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Contents

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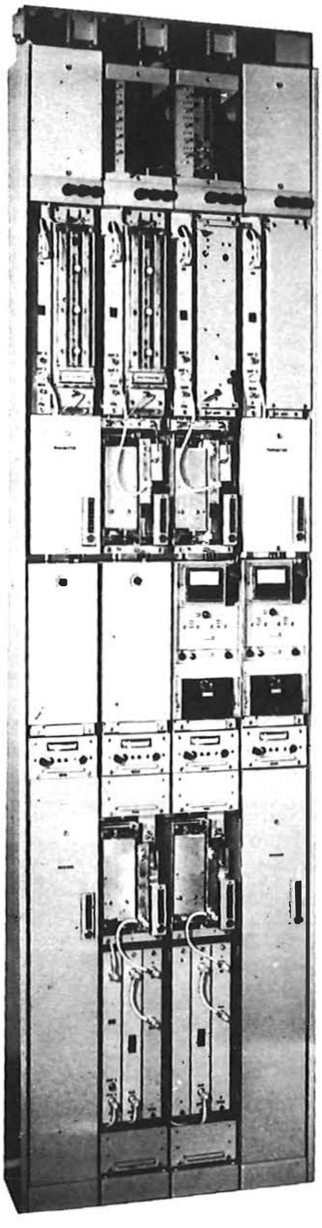

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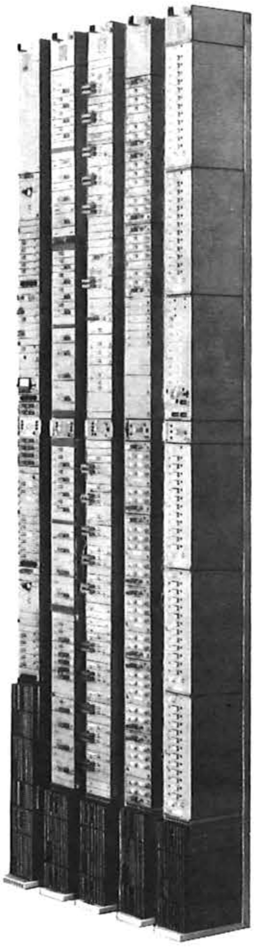

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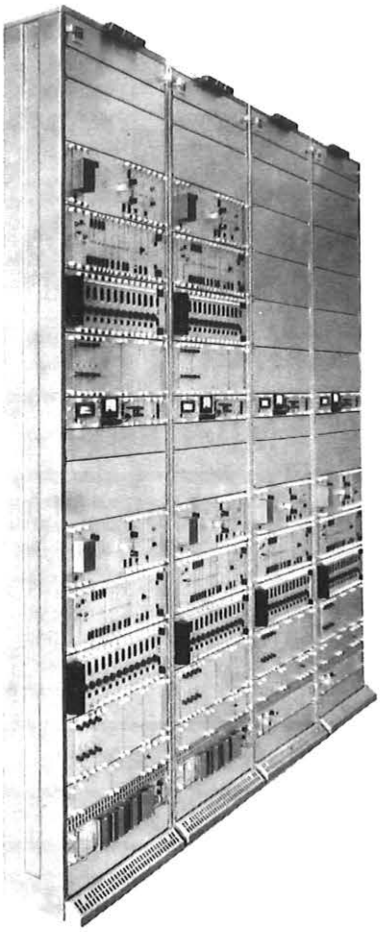

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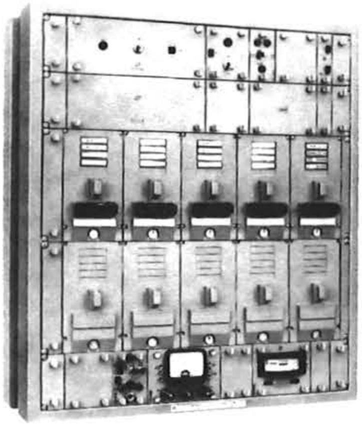

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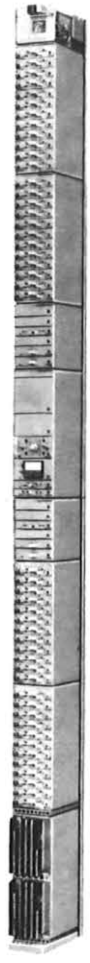

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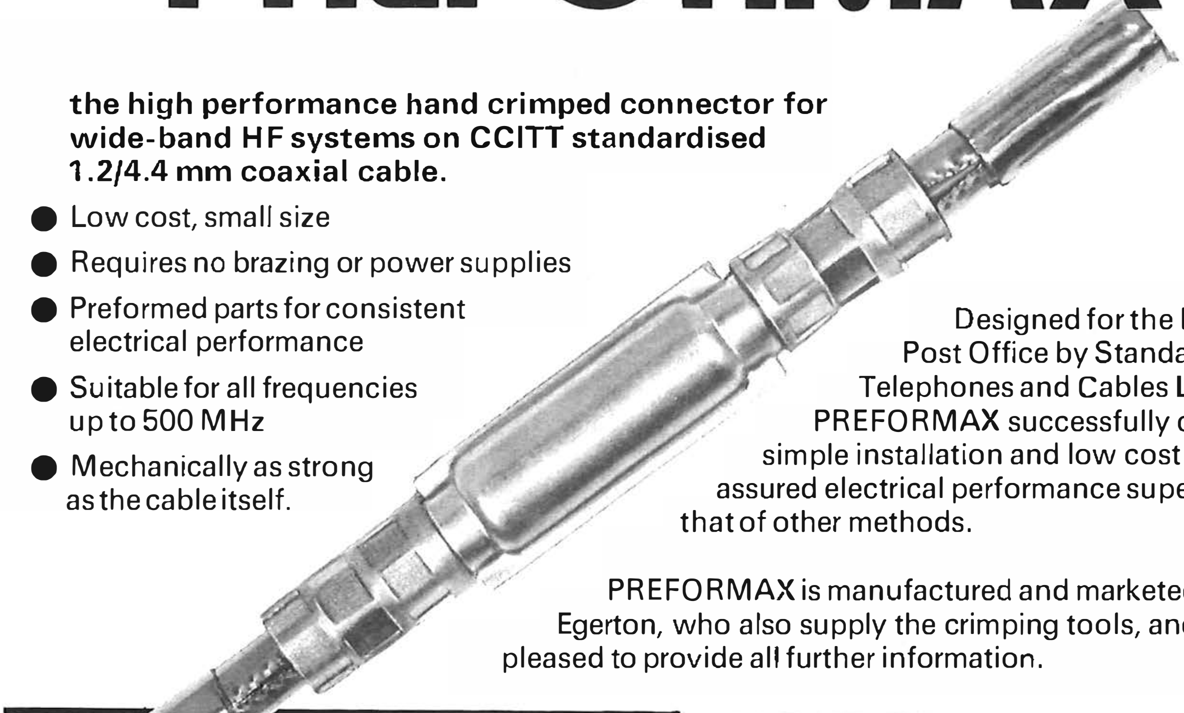

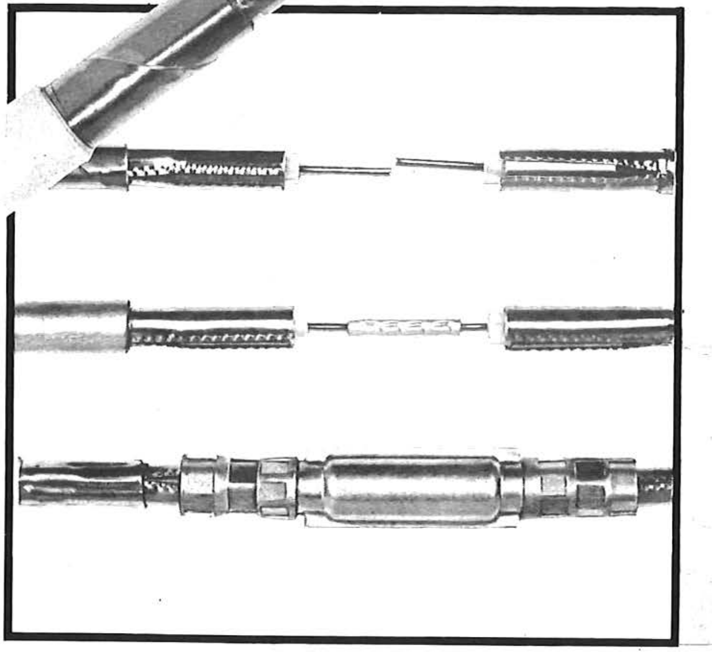

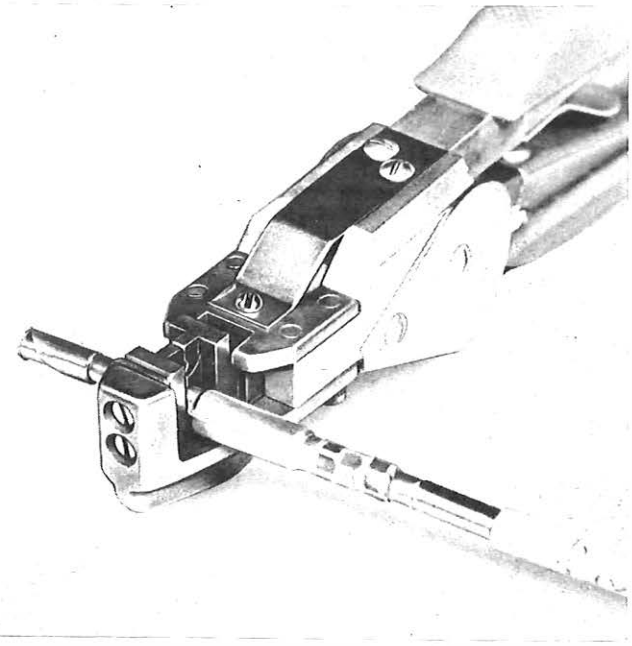

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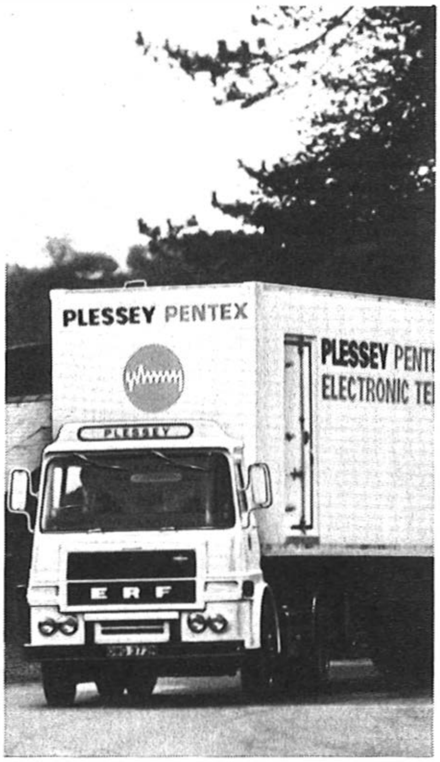

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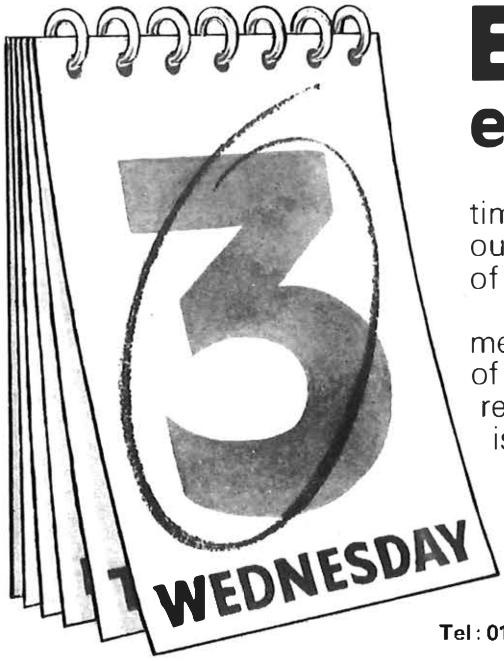
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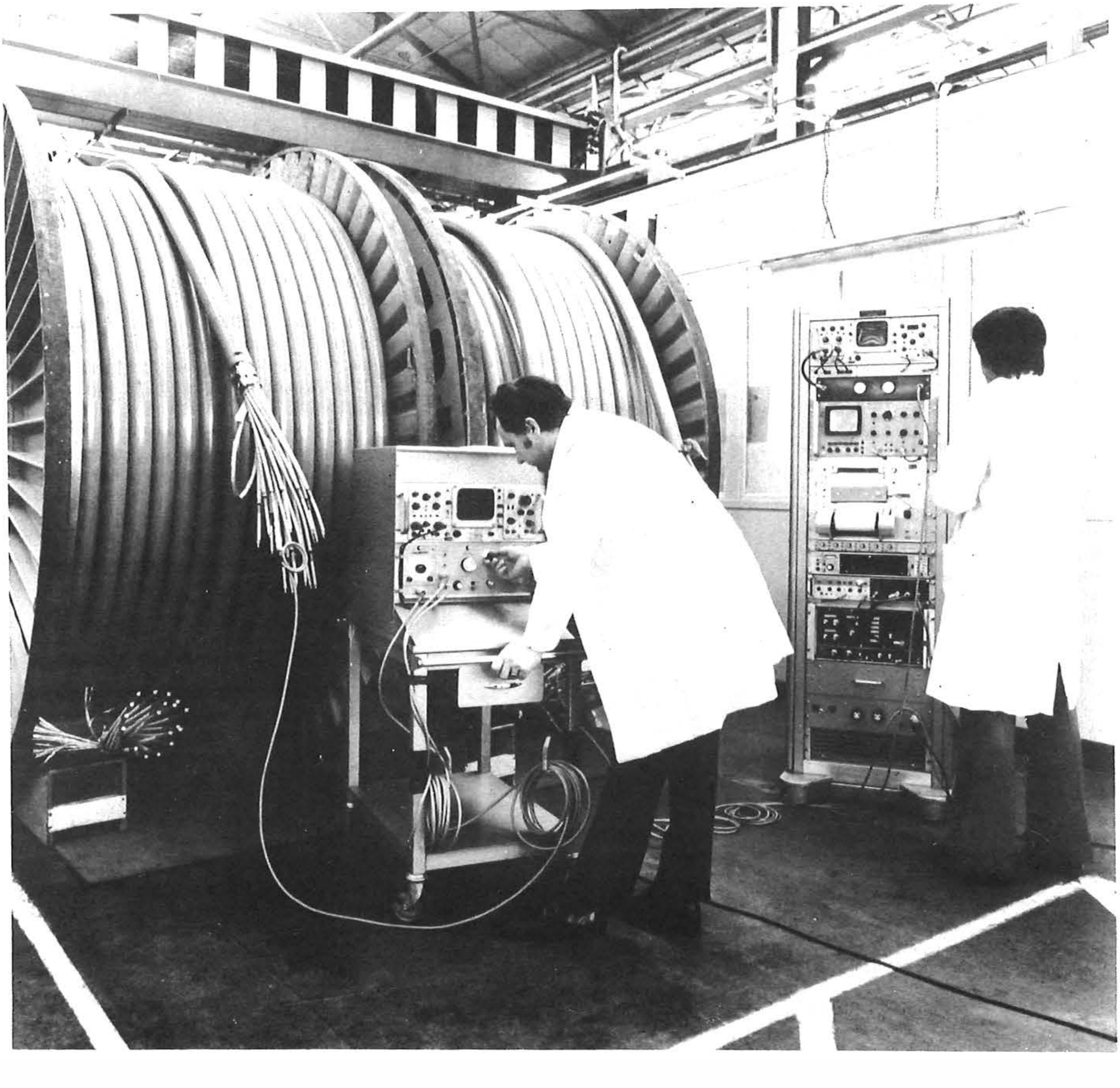

