t.a.s., telex and p.a.t.x", by Mr. B. Sheekey.
1973	
30 January	"A technical view to lighthouses and lightships", by Mr. G. Winterburn.
20 February	"The laser in optical telecommunications," by Mr. M. R. Matthews.
20 March	"Stored program control" in the London Telecommunication Region, by Mr. E. Lewis.
17 April	"Mechanical aids in the Modern Post Office", by Mr. H. Brown.

All of these talks will be held in the second floor Assembly Hall of Fleet Building, and start at 17.30 hours. There are

free refreshments served in the first floor restaurant from 17.00 hours. All Post Office staff are cordially invited to attend any talk.

The New Quarterly Journal (N.Q.J.) is continuing to run, but we have a new editor. Brian Baker resigned last year and the post has been filled by Chris Fry. The N.Q.J. is your house journal and the editor is always in need of extra material; please send him some.

The London Centre Committee elected at Conference this year is as follows:

*Chairman:* Mr. J. Carver; *Vice-Chairman:* Mr. P. D. Southgate; *Secretary:* Mr. P. L. Hewlett; *Assistant-Secretary:* Mr. J. Simkins; *Treasurer:* Mr. R. Gray; *Editor:* Mr. C. Fry; *Visit-Secretary:* Mr. D. Denchfield; *Technical Quiz Organizer:* Mr. D. Thomas; *Registrar/Librarian:* Mr. D. Randall; *Projects Organizer:* Mr. P. D. Southgate; *National Committee Delegates:* Messrs. J. Dow and P. L. Hewlett.

This year, the C. W. Brown award was given to B. Baker and L. Trudgen, Mr. Baker was given the award for his services as Editor of the N.Q.J. and Mr. L. Trudgen for long and loyal service to the East Area London Telecommunication Region Committee.

A full program of visits has been arranged for the forthcoming session and notice of these will be given in due course.

The Library is functioning and any members who wish to borrow books or catalogues should contact Mr. Randall.

The membership of the London Centre stands at about 6,000, this is not as large as it could be; make sure that all of your colleagues are members; bring them along to our talks and take advantage of your Association.

For any further details please contact your local representative or myself.

P. L. HEWLETT

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## The Associate Section National Committee: First Year Report

The past year has been an historical and eventful one for the Associate Section, with the first meetings of the newly formed Associate Section National committee having taken place.

### History

The Associate Section was sponsored by the Main Institution and came into being in 1932 as a result of spontaneous interest in the idea throughout the country.

From that time (apart from the inevitable suspension of activities during the war years 1939 to 1945) the Associate Section has continued to grow and thrive. Although the Post Office has provided guidance and counsel in the presence of the official 'Liaison Officers', growth has always been spontaneous and has depended on local interest. Good Associate Sections have always been characterized by a spirit of enthusiasm, which is reflected in the lively and varied programmes of such sections. This state of affairs seems to have gone on happily from year to year—with most sections being self contained, and entirely independent of any other sections.

### New Ideas

In recent years, however, there has been a move towards closer ties with other sections. This was first evidenced by the setting up of Associate Section Regional Structures in some of the Regions. This arrangement enabled representatives from each section in the Region to meet at least once a year and exchange ideas; a system that worked to the mutual benefit of all. In due course, these ideas seem to have led to the next logical step; the forming of a representative National Committee.

### Proposals

The idea of forming a National Committee was discussed in various quarters from time to time, but it was not until 1969 that any firm ideas materialized. In that year, the London Centre listed their ideas on the subject in a paper entitled "The Proposal", which was then presented to their Liaison Officer. This paper was duly discussed at the Liaison Officers' Conference in October 1971. At this meeting the Liaison Officers decided to "sound the country out" on these proposals, and arrangements were made to invite Associate Section representatives from each Region in the country to attend a conference along with their Regional Liaison Officers, where the ideas could be discussed. After this meeting, the representatives would return to their Regions with a full knowledge of the proposals, which could then be discussed within the Region. Allowing time for this "within Region" discussion of the proposals, another meeting of the representatives would then be called, at which the attitude of the whole country could be gauged on whether to set up a National Committee or not.

### Realization

The first of these meetings took place on 27 March 1971, and the second meeting on 17 July 1971. Both meetings were held at Stone Central Engineering College. At the July meeting the vote was for the setting up of a National Committee. A draft constitution was then drawn up and officers of the committee were selected.

The declared aims of the new Associate Section National Committee were stated as follows:

To operate Rule 55(b) of the I.P.O.E.E. rules. "Rule 55(b), to receive suggestions and interchange ideas in connexion

with communication engineering generally", and within this framework to make the following specific aims

- (a) to facilitate the exchange of ideas,
- (b) to provide financial and administrative aid to smaller sections,
- (c) the setting up of an Associate Section national magazine, which would give our members a national voice, and be instrumental in propagating ideas on a national scale,
- (d) The organizing of prestige visits to, and exchange of information with, foreign places of technical interest,
- (e) to make the Associate Section more attractive to potential members as a national corporate body,
- (f) the organization of a national technical quiz contest,
- (g) the appointment of one member of the national committee to act in a liaison capacity for group projects.

Ratification of the constitution took place at another meeting of the delegates, which was held on 6 November 1971, also at Stone. At this meeting it was agreed that payment to the National Committee should be at the rate of 5p per member per year, payable from 1 April each year. Plans for implementing the items mentioned above were also made. The magazine was to be known as *National News*, priced at 5p, and initially produced on a quarterly basis. An assessment would be made after the first year of issue and plans for future distribution then finalized. The Quiz would be on a Regional Knock-out basis, with the finalists competing for a National Prize. The projects co-ordinator asked for details of all section projects in order that he could compile a suitable reference list, and be able to help any other sections seeking assistance with similar projects. The ratified constitution, and details of the plans mentioned above were then given to the President of the Associate Section, Dr. P. R. Bray, for presentation to Senior Council at their next meeting. Authority for the Associate Section National Committee to proceed as planned was duly received from Senior Council.

#### *The First Year*

During 1972 the first two meetings of the Associate Section National Committee took place, the first on 8 April, the second on 9 September, both meetings being held at Stone.