The Post Office Electrical Engineers' Journal

EDITORIAL

The *Journal* has published a Supplement containing model answers to City and Guilds of London Institute (CGLI) Examinations in telecommunications subjects since July 1931. All information received from readers of the *Journal* indicates that this is a valuable service which is very popular with the student readership. The main reason for this popularity is almost certainly that actual questions set in the previous year's examinations are answered, in many cases by the Chief Examiner in the subject who is responsible for setting the question paper and controlling the marking of answers.

In the near future, the responsibility for all adult technician education will pass to the Technician Education Council (TEC); this body will then control examinations in telecommunications subjects, replacing those for National Certificates and those of the CGLI. The courses in telecommunications subjects will probably be based on standard units agreed by the TEC to enable employers like the British Post Office to judge the performance of its students on a national basis. However, the examinations will almost certainly be set locally by colleges, and not nationally as with the present CGLI examinations.

The Board of Editors is very concerned that the Supplement should retain its degree of usefulness to the student readership. Urgent consideration has, therefore, been given to the possible alternatives that could be published in the Supplement when the TEC examinations have replaced those of the CGLI. The Managing Editor will be very pleased to receive readers' opinions and ideas on this subject. Of particular interest are opinions on whether the Supplement should

(*a*) be converted into a textbook format, covering the syllabi of selected subjects in instalments,

(*b*) retain its question-and-answer format, with a mixture of descriptive and numerical types, or

(*c*) concentrate solely on numerical answers, thereby permitting more answers to be published which should enable the national situation to be better represented.

Aluminium Alloy as a Conductor for Local-Network Cables

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UDC 621.315.2: 621.315.5: 669.715

Aluminium alloys have been adopted in place of copper for selected cables of the local network. The progressive development that led to this change is described and the economic justification is discussed.

INTRODUCTION

Copper has been used as a conductor for telecommunications cables for very many years, but for various reasons its market price has been erratic. During the last decade or so, the fluctuation in price has been very marked and has sometimes reached an alarmingly high level. In contrast, the price of aluminium has remained relatively stable, as shown in Fig. 1. It is not surprising, therefore, that a change from copper to aluminium has often been suggested on economic grounds. With the possibility of change in mind, lengths of aluminium cable have been installed in the British Post Office (BPO) network at various times over the last 20 years, to gain field experience of their performance.

During the mid-1960s, the difference in price between aluminium and copper was sufficiently large, and the prospect of a continuance of the situation sufficiently strong, to justify a change to aluminium. The detailed considerations that led to this change and the development of appropriate jointing techniques have been described in an earlier issue of the *Journal*[1]. However, field experience with aluminium in the local distribution network was not entirely satisfactory, and aluminium alloys have now been adopted in place of the pure metal. This article describes the development of these alloys and the further studies that have led to the extension of their use to the cables of the local main network. The possibilities of the even wider use of aluminium alloy as a cable conductor are outlined.

COPPER

Copper was one of the first metals to be used by man. Nowadays, it is imported into this country in refined form as wire bars produced by an electrolytic process. For conversion to wire, these bars are first passed through a rolling mill where they are heated and reduced in stages to rod about 5 mm in diameter. This rod is then pickled to remove the surface oxide, washed to remove any contaminant and then dried ready for drawing down to the size of wire required. In the drawing mill, the rod is reduced in size—again in stages—by being pulled through a succession of dies, each smaller in diameter than the one before. Because the drawing-down process hardens the metal, it is necessary to anneal the wire at various stages during the process. For balanced-pair cables, such as those used for the local and junction networks, the copper wire is fully annealed before use.

Unfortunately, copper occurs as a workable ore (commonly chalcopyrite) in very few places in the world and, from time to time, the output of copper mines and refineries is affected by factors quite outside the control of the consumer. This explains the sometimes unpredictable price of copper wire bars. The demand for refined copper for telecommunications cables is not very great in comparison with the demands for other purposes, and so the price is not significantly influenced by the extent of its use in the BPO.

The early experimenters in electricity used copper as a conductor, and Cooke and Wheatstone adopted it in 1837 for their underground telegraph line laid from Euston to Camden Town[2]. Copper has many merits; not least is the facility with which it can be drawn into the form of a wire. Such a wire is

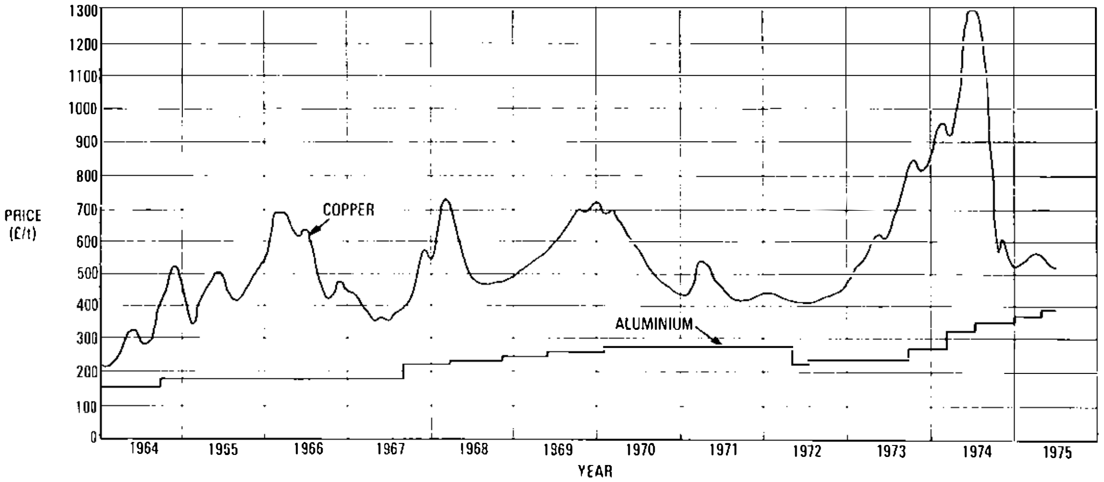

FIG. 1—Price comparison between copper and aluminium for BPO cables

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† Operational Programming Department, Telecommunications Headquarters.

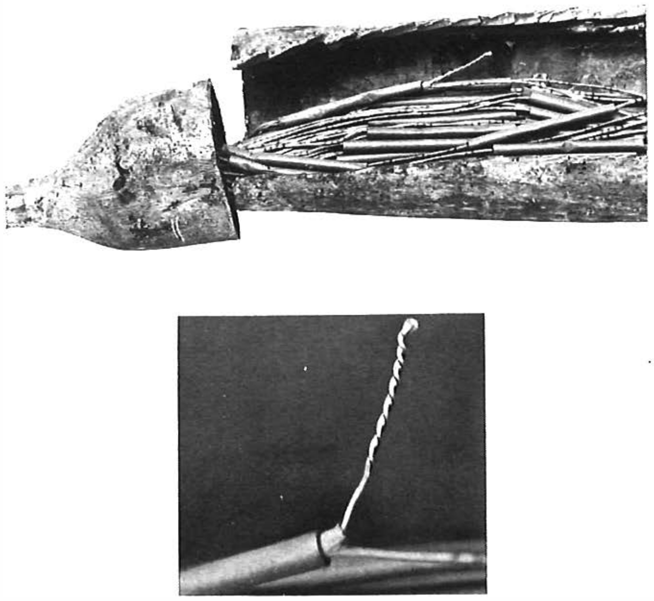

FIG. 2—Joint from experimental cable at Bordon

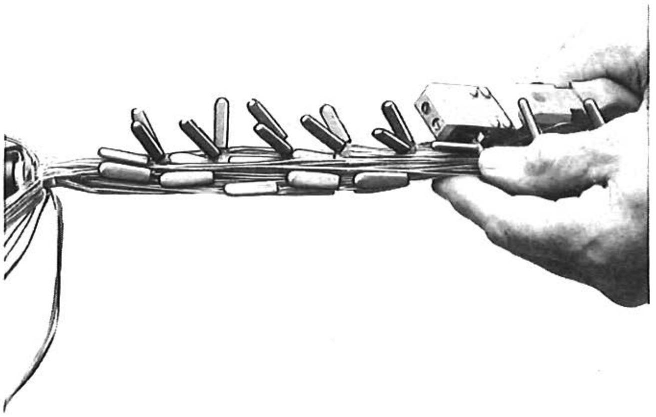

FIG. 3—Typical wire joint made with the CWI No. 1

comparatively strong, it can be stretched or bent without breaking, it is a good conductor of electricity, and it can be jointed easily with a crank-handle twist, by crimping, or by soft soldering. Copper has been accepted for very many years as the right and proper metal for use in telecommunications cables, and it is only the economic factor which has led engineers to seek a substitute.

ALUMINIUM

Aluminium, a comparatively new metal, was discovered by Sir Humphrey Davy in 1807, but commercial production started only in 1887. It is extracted from the ore bauxite, which is found in quantity in many parts of the world. The bauxite is first treated by the Bayer method to produce alumina (a white powder), and then reduced to metal by the Hall-Héroult electrolytic process. The resulting aluminium billets are then shaved to remove surface contamination, and converted to wire by drawing-down in stages. As with copper, it is necessary to anneal the wire at various points in the drawing-down process. For many years, it has been appreciated that aluminium would be a possible substitute for copper for telecommunications purposes. It has the advantage of lightness, but its resistivity is somewhat greater than that of copper. Jointing of aluminium conductors presents problems not experienced with copper, because the metal rapidly acquires a thin film of oxide even when exposed to normal atmospheres. This oxide film is not only a good insulator, but is also hard and adheres firmly to the surface of the wire. Any method of jointing, therefore, must be capable of removing or breaking through this oxide film and preventing it from forming again at the contact faces.

In 1900, the BPO, disturbed by the high price of copper, turned briefly to aluminium as a substitute in open-wire construction. Ten years later, Captain Scott took aluminium wire to Antarctica for use with field telephones, but his object was primarily to save weight. He used bare wires laid on the surface of the snow, and in 1959, some 50 years later, a partly-used drum of this wire that had been lying in the open was found and returned to the UK[3] for examination. Despite its long exposure to the elements, it was found to have half its original tensile strength remaining. Analysis showed it to contain about 0·5% iron and 0·3% silicon—not unlike some modern alloys of aluminium.

In 1954, an experimental junction cable[4] was laid between Dover and Deal (a distance of about 15 km), using aluminium as the conductor, lapped paper as the insulation and polyethylene as the sheath. A wrapping of aluminium foil was interposed between the core and the sheath to provide electrical screening. The conductors were of 1·1 mm diameter, three-quarter-hard aluminium wire, arranged in star-quad formation to give a total of 54 pairs. The performance of this cable has been closely watched ever since and no trouble has been reported. Various shorter lengths of cable with aluminium conductors, some with paper insulation and some with polyethylene insulation, have since been manufactured and installed in the network at different times, and all have given satisfactory service.

Fig. 2 shows a joint taken from an experimental cable laid in 1954 at Bordon, Hampshire, and recovered in good order in 1972 following a rearrangement. The conductors were jointed by the crank-handle twisting method and the tips welded electrically. Although this technique used simple equipment, it was tedious and not sufficiently reliable for general use. The conductors adjacent to the weld areas could sometimes become embrittled by the weld heat and, even with a small movement, the welded tip could be broken off.