Considerable progress has been reported in all activities. The magazine has been produced as planned, and has by all accounts been well received. At the September meeting the future financing of the magazine and scale of issue was discussed at length. For its first year the magazine was financed very largely out of National Committee funds in hand, but ideas for making the magazine financially independent of the main National Committee funds were put forward. The magazine Editor was asked to make these views known to the membership in the Autumn, 1972 issue of the magazine.

The Quiz Organizer reported good progress in plans for the National Quiz. In many regions a Regional Quiz organizer had been selected to organize the Quiz contests within the

Region. The prize to be awarded to the winning National Team will be a trophy, and will be known as 'The Bray Trophy' named in honour of the President of the Associate Section, Dr. P. R. Bray, who has done so much to make the launching of the National Committee possible.

The Projects Co-ordinator is building up a dossier on such projects as workshop construction, electronics construction, model construction, canoe building and glider construction. Information and know-how can then be made available to other interested groups.

#### *Summary*

Much hard work has gone into the organizing of the National Committee and the activities arising from this. National Committee delegates can feel pleased with progress in the first year, but there is no room for complacency. Not all sections in the country are convinced about the value of "sharing" ideas which is the basis of the National Committee principle. In certain quarters a feeling of apathy is evident, manifesting itself as the well known and insular "I'm all right Jack" attitude.

The National Committee idea is entirely democratic, if people do not wish to participate then they need not, but they may well be losing out. There is nothing more refreshing than swapping ideas with other people. The National Committee principle means that all ideas can be pooled, with all participants than having access to this common pool. The purpose of the Associate Section magazine *National News* is to circulate good ideas and reflect all that is best in Associate Section activities. The National Quiz is a bringing together on a friendly competitive basis, whilst the Projects Co-ordination idea epitomizes the principle of sharing knowledge.

Further details about the National Committee can be obtained from the two delegates in each Region, or the Chairman Mr. J. Dow (Telephone: 01-226-1262 Extension 459), or the Secretary, Mr. P. Hewlett (Telephone: 01-261-4860).

This report cannot close without expressing a sincere thank you from the National Committee to Dr. Bray for his invaluable help and guidance in getting the whole thing off the ground. At the inaugural meeting, when the delegates had voted for setting up a National Committee, Dr. Bray said that he thought the delegates had made a correct choice, and he believed that this was the way the Associate Section could now evolve. The National Committee could play an important part in drawing together the threads of common interest between the Centres, but the extent to which this end is achieved was completely in the hands of the membership, as indeed was the usefulness and standing of the Associate Section as a whole.

Valuable assistance was also given by the late Bob Walters, Private Secretary to Dr. Bray. Bob was a staunch friend of the Associate Section and it is with deep regret that we record his passing.

C. F. NEWTON

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## Obituary

### **Mr. R. V. Walters**

Robert Verden Walters passed away suddenly on the evening of 10 August 1972.

Many Associate Section Members will not have heard of Bob Walters. Some will have known him as a member of the staff at the Technical College at Stone, where he had worked since its inception in 1947. A few will have been aware of his dedicated service to the Associate Section.

It is because of this service that it is proper he should be remembered by this notice.

Partly perhaps by virtue of his holding office as joint Secretary of the Stone-Stoke Centre of the Institution, but certainly because of his obvious enthusiasm in *I.P.O.E.E.*

matters, he was asked to participate in Associate Section work.

Right from the start he proved invaluable in organizing the Regional Liaison Officers' annual conference. His contribution far exceeded the normal attention to details. He acted as minute Secretary, and in so doing his experience and, once again, his dedication proved him to be an invaluable and I fear irreplaceable aide to the Presidential office.

These qualities stood him and us in good stead when the National Committee was being formed, and for its first meetings.

I know Committee members will feel with me that the Associate Section has suffered the loss of a good friend, and will endorse this tribute to him.

P. R. B

# Institution of Post Office Electrical Engineers

## Election of Members of Council 1972-73

The results of the recent elections of Council are as shown below, the names being shown in order of votes counted.

### Grade Representation

Staff Engineers, Chief Motor Transport Officers, Submarine Superintendent, Senior Principal Scientific Officers, Assistant Staff Engineers, Motor Transport Officers Class I, Deputy Submarine Superintendent, Principal Scientific Officers, Chief Experimental Officers, Commanders (Cable Ships), Chief Factories Engineer and Principal Costs Officers of the Post Office Headquarters Departments and Regional Engineers of the London Regions.

Mr. H. BANHAM, Telecommunication Headquarters, returned unopposed.

Executive Engineers, Motor Transport Officers Class III, Experimental Officers, Scientific Officers, Second Officers, Second Engineers and Technical Costs Officers of the Post Office Headquarters Departments and Factory Overseers of the Factories Division (London).

Mr. J. C. FLETCHER, Telecommunications Headquarters.  
Mr. S. J. WHITCOMBE, Telecommunications Headquarters.

Executive Engineers and Assistant Regional Motor Transport officers of the London Regions.

Mr. M. S. ARMITAGE, London Telecommunications Regions, returned unopposed.

Executive Engineers, Assistant Regional Motor Transport Officers, Experimental Officers and Scientific Officers of the Provincial Regions. Factory Executive Engineers and Factory Overseers of the Factories Division (Provinces).

Mr. D. L. STEVENSON, Scotland Telecommunications Region.

Mr. H. R. H. CLOUGH, North Western Telecommunications Region.

Mr. J. W. ROBERTS, Midlands Telecommunications Region.  
Mr R. C. MORRIS, Eastern Telecommunications Region.

Affiliated Members of the Post Office Headquarters Departments and of the London Regions.

Mr. E. C. OFFORD, Telecommunications Headquarters returned unopposed.

Affiliated Member of the Provincial Regions.

Mr. R. B. LLOYD, Northern Ireland, returned unopposed.

The Constitution of the Council for the year 1972-73 will, therefore, be as follows:

Mr. N. C. C. DE JONG—Chairman.

Mr. D. WRAY—Vice-Chairman.

Mr. H. T. McGRATH—Honorary Treasurer

Mr. H. BANHAM—Representing the Staff Engineers, Chief Motor Transport Officers, Submarine Superintendent, Senior Principal Scientific Officers, Assistant Staff Engineers, Motor Transport Officers Class I, Deputy Submarine Superintendent, Principal Scientific Officers, Chief Experimental Officers, Commanders (Cable Ships), Chief Factories Engineer and Principal Technical Costs Officers of the Post Office Headquarters Departments, and Regional Engineers of the London Regions.

Mr. S. H. SHEPPARD—Regional Engineers of the Provincial Regions.

Mr A. H. ELKINS—Senior Executive Engineers, Motor Transport Officers Class II, Senior Experimental Officers, Senior Scientific Officers, Chief Officers, Chief Engineers and Senior Technical Costs Officers of the Post Office Headquarters Departments and Assistant Factory Managers of the Factories Division (London).

Mr. K. F. MARSHALL—Senior Executive Engineers and Regional Motor Transport Officers of the London Regions.

Mr. M. W. BAYLEY—Senior Executive Engineers and Regional Motor Transport Officers of the Provincial Regions. Factory Senior Executive Engineers and Assistant Factory Managers of the Factories Division (Provinces).

Mr. J. C. FLETCHER—Executive Engineers, Motor Transport Officers Class III, Experimental Officers Scientific Officers, Second Officers, Second Engineers and Technical Costs Officers of the Post Office Headquarters Departments and Factory Overseers of the Factories Division (London).

Mr. M. S. ARMITAGE—Executive Engineers, and Assistant Regional Motor Transport Officers of the London Regions.

Mr. D. L. STEVENSON—Executive Engineers, Assistant Regional Motor Transport Officers, Experimental Officers and Scientific Officers of the Provincial Regions. Factory Executive Engineers and Factory Overseers of the Factories Division (Provinces).

Mr. J. M. MACKIRDY—Assistant Executive Engineers, Technical Assistants, Senior Scientific Assistants, Assistant Experimental Officers, Third Officer, Fourth Officers, Third Engineers, Fourth Engineers, Electrical Engineers and Assistant Technical Costs Officers of the Post Office Headquarters Departments and Factory Foremen and Assistant Factory Foremen of the Factories Division (London).

Mr. G. F. MORLEY—Assistant Executive Engineers and Technical Assistants of the London Regions.

Mr. R. C. MALTBY—Assistant Executive Engineers, Technical Assistants, Senior Scientific Assistants and Assistant Experimental Officers of the Provincial Regions. Factory Foremen and Assistant Factory Foremen of the Factories Division (Provinces).

Mr. M. COCKERELL—Inspectors of the Post Office Headquarters Departments and of the London Regions.

Mr. M. RICHARDS—Inspectors of the Provincial Regions.

Mr. C. F. GOLDSMITH—Draughtsmen and above and Illustrators and above of the Post Office Headquarters Departments and of the London Regions.

Mr. K. CHINNER—Draughtsmen and above of the Provincial Regions and of the Factories Division (Provinces).

Mr. D. R. BEARHAM—Corporate Members holding non-Engineering posts in the Post Office (Rule 11(a)).

Mr. E. C. OFFORD—Affiliated Members of the Post Office Headquarters Departments and of the London Regions.

Mr. R. B. LLOYD—Affiliated Members of the Provincial Regions.

## Increase in Institution Subscriptions

Members were asked in July 1972 to vote for or against the following amendments to Rule 13.

“The annual subscription to the Institution shall be as follows:

### CORPORATE MEMBERS

Member .....	£2·40
Affiliated Member .....	£2·40

### NON-CORPORATE MEMBERS

Corresponding Member .....	£2·40
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Members who are retired from the Post Office following the normal operation of the service regulations and who retain their membership, may commute their annual subscriptions by payment of £3·50.”

The results of the voting were:

For amendment .....	5,016
Against the amendment .....	860

In consequence the increased subscriptions will be effective as from 1 July 1972.