EXPERIENCE WITH ALUMINIUM IN THE LOCAL DISTRIBUTION NETWORK

Early Designs of Cable

An economic study in 1965 had shown that significant savings in capital outlay would result from the adoption of aluminium in place of copper for the conductors of cables in the local distribution network. It was realized at the outset that a change from copper to aluminium would have to be made in progressive stages, each planned to allow manufacture of the new cables to proceed with due economy, having regard to the rate of demand and the availability of aluminium wire.

During 1967, the first production cables appeared. They used 0·8 mm and 0·6 mm diameter aluminium conductors. The former were designed to be equivalent in loop resistance to 0·63 mm copper, while the latter were equivalent to copper somewhere between 0·5 mm and 0·4 mm in diameter. Design on a resistance basis implied an increase of overall diameter of the cables, but this was judged to be of little importance in the distribution network. The Connector, Wire, Insulated (CWI) and its associated crimping pliers, which had originally been developed for use with copper conductors, was adopted for jointing the new cables. Two versions of the CWI were required to cover the range of conductor sizes (No. 1 and No. 2) and it was necessary to provide a shim adjustment for the crimping pliers to suit the appropriate connector. Fig. 3 shows a typical joint made with the CWI No. 1 and the crimping pliers.

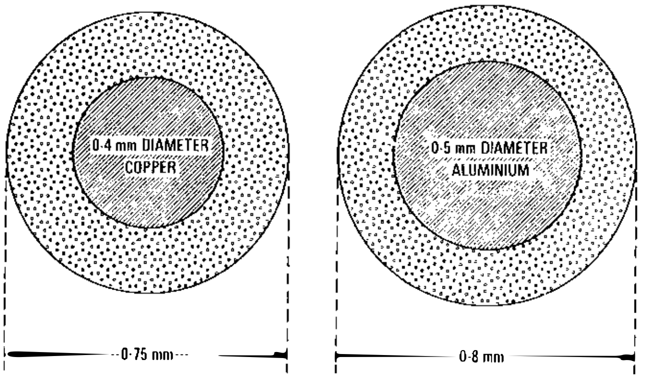

FIG. 4—Comparison of overall diameters of cellular-polyethylene insulated wires for fully-filled local-distribution cables

Optimum Designs of Cable

With the subsequent adoption of the optimum design concept[5], and the introduction of a new method of local-line transmission planning[6], a cable with 0·5 mm aluminium conductors was introduced. Later on, the 0·8 mm and 0·6 mm designs were abandoned, and so it became unnecessary to continue with the complication of 2 sizes of connector and the adjustable crimping pliers. The CWI No. 2 then became redundant and there was no longer any need for the shim adjustment to the pliers.

The new local-line planning method allowed a maximum attenuation of 10 dB at a frequency of 1600 Hz and a maximum loop resistance of 1000 Ω. However, the design of the existing 0·4 mm copper-conductor cable was such that the allowable length was limited by its resistance rather than by its attenuation, and it therefore had a transmission capability that could not be fully exploited. Advantage was taken of this in the design of the 0·5 mm aluminium-conductor cables; for these, an increased attenuation was allowed so that the transmission limit almost coincided with the loop-resistance limit. A reduction was, thus, made possible in the thickness of the insulation, with the result that the change from 0·4 mm copper conductors to 0·5 mm aluminium conductors did not involve any significant increase in the overall diameter of the cable.

The 0·5 mm aluminium cables, manufactured to the optimum design, had cellular-polyethylene insulation and were fully-filled with petroleum jelly.[7] Fig. 4 compares the insulation thickness for the 2 conductors and shows that the aluminium cable used slightly less cellular polyethylene than did the copper one. For production cables, the loop capacitance of the aluminium cable was typically 61 nF/km as compared with 47 nF/km for the copper cable.

Some characteristics of these cables are listed in Table 1, which includes figures for the 0·4 mm copper-conductor cables for comparison.

TABLE 1

Cable Characteristics

Type of Cable	Loop Resistance (Ω/km)	Attenuation at 1600 Hz (dB/km)	Limiting Length for Resistance (km)	Limiting Length for Attenuation (km)
0·5 mm Aluminium	287	2·7	3·5	3·7
0·4 mm Copper	274	2·2	3·6	4·5

Choice of Wire

Adoption of fully-annealed aluminium wire was considered, but its tensile strength was found to be insufficient to withstand the rigours of the insulating process in the factory. In the event, three-quarter-hard aluminium was chosen as it had been used successfully on earlier experimental cables. It was appreciated that the cold-flow characteristics of aluminium would preclude its use for screwed connexions and that its use in distribution cabinets might cause handling problems. The planning rules thus confined the new aluminium cables to intermediate lengths.

Field Experience

Field experience with the new three-quarter-hard aluminium cables in the local distribution network was not as satisfactory as had been hoped. Although the tensile strength of the wires was adequate, their handling characteristics were markedly inferior to copper, and breakages occurred when the wires were bent sharply at joints. Furthermore, although the planning rules confined the new cables to intermediate lengths, attempts were made to terminate them at distribution cabinets and breakages were reported.

As a result of these troubles, three-quarter-hard aluminium failed to gain ready acceptance by the field force, and it was apparent that a wire whose mechanical characteristics were more akin to those of copper would have to be produced. Attention was thus directed towards the use of aluminium alloys, some of which, although slightly more expensive than the pure metal, were known to have mechanical characteristics more closely approaching those of copper.

Before embarking upon the development of aluminium alloys, it was clearly necessary to review the desirable characteristics of a cable conductor to identify the particular feature, or features, of three-quarter-hard aluminium that had caused it to fall short of expectations. The commencement of this development coincided with the establishment of new laboratories for the External Plant Development Division at Carlton House, Wembley. These provided proper facilities for all kinds of tests on wire and cables to reproduce, as far as possible, all the conditions that might be expected in a field environment.

REVIEW OF THE DESIRABLE CHARACTERISTICS OF A CABLE CONDUCTOR

Manufacture

For cable manufacture, the essential features of a conductor are ductility and tensile strength, so that the wire can be passed off the storage reel, through the insulating device, and laid up in the form of a cable without breakage. Tensile strength is particularly important if high-speed processing is to be successful.

Installation

The length of cable that can be drawn into a given duct without damage is determined partly by the strength of the conductors taken as a whole and partly by the extent to which each conductor will stretch without fracture. When a cable is pulled through a bend in a duct under tension, there is a tendency for unequal sharing of the load between the conductors and the consequent possibility of failure in succession as each small group takes on the whole load. It is important, therefore, that a cable conductor should be capable of stretching without fracture and it is desirable, but not essential, that this should take place within the elastic limit of the material.

Jointing

For satisfactory field performance, it is desirable that a joint should have as low a resistance as possible and that the

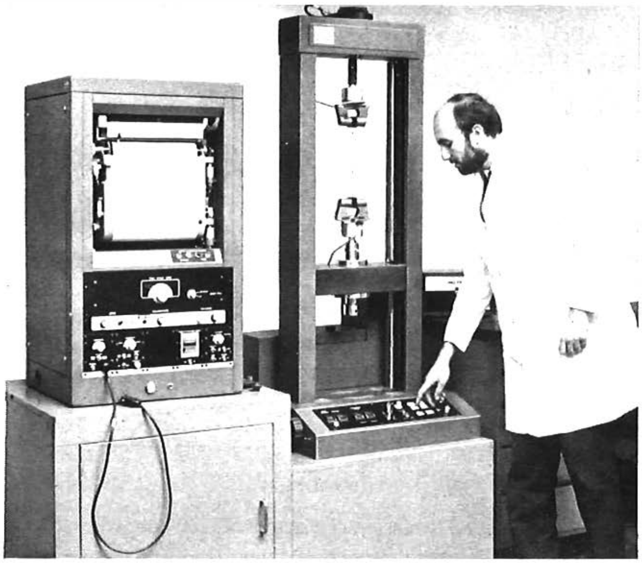

FIG. 5—Tensile testing machine

resistance should remain stable for the whole of the life of the joint. The effectiveness of a jointing method depends partly upon the device proposed (for example, CWI No. 1) and partly upon the wire itself, and it follows that jointing aspects must be given due consideration whenever a change of conductor is contemplated. In practice, this means that, unless a new wire is suitable for use with existing jointing methods, the merits of the new wire must justify the development and introduction of a new jointing method.

Whatever the jointing technique adopted, the essential mechanical requirement of a conductor for jointing purposes is its handleability—an all-embracing term which is difficult to define in practice. It includes, however, the various processes of folding back bunches of conductors for selection of pairs and bending conductors during jointing.

Terminating

Although it was not the original intention to use three-quarter-hard aluminium for terminating in flexibility cabinets, it was obviously desirable that this possibility should be considered in the development of aluminium alloys. The requirements are basically similar to those for jointing, with the added need to have a conductor that can be passed through the holes in a fanning strip without breakage.

Conductivity

Good conductivity is desirable because the overall diameter of the cable can be minimized, thus leading to a saving on sheathing material and economies in the use of duct. It was hoped that the conductivity of an aluminium alloy would not be significantly less than that of three-quarter-hard aluminium and thus a target of 61% IACS* was set. It was accepted, however, that conductivity would not be the main criterion in the choice of an alloy and that the mechanical features would take precedence.

Durability

With the passage of time, it is desirable that deterioration should not occur at all, but, in practice, it is possible that slight changes could be accepted. This feature emphasizes the need for some kind of ageing test on any new conductor.

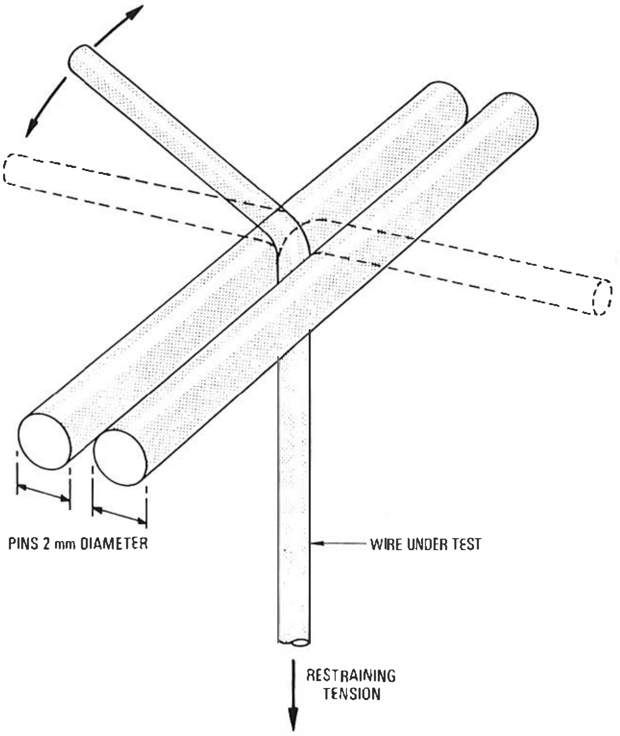

FIG. 6—180° reverse bending test for bare wires

DEVELOPMENT OF ALUMINIUM ALLOYS

When the BPO decided to investigate the potential of aluminium alloys, the whole matter was discussed with the cable manufacturers, because a decision to adopt alloys might well necessitate plant modifications. The characteristics of an aluminium-alloy wire, whatever its composition, are critically dependent upon the various stages of drawing-down and annealing; therefore, the effectiveness of the resultant product is influenced more by the manufacturing process than by the make-up of the alloy itself. Consequently, a performance specification rather than an alloy specification was needed; this would allow each of the cable manufacturers to produce an alloy (or alloys) best suited to the manufacturing facilities available. Progressive development could then proceed independently.

Cable Specification

A preliminary study showed that the essential requirement was to develop an aluminium alloy having a much greater elongation than three-quarter-hard aluminium, but with a tensile strength that was not significantly less. The original specification for a cable containing 0·5 mm diameter aluminium-alloy conductors required the following tests to be performed on a sampling basis in the factory during production. Bare wires, taken from manufactured cables, were to be used for the tests, after preparing each sample by softening the insulation in a suitable solvent so that it could be removed without damage to the wire itself.

(*a*) *Tensile Tests.* The ultimate tensile force was specified to be at least 22 N, as measured over a gauge length of 250 mm with the rate of separation of the grips not exceeding 100 mm/min. The elongation was to be not less than 5%. A suitable testing machine is shown in Fig. 5.