A. B. WHERRY  
General Secretary



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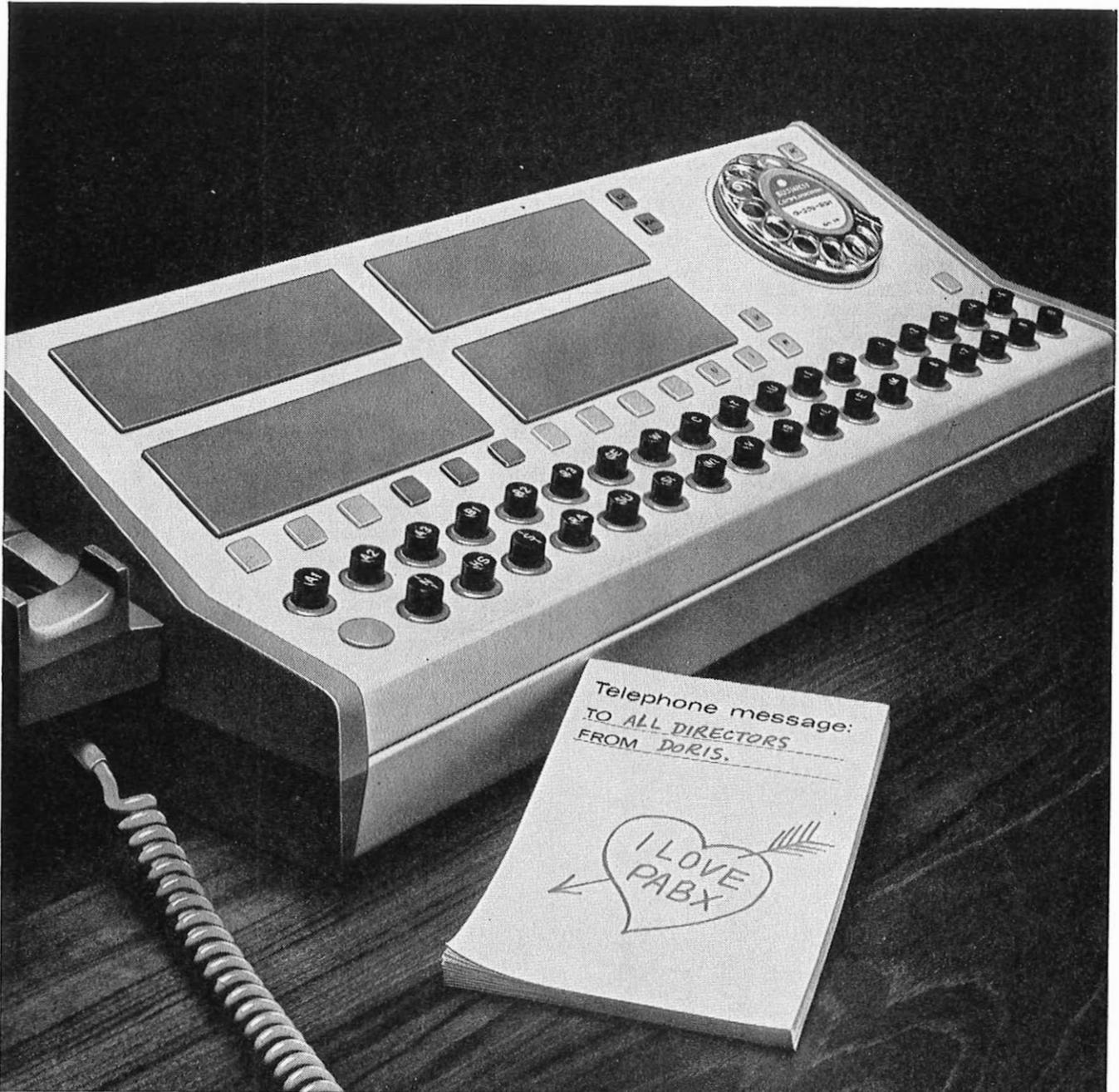
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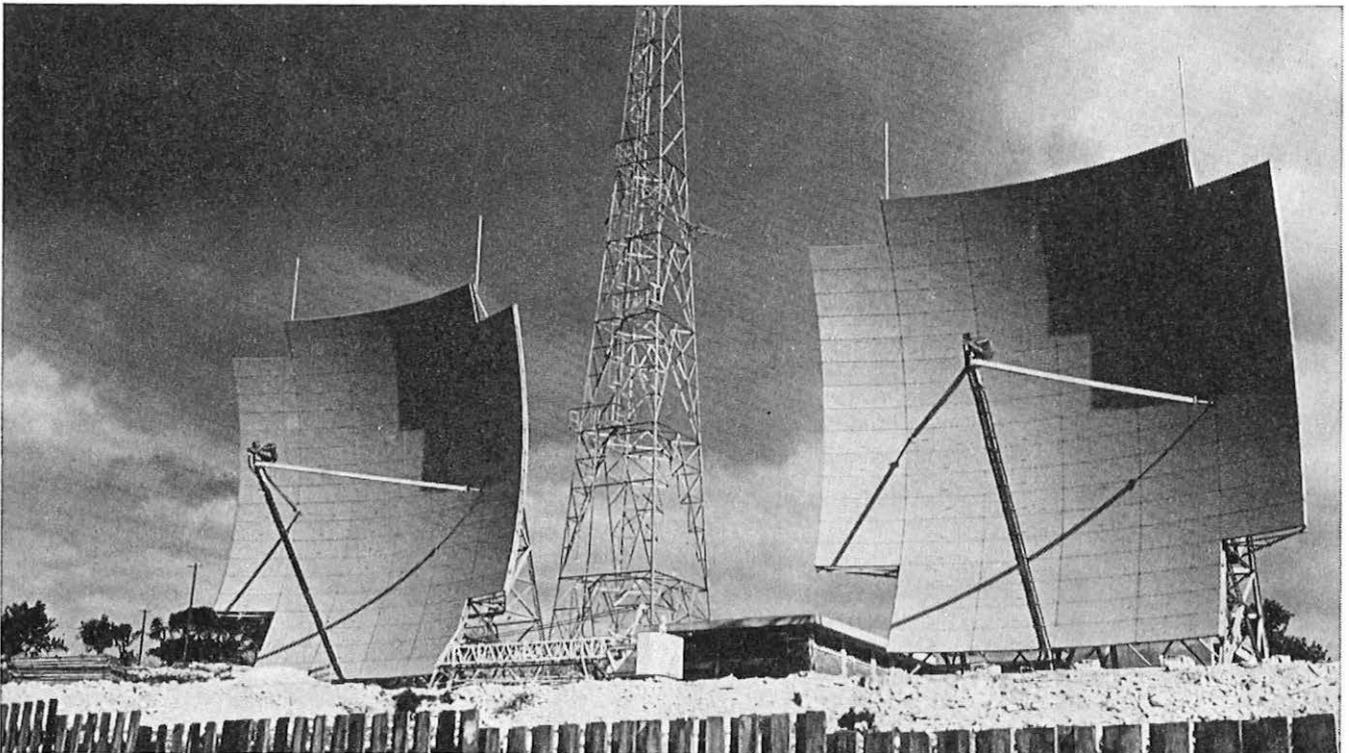
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Fairey Electronics ATR20 series relays are currently being used in full duplex, half duplex and differential duplex telegraph systems. Sensitivity is adequate for CCITT Recommendation V24 inputs, for example as an interface with Tariff J circuits. Very considerable improvements in performance, reliability and equipment bulk are being achieved.

Abridged Specification	ATR20 series polarised relays
Isolation	Meets BPO safety requirements
Mode	Single-pole changeover as each-side stable, one-side stable (+ or - side stable) or centre stable. Or, single-pole on/off (inverting or non-inverting action)
Speed	Typically 1,000 bauds at 100V output increasing to 5,000 bauds at 30V
Maintenance	None (no moving parts)
M.T. B.F.	4½ years (calculated) under typical conditions
Input impedance	15kΩ/30kΩ depending on mode
Input level	3.0V to 100V single or double current
Output voltage	6.0V to 100V single or 6-0-6V to 100-0-100V double
Output current	1.0mA – 250mA
Power supply	No external supplies are required other than the output signalling battery

Fairey Electronics ATR20 polarised electronic relays are offered (1) as plug-in replacements for existing e.m. types, (2) on p.c. boards for new equipment, or (3) as a complete interface package in a 19in rack containing up to 10 relays, filters and barretter lamps.

## You ought to know more about ATR20 relays

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I'd like to inquire further into Fairey solid-state telegraph relays and associated equipments.