(*b*) *Bending Tests.* A test piece was specified to be subjected to repeated bending under the conditions shown in Fig. 6. A minimum of 9 reverse bends over the full 180° was required before failure. In addition, a test piece was to be wrapped around a mandrel of its own diameter for 8 turns, and then the last 6 turns were to be repeatedly unwrapped and wrapped on again. A minimum of 3 unwrap/wrap cycles before failure

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* IACS—international annealed copper standard

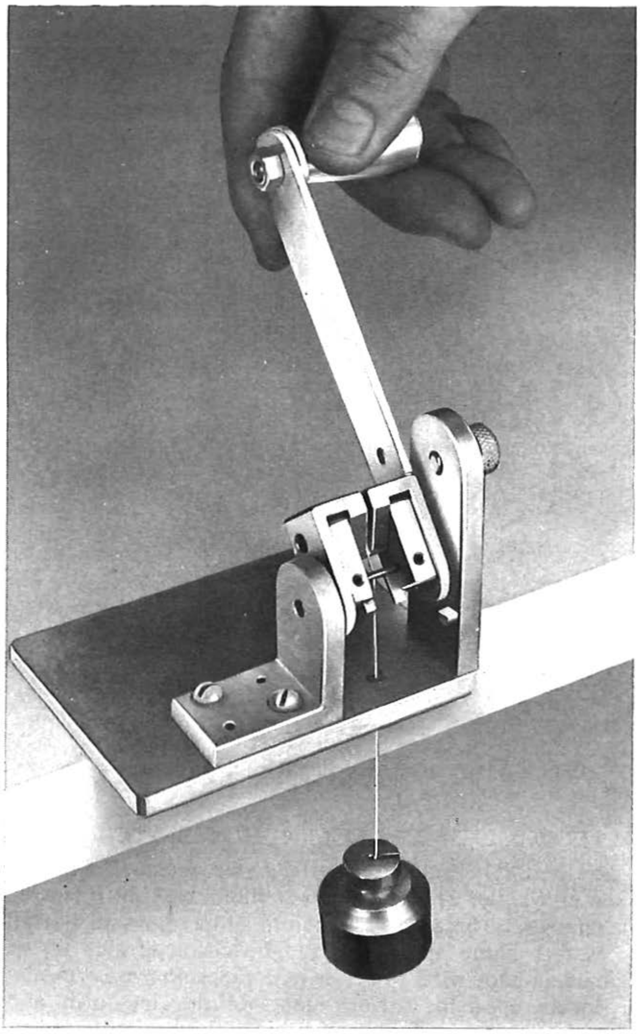


FIG. 7—Bending-test machine

was required. Fig. 7 shows a suitable machine that has been developed for these tests.

Type Approval

Before manufacture in quantity commences, a length of cable from pilot production is required for type approval by the BPO. This approval process entails rigorous checks on handleability in the External Plant Development Division laboratories at Carlton House and a close examination of the materials aspects by the Quality Assurance Division of the Purchasing and Supply Department.

Test Results

Many aluminium alloys were tested in various ways and compared with both the three-quarter-hard aluminium they were likely to supersede and the copper that had already been displaced. The cable manufacturers offered a large selection of aluminium alloys in 2 basic families: one containing iron and the other magnesium. In most cases, there were additional traces of manganese, copper, silicon or zinc. The results are summarized below.

(*a*) *Tensile Tests.* Fig. 8 shows load/extension characteristics for bare wires taken from typical production cables. There is little to choose between the tensile load each kind of wire will withstand. This is a clear advantage for aluminium cables when being pulled into ducts. For the aluminium-alloy cables the results are derived from a sample of 250 wires taken from cables from all sources of manufacture and the target figure of 22 N has been met.

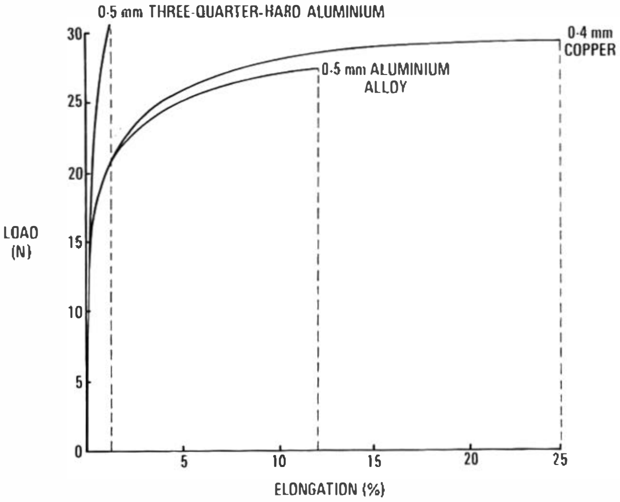


FIG. 8—Load/extension characteristics for bare wires

The low elongation of three-quarter-hard aluminium when stretched to breaking point, compared with the much higher figures for copper and aluminium alloy, is also shown in Fig. 8. For the sample of 250 aluminium-alloy wires, a mean value of 12% has been achieved. The elongation figure originally specified for aluminium alloy has been more than doubled during the course of the recent development of alloys. This property of a wire (the capability of stretching without breaking) is very important for cables, and has clearly been a significant factor in the satisfactory performance of copper cables over the years.

An interesting feature which came to light during the tensile testing programme was the marked tendency for the elongation of the three-quarter-hard aluminium to diminish progressively under repeated loading, such as might occur while being installed in a duct. The effect is also apparent in both copper and aluminium alloys, but to a much lesser extent. This feature is included as one of the type-approval tests for aluminium-alloy cables.

(*b*) *Bending Tests.* A sample of 50 wires of each kind gave very consistent results and the figures are given in Table 2. Aluminium alloys appear to give an even better performance than copper on the reverse-bend test, but there is little to choose between any of them in the wrapping test.

TABLE 2

Results of Bending Tests

Test	Type of Conductor		
	Copper	Three-Quarter-Hard Aluminium	Aluminium Alloy
180° Reverse Bends	12	7	18
Helical Wraps	8	7	7

(*c*) *Conductivity.* The target figure of 61% IACS has been achieved in most cases, but where the mechanical performance is satisfactory and the electrical specification is met, a lesser figure is being accepted.

(*d*) *Durability.* Long-term ageing tests are being carried out by the BPO Quality Assurance Division and these will continue

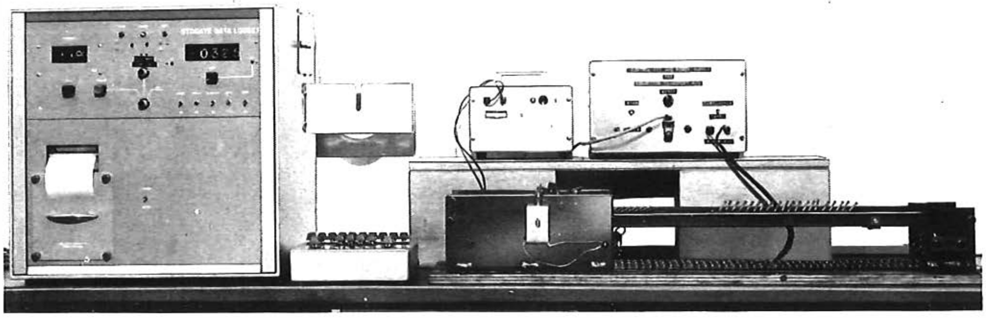


FIG. 9—Joint resistance tester

progressively as the manufacturing processes develop. So far, no sample offered has failed to meet the minimum requirements.

DEVELOPMENT OF CONDUCTOR JOINTING AND TERMINATING TECHNIQUES

Even before the consideration of aluminium as a conductor, jointing developments were moving towards the use of crimp-type connexions. Compared with the dry copper twist, they offered a higher degree of reliability, together with a lower and more stable resistance. The American *B-wire connector* was probably the first successful move towards the crimping technique, and the BPO CWI Nos. 1 and 2 were derived from this. Development of the Jointing Machine No. 4 for local main network cables[8] followed and, again, the crimping technique was adopted.

Study of the problems experienced with the CWI No. 1 on the three-quarter-hard aluminium cables of the local distribution network showed them to be largely due to the hardening effect of the pulling-in tension during installation. This was relieved partly by a small relaxation in the degree of crimping, but more particularly by the introduction of the aluminium-alloy wires.

With the prospect of extending the use of aluminium alloys to the local main network, it was apparent that the jointing-machine crimp (CWI No. 4) would need to be adapted to suit aluminium alloy as well as copper, and a new design of crimp was undertaken. This new crimp (CWI No. 6) is suitable for jointing 0·32–0·63 mm copper and 0·5 mm aluminium-alloy conductors. Although production quantities of the CWI No. 6 have been small compared with the earlier CWI No. 4, laboratory tests and limited field experience show that satisfactory performance can be achieved on the full range of combinations of conductor and insulation types at present used or planned for the local main network. At present, this involves about 80 possible combinations for the CWI No. 6 and about 60 for the CWI No. 1, although some of these will occur only occasionally in practice.

Methods of testing crimped joints follow a fairly standard pattern. The principal causes of resistance variation during the life of a crimped joint are dimensional changes with variation of temperature and build-up of corrosion products. Accelerated life tests, in general use, involve subjecting the joint to cyclic changes of temperature and humidity in excess of those normally experienced in practice. Other tests are also used to check possible design failure mechanisms; for example, vibration tests.

In the UK, underground cable temperatures vary only a few degrees around 10°C. A wider range of cable temperature may be experienced under some conditions (for example, with prolonged work in a manhole or on aerial cables), and for design purposes a temperature range of −5°C to 40°C is generally assumed.

For pressurized cables, the relative humidity should be low because the air supplied is normally controlled to a relative humidity of 1% or less. The air pressure is relied upon to prevent the ingress of moisture to the joint if a minor leak occurs in the sheath closure.

For the fully-filled cable joints, the problem of humidity is dependent mainly upon the quality of the sheath closure. The CWI No. 1A, filled with petroleum jelly, was standardized some 2 years ago. For a small increase in cost, this gives a high degree of protection under high-humidity conditions, although if immersed in water (for example, due to a leaking sheath closure) the protection is limited, and failure will occur, on average, after about 6 months.

Accelerated Life Tests

Full life testing of crimp joints involves considerable time and effort, and is usually undertaken only as part of the design of a new form of connector. For normal production tests, it is generally sufficient to establish that the performance of the connectors does not depart from the expected pattern.

The crimp-jointed conductors are subjected to a temperature of 50°C at 75% relative humidity for 2 h followed by 2 h at a temperature of −5°C, and the cycle repeated. The initial resistance of the joint is measured, and the resistance re-measured at intervals of 40 cycles, normally up to 200 cycles. For routine tests, batches of 300, or more, are used to check crimp/conductor combinations. The resistance measurements are compared for variation of mean value and spread about the mean. Long-term testing by the BPO Research Department shows that joints are quite acceptable if, after 200 cycles, the variations of resistance are within 10% of the mean value, with a standard deviation within 10% of the mean for a sample batch. The results also show that particular crimp/conductor combinations, with resistance variations outside these limits, are not necessarily unacceptable. For example, joints that after 200 cycles are within 25% of the mean and have a standard deviation within 25% of the mean, may be quite acceptable, provided the resistance variations have stabilized after about 150 cycles and the stability pattern is confirmed by tests of 1000 cycles or more.

Because of the wide range of conductor and insulation combinations, this testing has been partially automated. Resistance measurements are carried out automatically by feeding boards carrying 20 joints on to the simple stepping conveyor shown in Fig. 9. At each step, contact is made to the wire on each side of a joint with 2 pairs of knife-edge blades. A constant-current source of 100 mA is connected to the outer blades. The voltage rise across these blades is limited to a maximum of 100 mV to reduce, as far as practical, the risk of breaking down incipient disconnexions developing within the connector. The inner pair of blades is connected to a digital millivoltmeter to measure the potential difference across the joint and give a punched-tape output. The tape for each batch of joints is then processed by computer.

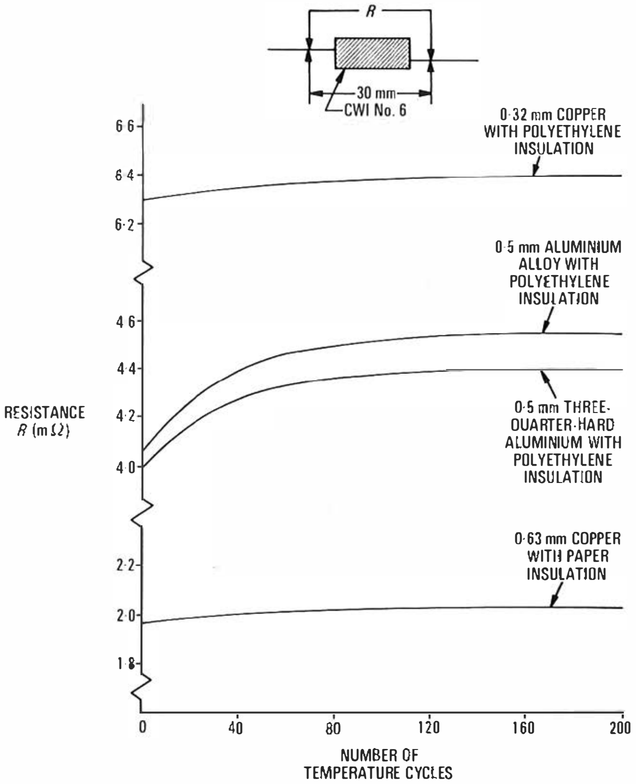


FIG. 10—Variation of joint resistance with temperature cycling: CWI No. 6 with copper and aluminium conductors