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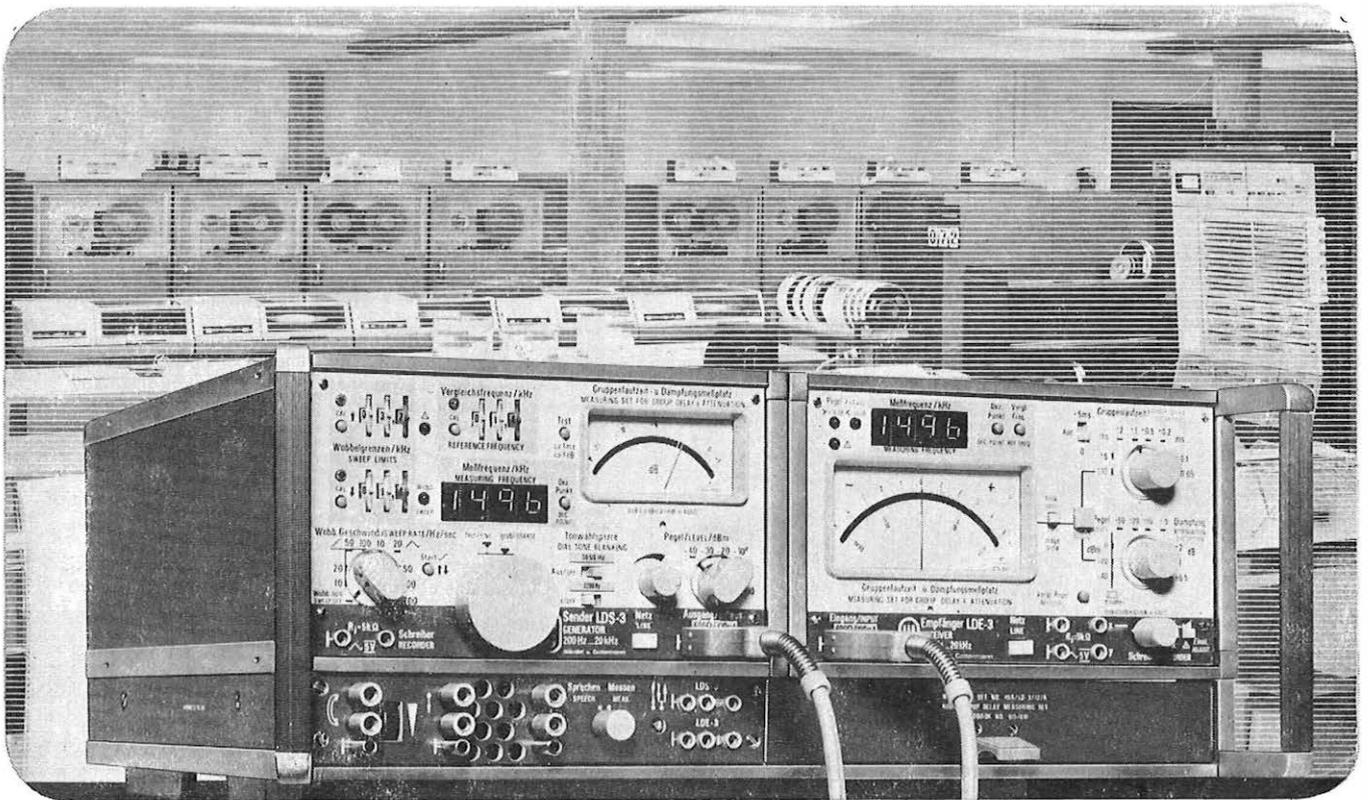
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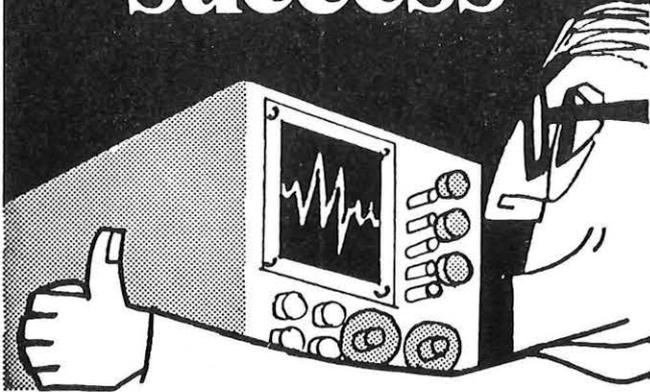
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# Mullard ICs approved for Post Office equipment

## FJ Series TTL integrated circuits first past the D3000 barrier

The Post Office Spec. D3000 is a tough one; tough in terms of its requirements for long life reliability, high-temperature tests. But FJ Series TTL ICs are also tough and reliable – so much so that Mullard are the first to get D3000 approval for TTL.

Post Office equipment suppliers can now use these proven devices in analogue and digital transmission equipment.

Initially, all the devices supplied will be from the medium-power FJ Series in ceramic 14- and 16-lead, dual-in-line encapsulations. Fourteen types are already approved and further work is in hand to ensure approval for the entire

series, including low-power types.

Mullard FJ Series ICs have become well known, because of their advanced specifications, and also because (like all Mullard components) they're very fully documented. If you haven't got details of these very important ICs, please ask your Mullard contact for literature.

## Injection logic – a promise in store

Integrated injection logic devices, currently being experimented with at Mullard Southampton, could result in bipolar ICs with packing densities as high as 400 gates/mm<sup>2</sup>.

Indications are that it will be possible to use I<sup>2</sup>L to fabricate bipolar integrated circuits comprising in excess of 1500 gates, using standard processing techniques which will have acceptable yields. Furthermore, power delay time products of 0.4 picjoule per gate and operating on less than one volt are possible.

At Southampton experiments are well ahead with a 1024-bit, bipolar, RAM chip. The access time is expected to be appreciably less than 100 nsec and cycle time in the region of 300 nsec. The high packing density and low heat generation are important features of this new technique.

It is too early as yet to forecast when I<sup>2</sup>L devices will be available commercially, but results are very encouraging.

This interesting technique is discussed in more detail in the next Post Office supplement of the Mullard Bulletin.

## Goodbye, Weston Cell

Mullard have just published a booklet about voltage reference diodes – specifically, the Mullard BZX90 family. Tough, substantially immune to temperature variation, highly stable... ideal for constructing a standard cell with none of the disadvantages of our trusty, but out-dated, friend the Weston Cell.

These solid-state devices are the keys to a wide variety of applications. Ask for a copy of the Mullard booklet Ref. TP1339. It tells you all about BZX90 diodes and includes some useful circuits.

## NEW SURGE SUPPRESSORS TO POST OFFICE SPECIFICATIONS

Fully met by standard diodes

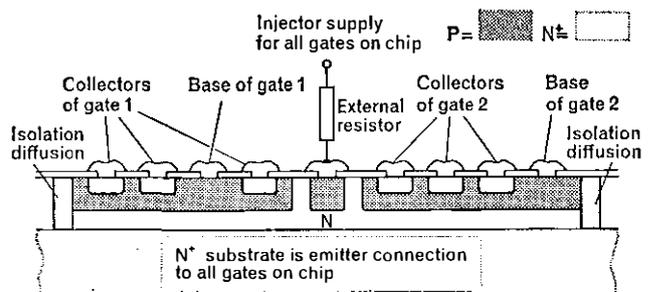
New Post Office specifications will set tolerances for the diodes used to suppress transients on busbars and thus protect semiconductor devices in power supply equipment.

A tight specification is necessary – particularly with respect to the exponential current pulse.

From standard devices in the comprehensive range of Mullard surge suppression