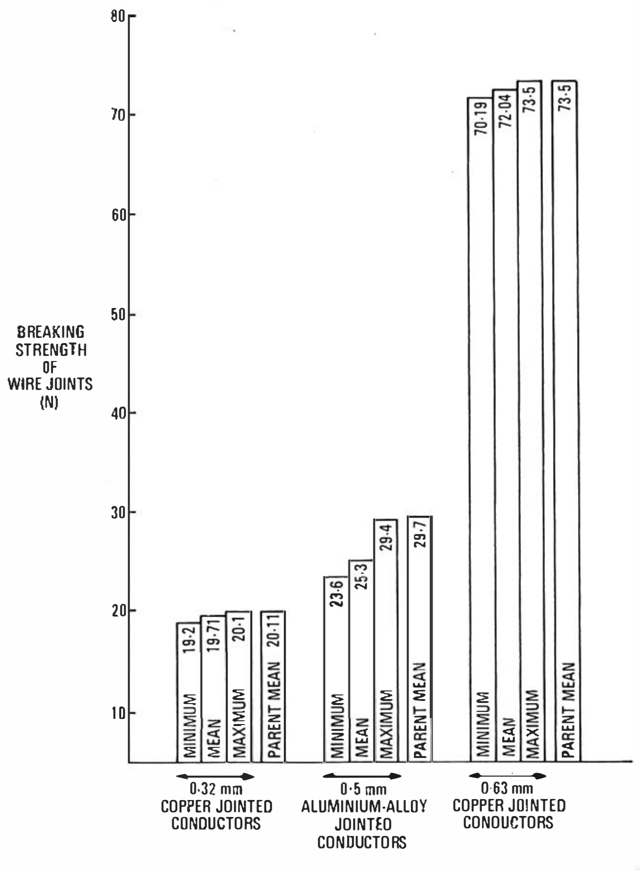


FIG. 11—Breaking strength of joints using the CWI No. 6

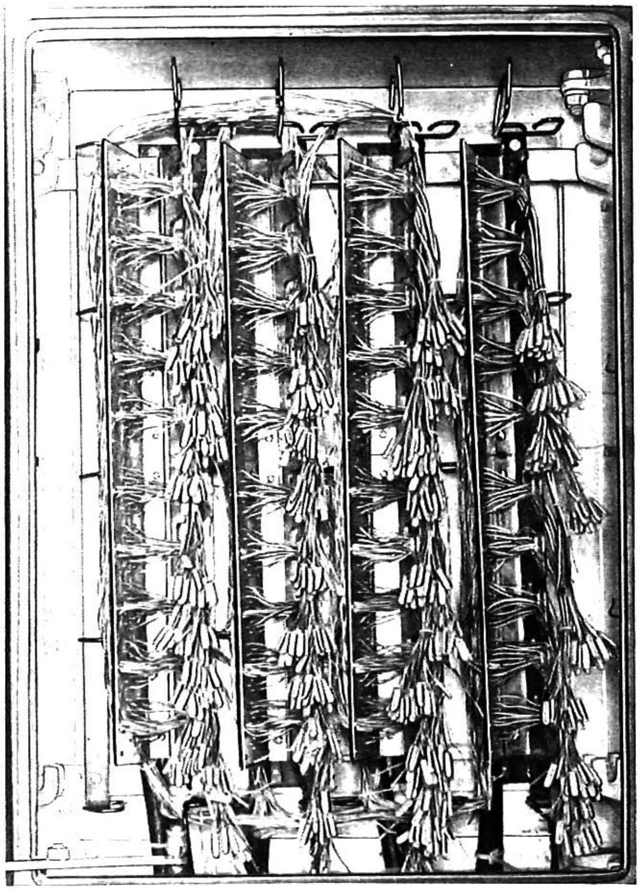


FIG. 12—Termination of aluminium-alloy cables at a flexibility cabinet

Typical variations of resistance for such cyclic testing of aluminium-alloy and copper conductors with the CWI No. 6 are shown in Fig. 10. The resistance rise for aluminium alloy is rather greater than for copper, but stable values are achieved within 200 cycles and are maintained with extended cycling. The results of these tests, the experience of connector performance with copper, and the present limited results with aluminium-alloy connector joints, aged naturally, give a good expectation of satisfactory field performance during the life of the cable.

Mechanical Testing

The simplest test of the handleability for jointing, and the easiest for comparisons, is a tensile test of jointed conductors. For this purpose, the minimum breaking load has been set at about 80% of that of the parent wire. Fig. 11 shows typical results of batch testing in this way. Nevertheless, with the background experience of three-quarter-hard aluminium, all normal jointing operations are carried out on samples of aluminium-alloy cable, both in the laboratory and in the field, in an attempt to identify potential problems. Such checks, backed by the wire tests described earlier, support a subjective judgement that handleability of aluminium alloy for jointing approaches that of copper.

Terminating of aluminium or aluminium-alloy cables presents problems, not least that of compatibility with existing designs of termination. At the flexibility cabinet, the problem is avoided mainly because the cross-connexion strip requires the use of the CWI No. 1A, as shown in Fig. 12. Similarly, at the main distribution frame (MDF) termination and the terminal blocks used for distribution points, the problem can be avoided by using copper tails jointed to aluminium with CWI Nos. 1A or 6, as appropriate, but this approach can only be regarded as an expedient.

Before the present need to consider the extended use of aluminium in external cables, the design of a tag-wrapping system for copper external cables was well advanced. It was tempting, therefore, to experiment with aluminium-alloy terminations of the same type. This approach was further encouraged by the growing need to double the number of pairs terminated on each vertical with the consequent problems of packing density on the terminal block. Work on aluminium tag wraps is continuing, but it is too early yet, in spite of initial success, to say whether entirely satisfactory results can be achieved, and alternatives are also under consideration. Meanwhile, the use of a copper tail cable remains the acceptable method.

THE LOCAL DISTRIBUTION NETWORK

Transition to Aluminium Alloy

During 1973, the conductor material for the 0·5 mm cables then in production for the local distribution network was changed from three-quarter-hard aluminium to aluminium alloy. Aluminium-alloy cables have a green marker tape immediately beneath the sheath to distinguish them from the aluminium cables, but there is no external marking. They are identical in design and construction with the cables they displace. Initial reaction to these aluminium-alloy cables is favourable. This may merely emphasize the marked contrast between three-quarter-hard aluminium and aluminium alloy, but, if true generally, it indicates success.

In 1974, cables with 0·7 mm diameter conductors in aluminium alloy were introduced to replace the 0·5 mm copper cables. These are similar in construction to the 0·5 mm aluminium-alloy cables and they can be jointed with the same connector.

Jointing Methods

Fig. 3 shows the traditional layout of a cable joint in the local distribution network using the CWI No. 1. The closure is effected by sliding over a polyethylene sleeve with moulded core ends, and sealing the whole by wrapping with a self-amalgamating polyisobutylene tape with an overlay of protective adhesive PVC tape. Joints of this kind are water-tight when properly made, but care and cleanliness are necessary if field problems are to be avoided. The basic problem is to prevent access of water to the conductor joints. Various attempts have been made to improve the integrity of the joint. Resin filling at first showed promise, but access for fault location was impractical and, after initial success, evidence accumulated to show that water was being drawn into the joint by capillary action along the wires. This resulted from the leaching of the oily fractions from the jelly on the wires into the resin, thus leaving a capillary path between the remaining wax crystals covering the wires. Trials using petroleum-jelly filling in place of the resin have recently been completed successfully in the North East Telecommunications Region. This goes a long way to overcoming the problems and allows retrospective action on existing unfilled joints; this practice is to be introduced. Meanwhile, other investigations have shown a need for an access-type joint for these small cables, both to replace in-line joints on 10–100-pair cables, and for underground radial distribution points for up to eight 2-pair leads into houses. This has led to the development and introduction of the Sleeve, Polyethylene No. 31A[9], and with it, as a result of work study, a jig-jointing method as shown in Fig. 13. The use of the Sleeve, Polyethylene No. 31A should considerably reduce the major fault hazard resulting from the need to gain access for fault-location or minor rearrangement purposes, and thus reduce the inherent problems of using aluminium in this part of the network. Trials are also in hand to simplify, and thus improve, the reliability of the frontage tee joint, abandoning the need to tape seal the joint by use of heat-shrinkable polyolefine materials.

FIG. 13—Jointing jig in use with the Sleeve, Polyethylene No. 31A

The particular problems of exploiting aluminium-conductor cable in the distribution network are inevitably bound up with the more general difficulties experienced in this part of the network, but these recent and current developments in sheath-closure techniques are expected to lead to a general improvement in reliability of plant, no matter which type of conductor is used.

Termination at Cabinets and Distribution Points

The problems of terminating aluminium-alloy cables at cabinets and distribution terminal blocks have already been discussed. Until a new design of terminal block is generally available, it will be necessary to continue using short copper wire tails. At the cabinet, the conversion from three-quarter-hard aluminium to aluminium alloy has overcome the earlier problem of wire breakage at the holes in the connecting strip, and the residual jelly on the wires tends to seal any pinholes in the insulation, giving negligible risk of wire corrosion if the humidity in the cabinet rises.

THE LOCAL MAIN NETWORK

When extension of the use of aluminium to the local main network was proposed some years ago, 2 quite different approaches were possible: either to build on the experience in the local distribution network and adopt the fully-filled technique, or to retain the existing pressurization system and use unfilled cables. The former approach seemed attractive because it would obviate the corrosion problem which was then thought to be a particular hazard with aluminium, but it was realized that fully-filling would be more costly both in cable price and duct occupancy. On the other hand, the latter approach was cheaper in initial cost and allowed a choice of paper or plastics for insulation, but was reliant on a properly effective pressurization system.

Trials with Fully-Filled Cables

When the relative merits of these 2 approaches were first assessed, the avoidance of corrosion was judged to be the dominant factor and so some experimental fully-filled cables, of various sizes up to 1600 pairs, were manufactured for trial in the local main network. At that time, aluminium alloys had not been developed and three-quarter-hard aluminium conductors, 0·5 mm in diameter, were used. These cables were assessed in the laboratory and some were later installed in the local main network for field trial. A small plastics tube was included within the core of each cable so that it could be incorporated in an existing route without jeopardizing the pressurization system. This tube also allowed intermediate joints to be protected by air pressure. It was realized that eventual acceptance of a completely-filled network would imply the filling of the joints themselves as well as the cable, and that the plastics tube could then be omitted.

In the event, these cables, although successful technically, were found to be unacceptable from the practical point of view. The jelly, of the usual pharmaceutical quality, was in itself quite harmless, but the amount needed for such large cables led to difficulties in handling wires prior to jointing and the jointing machines required frequent cleaning to keep them properly operational. It became apparent that further development work would be necessary before a large fully-filled cable, acceptable for the needs of the local main network, could be produced.

Designs for Pressurized Cables

While the experimental work on fully-filled cables was progressing, a comprehensive cost comparison was being made to assess the relative merits of fully-filling and pressurization in the local main network. This showed (not entirely unexpectedly) that, given an established pressurization network, it would be preferable to retain it, and improve it if necessary, rather than to abandon it in favour of fully-filled cables. Fears were expressed because of the corrosion problem, but consideration of the conditions likely to be met in practice and review of the satisfactory service given by the Dover–Deal, Bordon, and other cables suggested that these fears were hardly justified. Designs for dry-core cables with 0·5 mm diameter conductors were thus prepared, and sample lengths were manufactured and assessed. These sample lengths used the newly-developed aluminium alloys, rather than three-quarter-hard aluminium.

The cables were designed to have the same electrical characteristics as the fully-filled ones then in production for the local distribution network, and to supersede the existing unit-twin cables with 0·4 mm copper conductors in the local main network. Some of the sample lengths manufactured for assessment used cellular polyethylene as the conductor insulation, while others used paper, either lapped helically over the wire or applied longitudinally in the form of a sealed paper tube[10].

As with the local-distribution cables, the new designs required a slightly thinner covering of cellular-polyethylene insulation over each conductor and the overall diameter of the finished cable is only marginally greater than that of the equivalent copper cable. For the paper-insulated cables, there are manufacturing limitations on the application of a very thin covering of insulation over the wires. For this reason, and because paper is somewhat inferior to polyethylene as a dielectric, paper-insulated cables are slightly larger in overall diameter than their cellular-polyethylene equivalents. This implies the use of slightly more sheathing material and this could well be an important factor in the long run. Where duct occupancy is important, the smaller cable is obviously to be preferred. The new aluminium-alloy cables are about two-thirds the weight of their copper equivalents and, thus, the problem of drum handling is eased. Furthermore, the prospect of using long-length cabling techniques is enhanced and the need for lubrication is reduced.

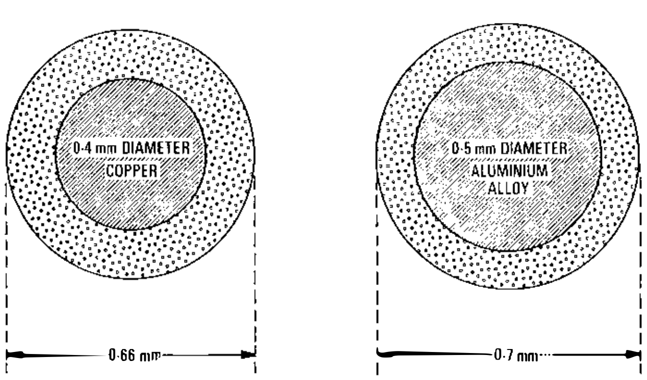


FIG. 14—Comparison of overall diameters of cellular-polyethylene insulated wires for unfilled local-main cables

Fig. 14 shows the very thin covering (0·1 mm radial thickness) that has been achieved by progressive development of the extrusion process for cellular polyethylene. The amount of material used is slightly less for the 0·5 mm aluminium alloy than for the 0·4 mm copper. It is doubtful whether any further reduction in radial thickness would be feasible from the manufacturing point of view, or desirable in service, because the resulting product would probably not be sufficiently robust for termination in flexibility cabinets.

Aluminium-alloy cables with 0·5 mm diameter conductors and cellular-polyethylene insulation for the local main network are now in production, and the first installation was made in the South Eastern Telecommunications Region (SETR) late in 1974. At present, the new cables are being used for intermediate lengths only. The rate of introduction depends upon the availability of aluminium-alloy wire and the provision of the necessary jointing equipment. Close liaison with the cable manufacturers is essential, because they have the task of changing their manufacturing techniques to suit the requirements of the new material. The first aluminium-alloy cables used batch-annealed wire, but long-term economies and a more closely-controlled product will result from the adoption of in-line annealing plant in the factories. Some plants of this kind are already in commission and others are being installed. As with the fully-filled aluminium-alloy cables for the local distribution network, a green marker tape is laid immediately beneath the polyethylene sheath.