diodes the PO20 (25kW) and PO21 (10kW) diodes were derived.

Both types meet the tight Post Office specification and are just two examples from the range of Mullard surge suppression diodes with power handling capabilities from 800W to 60kW; stand-off voltages from 3.9V to 62V; available in normal and reverse polarity versions.



Cross-section of a pair of gates with PN injection of minority carriers



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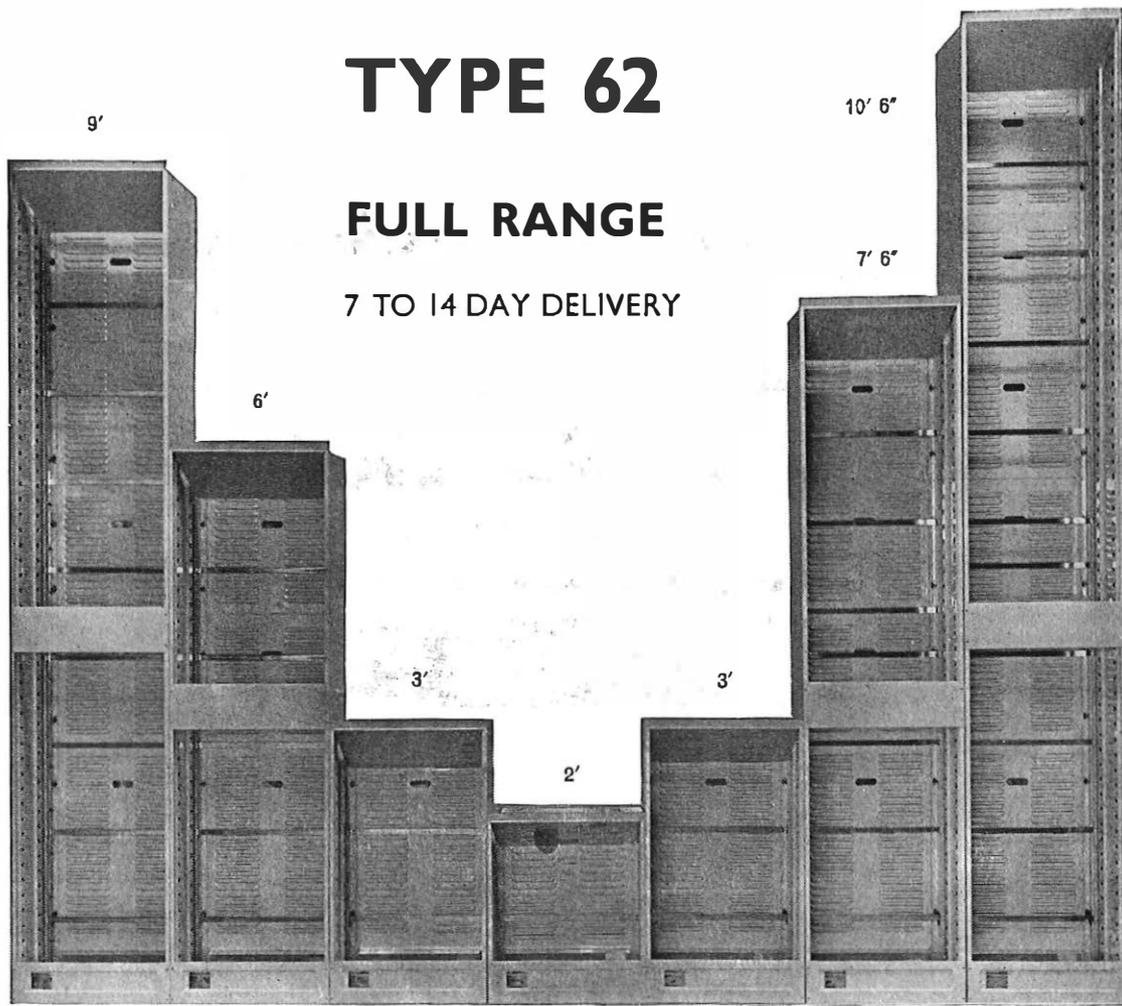
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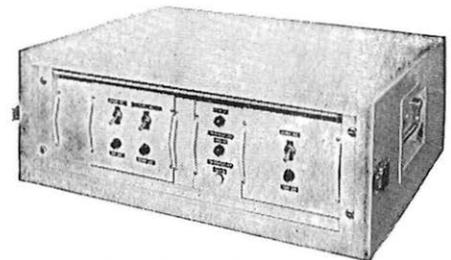
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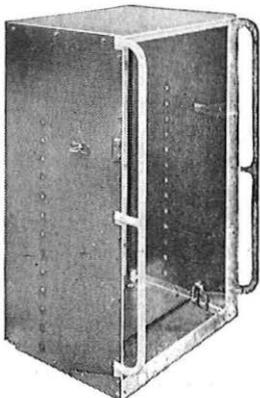
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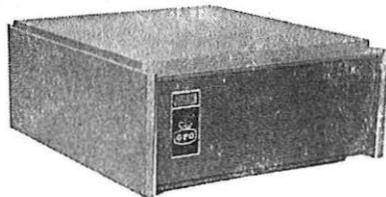
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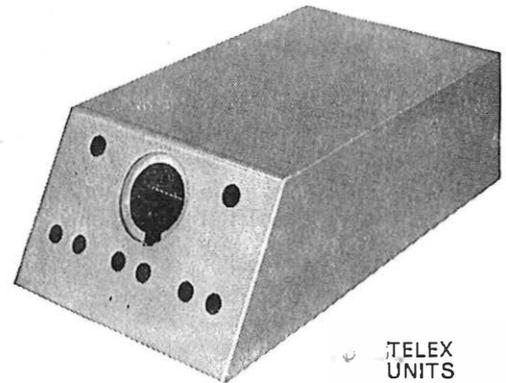
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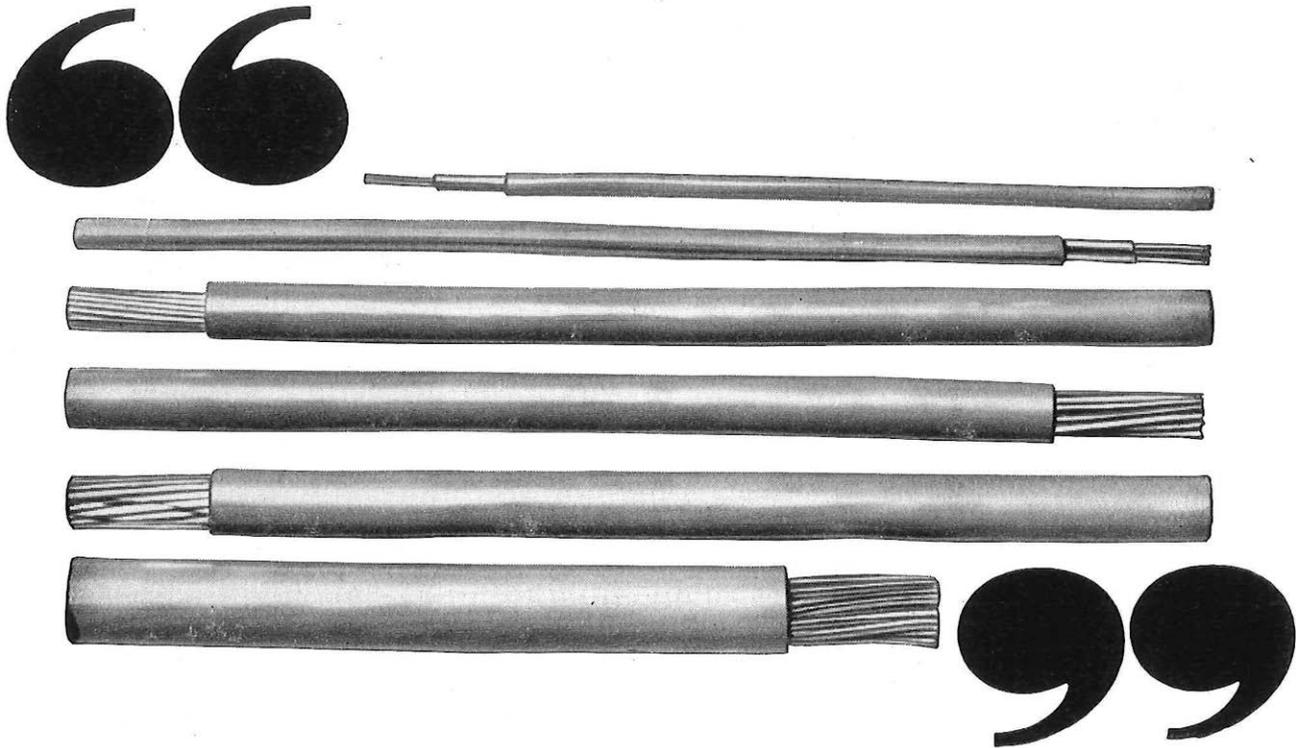
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# Here it is!

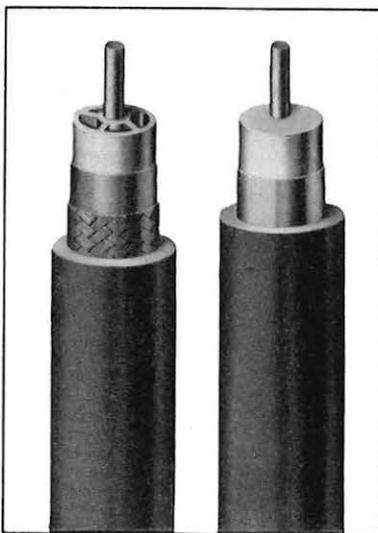
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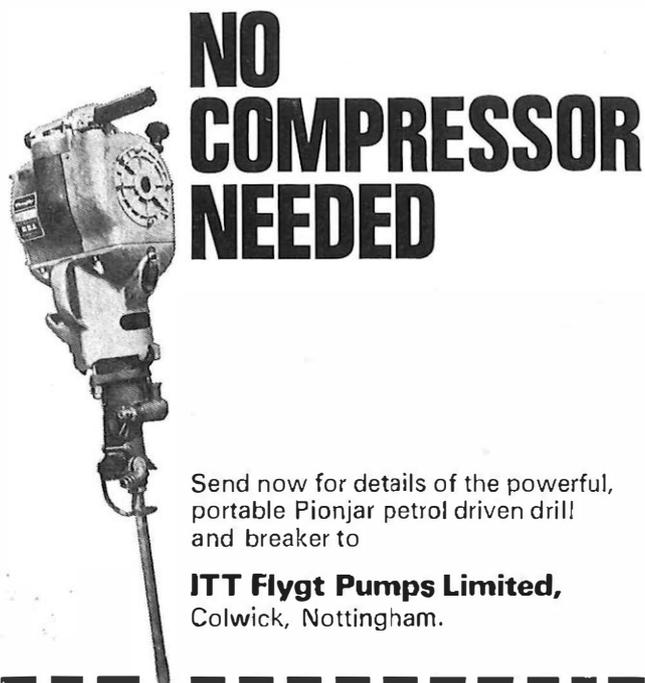
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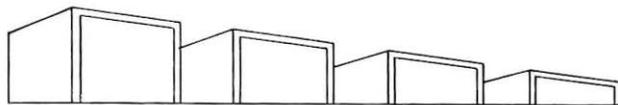
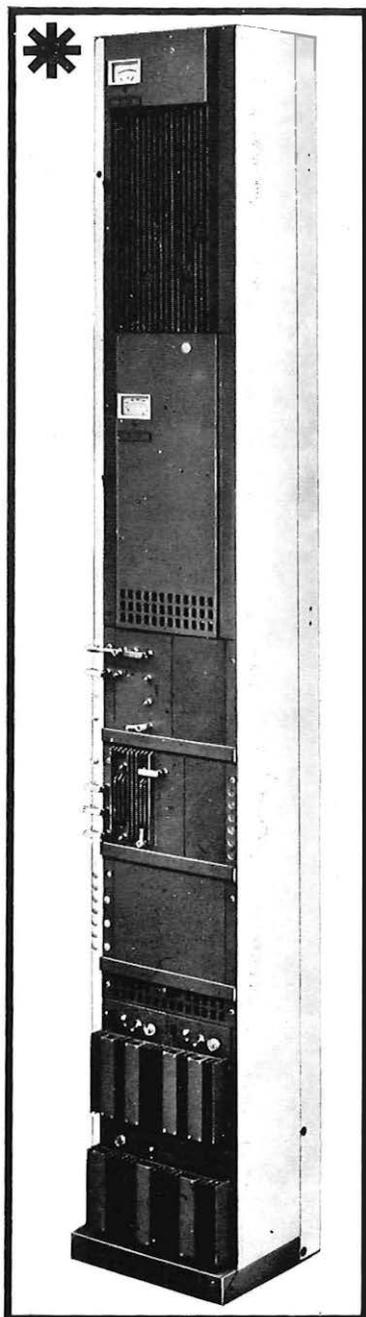
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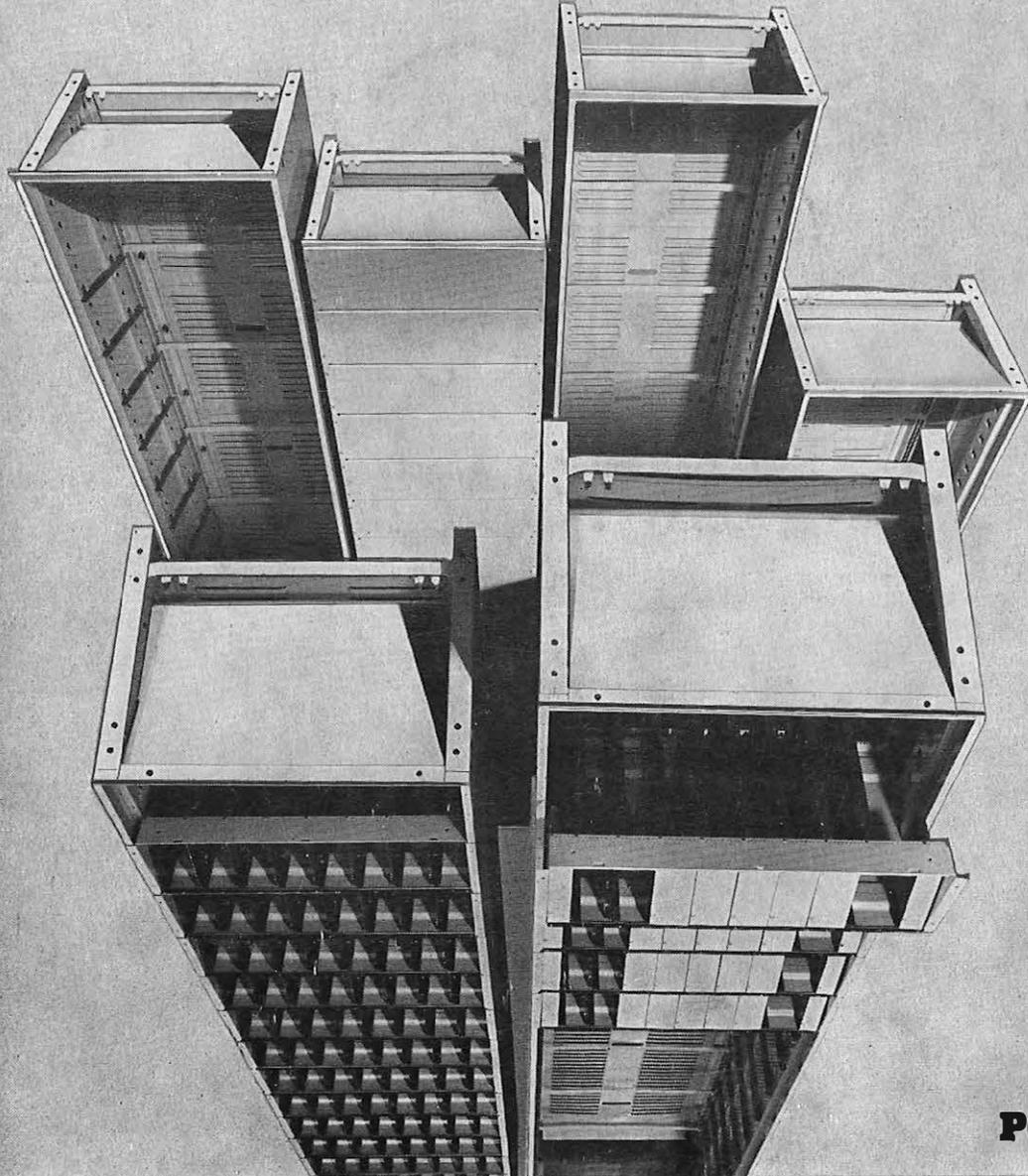
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