The paper-insulated versions were both shown to be satisfactory, but because of the subsequent policy decision to adopt cellular polyethylene for the insulation of all local main network cables, further consideration of the paper-insulated types has been abandoned. Nevertheless, the paper-insulated cables with 0·5 mm aluminium-alloy conductors made for assessment will be incorporated into the network to provide long-term information on their service performance.

Jointing Methods

The introduction of aluminium-alloy conductors into the cables used in the local main network is dependent upon the use of the Jointing Machine No. 4 and the CWI No. 6. This is the only method of jointing available that will cover the full range of cable types that it may be necessary to joint to the new cables.

For various reasons, however, the jointing machine is not yet available in all areas. Nevertheless, the CWI No. 1A can be used to joint some gauges (mainly 0·4–0·63 mm) of polyethylene-insulated conductors found in this part of the network. The use of crimping pliers and the CWI No. 1A for these larger cables (over 100 pairs) can be tedious and tiring.

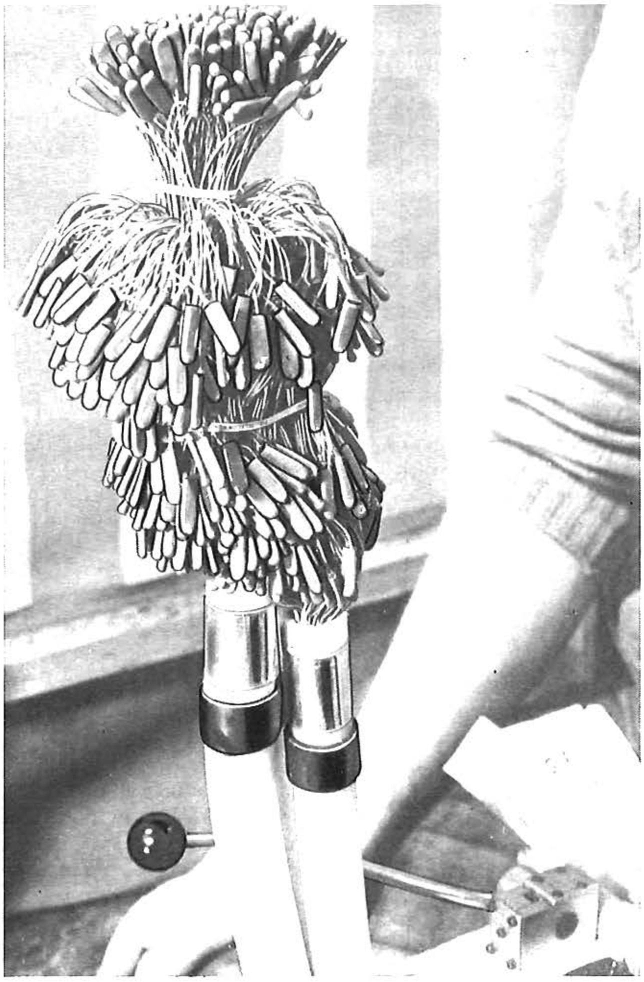


Fig. 15—Main distribution cable joint with CWI No. 1A, prepared for closure with a cap or single-ended sleeve

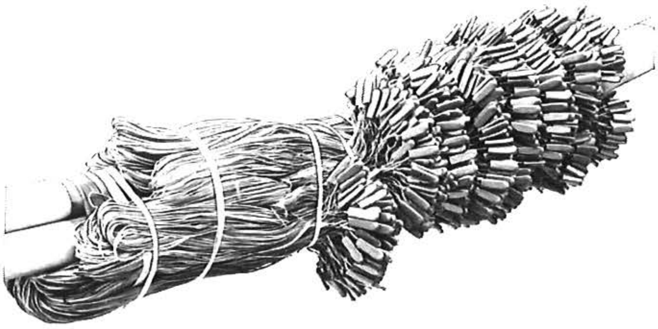


Fig. 16—Main distribution cable joint with CWI No. 1A; expedient arrangement to allow normal in-line closure

The jointing jig used for distribution cables offers advantages in this respect, but the normal in-line jointing layout cannot be easily used. For smaller diameters of cable, the cap-ended sleeve arrangement, shown in Fig. 15, can be adopted at the expense of a non-standard cable layout. An adaptation of this approach for larger cables, or where the cap-ended sleeve arrangement is not practical, is shown in Fig. 16. Both of these methods give sufficient slack to allow the wires to be brought to the crimper on the jig for jointing with the CWI No. 1A. This slack-wire arrangement, dictated by the use of the jig, requires that the cable butts be strapped together to give the completed cable joint the necessary tensile strength. Both styles of joint tend to be more bulky than is usual, mainly because of the CWI No. 1A. The cap-ended sleeve version is restricted to cables of up to about 400 pairs because of cable stiffness and bending-radius considerations. The second or in-line arrangement can be used for cable sizes up to 1000 pairs, but 800 pairs is perhaps the largest convenient size. Nevertheless, this range covers the majority of the commonly-used cable sizes. The most important restriction is that such joints cannot be used with lapped-paper insulated conductors due to the high risk of contacts between wires. It is possible, however, to use conductors with longitudinal-paper insulation.

Termination at Cabinets and MDFs

The aluminium-alloy conductors used in the new local-main cables are identical with those in the local-distribution cables and, mechanically, they are acceptable for termination on connecting strips in cabinets. The only difference is the absence of petroleum jelly. It is not thought that this will lead to corrosion problems at pinholes in the wire insulation; nevertheless, the problem is being examined and, initially at least, it is convenient in the SETR trials for the alloy cables to be restricted to intermediate lengths. The problems of terminating the alloy cables at the MDF are under consideration.

CORROSION

Corrosion of a cable conductor requires the presence of water containing traces of salts in solution, and all water affecting underground plant can be assumed to be contaminated in this way. The mechanisms by which corrosion can occur are

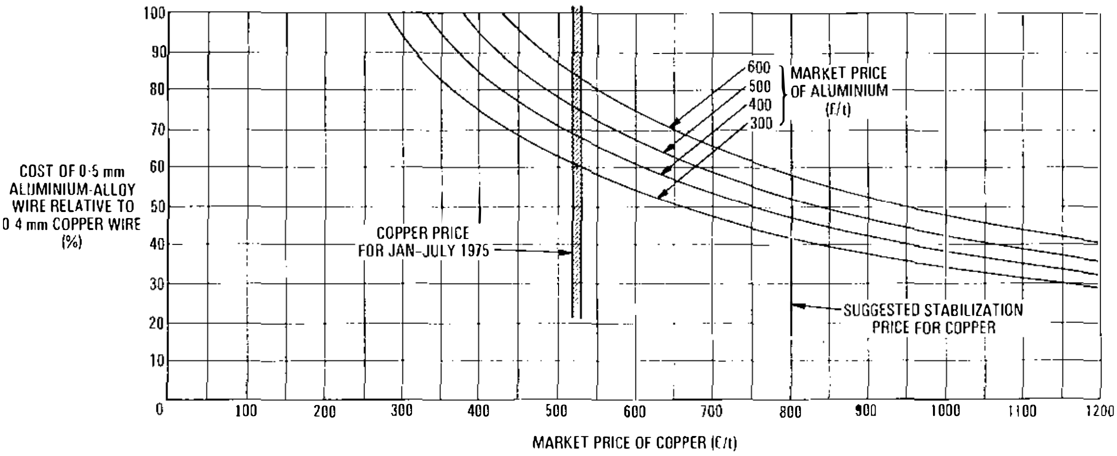
(*a*) electrolysis, as in a working cable where a direct potential is applied,
(*b*) local action, where dissimilar metals are in contact, and
(*c*) chemical action, where a cable becomes wet during installation or repair.

For a working cable, all the A-wires and the aluminium moisture barrier are normally at earth potential, whereas all the B-wires are at a negative potential relative to earth. Corrosion will thus tend to occur at the A-wires or the moisture barrier, rather than at the B-wires, but this will happen only in the presence of moisture assuming there are pinholes in the polyethylene insulation. The most likely path is between the moisture barrier and a pinhole in the B-wire. In these circumstances, corrosion is rapid and a wire (whether aluminium alloy or copper) will be severed within hours rather than years. It is unlikely that the moisture barrier would be badly damaged because its area is comparatively large.

For a paper-insulated cable the situation is slightly different, because there can be no pinholes as such and moisture would affect the whole length of the wire. Rising humidity in the cable core would make the cable unserviceable because of low insulation well before it reached the point where corrosion started.

For the fully-filled cables of the local distribution network, the conductors are protected by the extruded polyethylene which forms the insulation, and the petroleum-jelly filling which prevents the passage of water along the core in the event of sheath damage in a wet situation. Additionally, the jelly blocks any pinholes in the insulation which might have appeared during the extrusion process. Exposure of the conductor at joints is avoided by the use of a grease-filled connector (CWI No. 1A).

For an unfilled cable in the local main network, the pressurization and desiccation system provides the necessary protection from corrosion by excluding moisture from the core. However, in contrast to the fully-filled cables, water could enter in the event of severe damage in a wet situation. The conductors would then be liable to corrosion damage at joints made with the CWI No. 6 and at pinholes in the polyethylene extrusion. Additionally, joints between alu-



Assumed cost of producing 0·4 mm wire from copper wire bar is £100/t, and cost of producing 0·5 mm aluminium-alloy wire from aluminium ingot is £500/t

FIG. 17—Cost comparison between 0·4 mm copper wire and 0·5 mm aluminium-alloy wire

minium alloy and copper are particularly vulnerable to corrosion by local action.

If a cable becomes wet because of external damage or some mishap during installation or repair, the drying-out process must be done thoroughly as residual moisture could well cause later damage. Aluminium-alloy cables are less tolerant of residual moisture than copper ones. For any cable, good working practices and maintenance procedures are important and, if due care is given to the pressurization and desiccation system, aluminium-alloy cables in the local main network should not be any more prone to corrosion troubles than copper cables.

ECONOMIC CONSIDERATIONS

One tonne of metal as purchased yields twice the length of 0·5 mm aluminium-alloy wire as it does 0·4 mm copper wire, and Fig. 17 shows a cost comparison between the two. The figures are based on the known cost of converting copper wire bars into 0·4 mm diameter wire by a long-established process, and the estimated cost of converting aluminium ingots into 0·5 mm aluminium-alloy wire by processes only recently developed. It has already been shown that slightly less insulating material is required for a 0·5 mm aluminium-alloy cable than for a 0·4 mm copper one and, since the overall diameters are about equal, there is no great difference in the amount of sheathing material required. It is evident, therefore, that the cost of the wire itself is the dominating factor and that the price relationship between copper and aluminium would have to change radically before any question of reversion to copper could arise.

There have been gloomy predictions about failure of the world copper supply by the end of the century, but these are unfounded[11]. It has to be accepted, however, that as the rich ores become more scarce, so the poorer ones will have to be exploited instead, and their lesser yield will increase the cost of copper production. The extraction of copper from its ore involves the mining and crushing of very large quantities of material, and it is evident that the amount processed for every tonne of copper produced depends upon the grade of ore available. The grade varies widely, but a deposit containing 0·4–0·8% copper is perhaps typical. Studies have shown that the cost of copper production could well be doubled by reducing the grade of the ore used from 1% to 0·4%, and doubled yet again by reducing it to 0·2%. In contrast, only 4 t of bauxite is needed for a yield of 1 t of aluminium and this proportion is unlikely to change. Despite the occasional discovery of a new and rich source of copper ore, the supply is undoubtedly more restricted than that of bauxite, and thus the relative cost of copper and aluminium will tend to change in favour of the latter.

The electrical energy needed for the reduction process in the production of aluminium is, however, greater than that required for refining copper[12], and thus a significant increase in the cost of electricity would favour copper. A new method of reducing aluminium to the pure metal has recently been developed and it is claimed to use considerably less electrical energy than the present Hall-Héroult process[13]. However, because of the high cost of investment in new plant for production, it is unlikely that this development will have a significant impact on the price of aluminium for some years.

During the first half of 1975, the market price of copper has remained steady at about £540/t, although it was said in 1974 that the eventual economic figure would be in the region of £800/t. This may merely emphasize the hazards of forecasting, but the earlier and sometimes violent fluctuations in the price of copper and the factors causing them seem to indicate that freedom from sudden and sometimes inexplicable changes is most unlikely. In contrast, the price of aluminium has remained steady at just under £400/t.

The fact remains that significant savings on capital expenditure have already been made even allowing for the cost of developing new manufacturing techniques and new installation practices, and from the evidence at present available, these savings seem likely to continue for the foreseeable future.

FURTHER DEVELOPMENT OF ALLOYS

The present development has resulted in the production of aluminium alloys which have an elongation considerably greater than that obtainable with three-quarter-hard aluminium and yet fall short of that given by copper. This has led to the suggestion that aluminium alloys should be developed even further, but this is a moot point. Such development would be expensive and hard to justify as being essential. The original object was to produce aluminium alloys with a fully acceptable field performance on the original premise that copper was entirely satisfactory, but three-quarter-hard aluminium was not. The limited field experience to date suggests that the original object has indeed been achieved, but more cables need to be installed and their performance assessed before a definite decision can be made on the question of further development of aluminium alloys.

FURTHER EXTENSION OF THE USE OF ALUMINIUM-ALLOYS FOR CABLES

The possibility of extending the use of aluminium alloys to the cables of the junction network is being investigated. Cable designs have been prepared and sample lengths are being manufactured for assessment.

It is doubtful whether the adoption of aluminium alloy in place of copper for the coaxial cables of the main trunk network could ever be justified because the amount of metal contained is very small in relation to the circuit capacity. However, it might be economic to use aluminium alloy instead of copper for the supervisory pairs where no increase in overall cable diameter would be involved.

CONCLUSIONS

BPO experience in the use of aluminium and its alloys as a substitute for copper in the local-distribution cables has been reviewed. The introduction of three-quarter-hard aluminium led to savings on initial cost, but as time progressed, it became increasingly apparent that its performance in the field was not entirely satisfactory. A subsequent change to aluminium alloy has found favour and there is now every reason to suppose that an acceptable substitute for copper has been found. Clear savings have been made on capital investment in cables despite the need to allow for the development of new manufacturing techniques and installation practices.

An economic study has shown that extension of aluminium alloy into the cables of the local main network will lead to considerable savings, and appropriate cables have been designed and manufactured. Installation commenced about a year ago. The possibility of extending the use of aluminium alloy to the junction network is under consideration.

ACKNOWLEDGMENTS

The assistance of the authors' colleagues in the preparation of this article and of the British cable manufacturers in the development of production techniques for aluminium-alloy cables is gratefully acknowledged.

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Book Review

Introduction to Diffusion in Semiconductors. B. Tuck, B.SC., PH.D., M.INST.P. Peter Peregrinus Ltd. 236 pp. 82 ill. £8·20.

Diffusion may well be the most important process used in the design and fabrication of semiconductor devices. In any case, it must rank high on the list, concerned as it is with the basic structure of all the devices. In 1961, some 13 years after the discovery of the transistor, Boltaks produced his definitive study, *Diffusion in Semiconductors* (Infosearch, 1963), and the present volume is a timely production, following another decade of technological development.

The differences in treatment provided by the 2 books reflect the changes in the status of the subject. Ten years ago, the emphasis was on research and the provision of detailed experimental results. Now, in parallel with research, there is a need for the device-development engineer to understand and apply the basic principles of diffusion technology to a much wider range of device types than was ever envisaged in the early 1960s. The book by Dr. Tuck will assist in meeting this requirement.

The presentation of the subject matter is based on the research effort of the last 2 decades, and references to the literature are used extensively in the textual examples. Diffusion phenomena lie close to the interface between physics and chemistry, and are now of interest to the electrical engineer. An inter-disciplinary approach is, consequently, essential. The author has recognized the different technical languages used in these 3 fields, and has achieved a successful reconciliation in a very readable style of English.

A macroscopic approach is used in the early chapters of the book, which bring together the mathematical solution of the diffusion equations for all the important cases arising in the technology, the relevant aspects of the chemistry of solid solutions, and the particular consequences of point-defects in crystal structures. The complementary atomic approach is used in addition, when discussing the theory of the diffusion coefficient and the various diffusion mechanisms in both elemental and compound semiconductors: substitutional, interstitial and the combined mode. A useful chapter is also included on diffusion techniques and the evaluation of the resultant diffusion profiles, although, in the latter case, the use of the scanning electron microscope for p n junction depth measurements could, perhaps, have been mentioned.

The overall result of the author's efforts is a very useful handbook, which will be of value to all those engaged in studying or using diffusion techniques in semiconductor-device fabrication.

M. F. H.

The Experimental Changes of Practice Committees: ECOPC 1

C. E. CLINCH, A. H. WILLITT, and T. E. MARKWELL†

UDC 65.01: 654.07

The British Post Office has for many years recognized the importance of co-operative efforts of staff and management in the field of telecommunications engineering, and this has been reflected in the work of the Experimental Changes of Practice Committees for nearly 50 years. This article sets out the aims and objectives of these Committees, and gives examples of changes sponsored by Committee 1. A Separate article will be published concerning the work of Committees 2 and 3.

HISTORY

An inaugural meeting of the Experimental Changes of Practice Committee (ECOPC) was held on 27 March 1928, consisting of official and staff representatives under the chairmanship of Colonel Sir Thomas F. Purves, the then Engineer-in-Chief. The ECOPC was among the earliest, possibly even the first, productivity committee in British industry. From the beginning, it was concerned with improved organization, efficiency and safety, and its agenda reflected that range. The work of the ECOPC was extended in the early 1960s, to provide joint consultation from the earliest stages on all engineering field trials and on organization and methods studies. Following this, the ECOPC was replaced in July 1965 by the 3 closely-related Committees listed below, each under the chairmanship of an Assistant Engineer-in-Chief:

(*a*) ECOPC 1, Safety Measures and External Construction (New Practices),

(*b*) ECOPC 2, External Construction (Organization and Productivity), and

(*c*) ECOPC 3, Maintenance and Internal Construction (Services and Productivity).

The change of British Post Office (BPO) status in October 1969 did not affect the work of the ECOPCs, which continued without a break after BPO Whitleyism's official demise and its later replacement by the Council of Post Office Unions and the new joint consultative machinery. It was tacitly accepted by higher management and the engineering unions alike that the importance of the work brooked no gap in its continuity.

Each ECOPC is now chaired by a Deputy Director, the 3 ECOPCs being linked to the Telecommunications Business Joint Council's Planning and Services Committee, under the chairmanship of a Senior Director.

OBJECTIVES

The main objectives of the ECOPC 1 are to ensure safe, efficient and economic working practices. If procedures are not economic in their use of the BPO's total resources (both men and materials), then the availability of work is limited. The Business, and therefore the work force, can survive only if its services can be sold.

However, the safety of staff and public are vital and often cannot be priced. What is the cost of life? The key feature of the ECOPC 1 is that of its dual role of safety and productivity. All new changes of practice have safety built-in at the field-trial stage and at all later stages. Each ECOPC 1 approved change is not concluded until it has been promulgated in Telecommunications Instructions (TIs). The cumulative effect of the ECOPC 1's vast range of new practices, being studied or introduced at any one time, probably accounts for about one third of the total engineering productivity. The total productivity resulting from this Committee over its lifetime, while not measurable, has been immense.

STUDIES OF ACCIDENTS

Much of the ECOPC 1 efforts start from the study of accidents. The aim is to learn from each accident how to reduce the risk for others. Individual accident cases are studied in detail and bulk statistics of accidents are perused. Effort is concentrated each quarter onto a particular category or categories of accidents; for example, falls of persons and handling of objects. The object is not to apportion blame, but to find clues to changes that can be made to tools, mechanical aids, equipment, practices or working instructions, such as TIs and Safety Handbooks, to reduce the likelihood of any repetition (Fig. 1). This is particularly so in the event of a fatality or serious accident when a very thorough investigation is initiated, although, from the point of view of safety, a fatal accident differs from any other serious accident only because of the sense of shock it generates.

Accident investigations have also revealed patterns of recurring accidents, particularly in the motor-transport field and in general external work, and over the years, the advent of the special problems discussed has resulted in the formation of sub-groups under the ECOPC 1. The nature and importance of these subjects is such that the sub-groups, described below, also continue to function and report regularly to the parent Committee. Each sub-group has been derived from special detailed studies, carried out by members of the ECOPC 1. Manpower considerations necessarily limit the number of such studies simultaneously in being.

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† Mr. Clinch, Mr. Willitt and Mr. Markwell are respectively Chairman, Vice-Chairman and Secretary of the Experimental Changes of Practice Committee 1.

Safety at Radio Stations Sub-Group

An example of the wide-ranging effect of the study of one fatal accident followed a fatality at Portishead Radio Station in September 1960, when a man was killed while engaged on mast-stay maintenance. Civil engineering consultants were called in to investigate all external practices for carrying out maintenance and construction work on masts and towers at all BPO radio stations and television link stations. They were also asked to advise upon the modifications necessary to bring these practices into line with the requirements of the Factories Acts and up to the highest standards for civil engineering work. An ECOPC 1 Sub-Group, Safety at Radio Stations, was formed. Its work includes not only comprehensive investigations into external safety measures, but also similar matters concerning internal safety.

Concerning safety, the work of the Sub-Group resulted in the production of 2 Rule Books:

(*a*) Rg 47 Part 1, (First Aid and Care of the Eyes) and Part 2 Regulations for Safety at Radio Stations (Internal), and

(*b*) Rg 48 (External).

With respect to operational working procedures, the Sub-Group's work led to the complete revision or replacement of all external working procedures and, similarly, of many internal procedures.

The Sub-Group continues to meet quarterly and is currently investigating safety standards at microwave radio-relay and space-communication earth stations. Its work has resulted in considerably improved safety standards at radio stations and has stimulated further action for improved safety standards in other spheres of BPO activity.

Motor Transport Accidents Panel

In 1957, an ECOPC 1 Motor Transport Accidents Panel was convened primarily to consider accidents on duty (other than traffic accidents) involving motor-transport and road-haulage staff in both the Postal and Telecommunications Businesses. Among other achievements, the panel has been responsible for a pocket reference for motor-transport staff entitled "The Safe Way to Vehicle Maintenance" and the institution of the "Jimmy McKain Memorial Trophy", awarded annually to the region with the lowest accident rate in motor-transport workshops.

Sub-Group on Climbing Techniques

In 1966, concern was expressed at an ECOPC 1 meeting about the number of serious accidents caused by falls from steps, ladders and poles, and that, despite all the precautions contained in the instructions, men were at risk when climbing or descending and when changing their position aloft. In consequence, the Sub-Group on Climbing Techniques was formed and it continues to meet at quarterly intervals. There are no immediate answers to the causes of many of the accidents involving climbing, and the discussions have necessarily been exploratory. These have, however, resulted in a number of investigations which in turn have led to improvements in the design of the equipment and working methods listed below:

(*a*) safety belts,
(*b*) ladders (new design and usage),
(*c*) protective clothing (seeking a suitable all-weather suit),
(*d*) recovery of poles, stays and wire,
(*e*) carrying of tools while climbing,
(*f*) methods of climbing ladders and steps inside buildings,
(*g*) tree cutting,
(*h*) climbing hazards in inclement weather,
(*i*) pole stepping, and
(*j*) rationalization of ladder sizes.

FIG. 1—Use of Lifters, Manhole-Cover No. 4 saves back injuries

FIG. 2—Pole testing: inspection around the soil line

One investigation in particular has resulted in a standard method of climbing being taught to all new entrants in the BPO Training Schools. A film "Climb Safely", which depicts a technique and drill for a man climbing a ladder, set against a pole in a working position, is now being used as the standard instruction film. The approach of the ECOPC 1 and the Sub-Group has been to accept nothing at face value, however time honoured, but to seek to look with new eyes and an open mind at each facet of every type of work carried out above ground level. As in all parts of the work of the ECOPC 1, the job is not finished until the changes have been promulgated in TIs, considered for Rg 41 and for *Engineering Safety*, and where appropriate, notified to regional training schools.

SAFETY OF OVERHEAD AND UNDERGROUND PLANT

The ECOPC 1 continues to act as a guardian over matters of safety, particularly in relation to overhead and underground plant, and in matters affecting the environment as a whole; for example, the testing of poles, gas explosions and gas-poisoning cases in manholes, and contamination of underground plant.

Poles

From the outset, the ECOPC 1 has been concerned with the condition of the 4-million or so wooden poles (and a comparatively small number of steel poles) in use and in stock throughout the country. The Committee has also been concerned with the mammoth task involved in trying to ensure that, by a regular cycle of testing, decayed and therefore potentially dangerous poles are removed or renewed before they present a hazard to men employed on overhead work (Fig. 2). The staff and official representatives, together, are particularly concerned with this matter, which has remained on the agenda since the inception of the ECOPC. Accident prevention is never fully successful. Constant vigilance, repetitive advice, training, sound supervision, and managerial interest and support all play a part in reducing accidents.

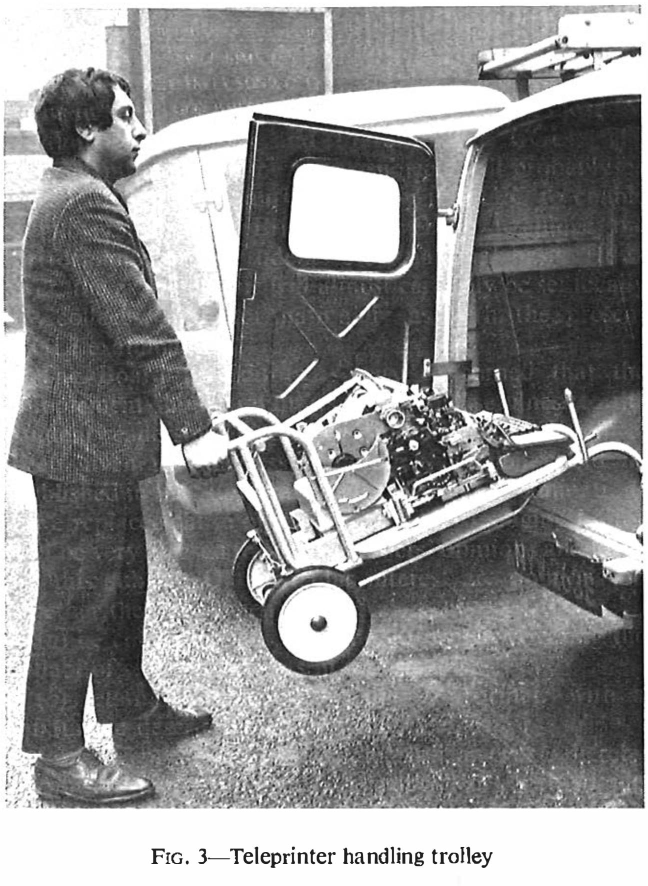

FIG. 3—Teleprinter handling trolley

Gas

A constant watch has been kept for many years (and continues to be maintained) on the incidence of gas explosions and gas-poisoning cases, whether or not BPO personnel have been involved. With the advent of North Sea gas (a dry gas unlike town gas and distributed under higher pressures), it became evident that the number of such accidents was increasing and, therefore, that BPO staff employed on underground duties were at greater risk. Following an ECOPC 1 meeting in August 1970, more stringent safety measures were instituted, and gas testing stations established throughout the country for the purpose of regular inspection of all gas testing equipment. A film entitled "Just a Few Minutes" has been produced by the BPO Film Unit to highlight the consequences—in this instance, an explosion in a manhole and severe burns to a jointer—of failure to test for gas before entering a manhole; this film has been highly commended by all concerned. It is significant that the incidence of gas explosions involving BPO personnel has been reduced to a minimum since the revised testing and safety procedures were introduced.

Investigations are also continuing into the possibility of producing a system of continuous gas detection to supplement, and perhaps to replace, the use of Indicators, Gas No. 5, but the risks are too great to allow the introduction of any new methods of gas detection until these systems have been fully proved.

The foregoing account pinpoints the more important aspects of recent developments under the ECOPC 1.

EXAMPLES OF ECOPC 1 DEVELOPMENTS

The ECOPC 1, as well as monitoring the work of its sub-groups, directly initiates changes. Some of these result in new equipment; others result in changes of materials or specifications and some changes in procedures. Examples are given below.

(*a*) An example of the development of a new mechanical aid is the teleprinter handling trolley (Fig. 3) that resulted from a study of back injuries. As a follow up to this, the continuing high level of accidents from handling of teleprinters has resulted in the initiation of changes in training courses to ensure that staff trained in teleprinter maintenance are also trained in the appropriate handling techniques.

(*b*) A number of accidents, which occurred when driving in earth spikes, led to the discovery that they were made in prisons. The prison requirements affecting security influenced the methods of manufacture which, in turn increased the risk of metal splinters being sheared off when hammering. The manufacturing techniques have been changed to reduce the accident risk.

(*c*) Considerable concern is felt over the use of toxic substances. Practically all work involves handling materials that are toxic to some people. The ink used for writing has some measure of risk for some people. Nothing is completely safe. Thus, it is necessary to assess the risks and, while the BPO sets extremely high standards for all materials and their handling techniques, there still remains a job to be done by the appropriate body—the ECOPC 1.

(*d*) Safety and working procedures have been produced for the 60 MHz transmission system.

(*e*) The safety equipment developed includes helmets, belts, long-drop harnesses, lifting devices, skips, cradles, gantries, ladders, pole-erection and other vehicular aids, and gas detectors.

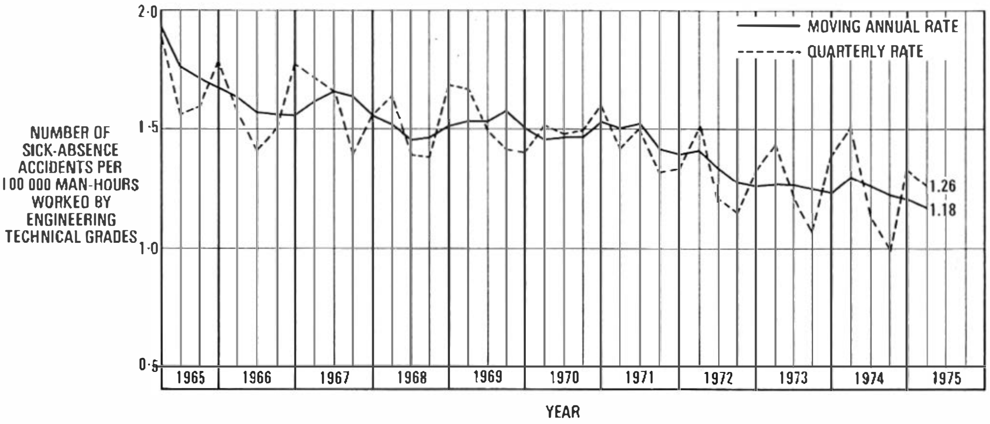

FIG. 4—Reduction of sick-absence accidents for Engineering Technical Grades in the Telecommunications Business

RESULTS

It is gratifying that the main statistics, based on the number of sick-absence accidents per 100 000 man-hours (the assumed length of a working life) worked by Engineering Technical Grades has shown continuing steady reduction throughout the life of the ECOPC (Fig. 4). Only the continuing and constant joint vigilance of the ECOPC and the Safety Officers will ensure that this trend is maintained in telecommunications engineering—the area of BPO work most at risk, because of the nature of the work, its variety and its continuous liability to change.

FIELD TRIALS

The need for new equipment or procedures usually leads to a field trial (Fig. 5). This, in turn, leads to the introduction of working practices that will improve service and productivity, and so contribute to an efficient telephone service at an attractive price. However well equipment is tested in the laboratory or factory, and materials are chemically tested and assessed for toxic effects, no guarantee of satisfaction for field operation can be given. The purpose of field trials is to build up practical experience gradually, in a way that can be readily changed or, if necessary, stopped until satisfactory procedures are found. While most people agree that field testing is necessary, it is difficult to control this activity. The experimenter wants to carry on improving his technique, the inventor never wants to see his idea abandoned, and the user is often anxious to terminate the trial stage and get the new equipment into production. Thus, before a trial starts, its purpose must be clearly defined and a time estimate established.

The initiative for launching trials does not always come from Telecommunications Headquarters (THQ). Many trials start within telephone areas and are discussed at Experimental Practices Panels, or are initiated in telecommunications region/board offices. If, however, the idea is expected to have potential for national adoption, then the appropriate THQ division acts as sponsor both for its own trials and for those of the regions/boards and areas. Whatever the scope of the trial, whether of local or national significance, staff representatives must be involved at the outset; the national ECOPCs and area panels provide a vital forum for discussion and a means of tapping the different sources of experience and valuable expertise.

Discussions, both on safety matters and new procedures, and on technical development, do not rest with the quarterly meetings of the ECOPCs. Members sometimes travel to various parts of the country to witness at first hand the demonstrations of new procedures and practices, and the trials of new equipment. These demonstration meetings form an invaluable and important part of the work of the ECOPCs; they enable staff and official representatives jointly to view and discuss the changes of practice under active field conditions, and to discuss them with those directly involved in the field.

ECOPCs 2 and 3

The effect of a field trial of national significance can be far reaching, and it sometimes happens that a technical development accepted for national adoption by the ECOPC 1 requires changes in organization and working procedures. Such a development concerned with external practices is transferred

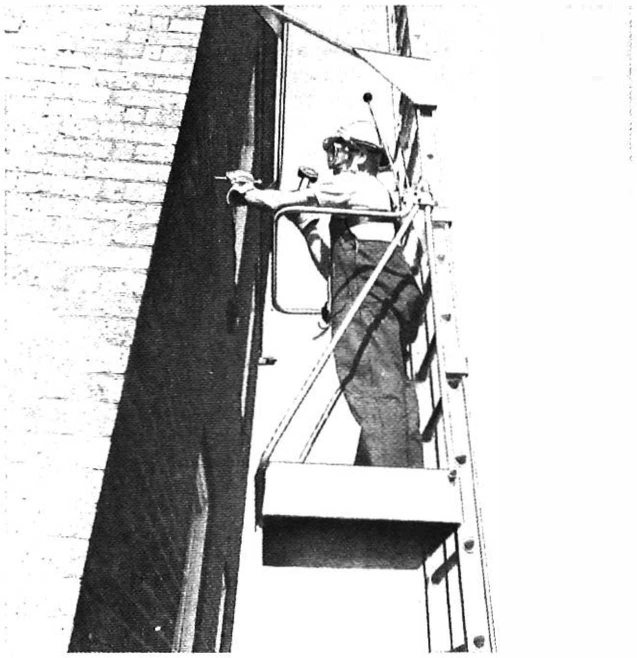

FIG. 5—The ESSVE Combined Ladder and Platform on field trial

to the ECOPC 2 for continuation of the particular trial to assess the ramifications of the new practice, and in turn the economic implications and productivity aspects. Similarly, changes of organization or procedures involving staff in the field of internal planning and construction, internal maintenance and its control, resulting from a field trial, are controlled by the ECOPC 3 and pursued to the same end. A separate article will describe the work of the ECOPCs 2 and 3 in more detail, including the effects of organization and methods studies and related field trials.

The principles of joint consultation, field testing, acceptance and implementation, are followed by all 3 ECOPCs and the particular development or new procedures are not removed from regular scrutiny by the ECOPCs until the final instructions are published and issued.

CONCLUSION

It has been truly said that the only constant thing in this life is change. Thus, the work of the ECOPCs is never completed; there are always new challenges and new ideas that need expert attention if the Business is to be run with the maximum efficiency and the minimum risk to life and limb. Fortunately, the special breed of dedicated servants of the ECOPCs, so wisely initiated in 1928 by the Engineer-in-Chief of that day, shows no present signs of dying out.

Book Reviews

Electrical Principles and Testing Methods. B. G. Woollard. McGraw-Hill Book Company (UK) Limited. viii + 331 pp. 266 ills. £3·00.

This book is outstanding, in that it covers the needs of students biased towards both the power and electronics courses at Part II level of the City and Guilds of London Institute (CGLI). It contains good chapters on the basic parts of the syllabus of Course 281 for grades T3 and T4 and, although the chapter headings are those usually associated with electrical power engineering, the contents are very similar to those relevant to telecommunications students following Course 271. Those familiar with both the Electrical Technicians' and the Telecommunications Technicians' examination results will know that students of telecommunications usually show a higher standard than those of electrical power engineering. Mr. Woollard, in this book, has met this by progressing rather more slowly, and with more detail, through the various sections of the CGLI syllabus. Thus, it is no bad thing to find more fully-worked examples in the text than is usual nowadays, and to have on offer a generous list of exercise examples at the end of each chapter. Readers of the *POEEJ* may like to know that, with patience, they will find the fully-worked answers to many of the exercise examples in the model answer Supplement to the *Journal*. The author has tabulated numerical answers to those questions where he considers it helpful.

The coverage of the book is interesting and highly practical as far as the student is concerned. Besides the conventional sections on circuits—exponential rise and fall of current, the d.c. circuit theorems, elementary single-phase and 3-phase a.c. theory with phasors and j notation—it also deals at some length with specifications and testing procedures for power installations. Also, instruments and measurement techniques, such as the use of a.c. bridges and cathode-ray oscilloscopes, are covered adequately, which is of particular interest because amongst these are some new items to be emphasized in the revised CGLI Telecommunications Syllabus 271.

This book is to be recommended as of more than average use to T3 and T4 grade students.

C. F. F.

Metric Conversion Tables for Engineers and Draughtsmen. E. R. J. Field and M. F. Shearer. The Technical Press Ltd. v + 26 pp. 50p.

This booklet provides a collection of metric conversion tables which could be useful in some work. It is reasonably priced, the layout is good, and the ranges and steps chosen will probably meet all general requirements. The tables are identified by symbols, and this assists the user to find the right table quickly.

However, as with many other published tables, it is unlikely that the information given will meet the specialized needs of most engineers and draughtsmen.

Conversion between imperial and metric dimensions is carried out for 2 main purposes: firstly, to give some idea of the physical size of an object to someone not familiar with metrication and, secondly, to replace imperial dimensions by the appropriate metric dimensions on, for example, the drawings for the manufacture of an item. The first need is adequately covered by the booklet although, for this purpose, 3 or 4 significant figures would be sufficient instead of the 7 given. The second need is not met so satisfactorily, since, when metricating, account must be taken of available stock sizes of material, and the tolerancing must be reviewed. Precise conversion should also follow British Standard 2856: *Precise Conversion of Inch and Metric Sizes on Engineering Drawings.*

Thus, the conversion is not always a straight-forward matter of replacing imperial dimensions by metric, and some redesign work is necessary. In fact, metrication gives an opportunity to do just this.

The preface suggests that the figures in different tables can be added to meet users' requirements. This is not advisable however, because of the difference in accuracy of the tables. For example, 90 miles is converted to kilometres with an accuracy of 0·1 m, but, in the table for converting feet to metres, the conversion for 9 ft is given to 0·000001 m. Both results are to 7 significant figures, but are of a different order.

It is unfortunate that, although the conversions are given to 7 significant figures, the bases used in calculating these are inaccurate in many of the tables. The definitive imperial unit of length is the yard, and this is legally defined as being equal to 0·9144 m. Thus, the inch is exactly 0·0254 m, or 25·4 mm, and not 25·3999 mm, as used in the tables on pages 5–9. Similarly, the bases for the tables for square and cube measurements are inaccurate.

This booklet will be of limited use, therefore, to engineers and draughtsmen, but should provide a convenient, concise reference for general purposes.

D. P.

A New Concept in Submarine Cable Depots

T. M. EMERY†

UDC 621.315.28: 621.315.29

Since the inception of submarine cables in the mid-1800s, there has been an increasing need for a comprehensive submarine cable-repair service within the British Post Office. This article describes the new Central Marine Depot at Southampton which fulfils the need and was opened in November 1974.

INTRODUCTION

The first submarine telegraph cable laid between the UK and the continent of Europe connected Dover to Cap Gris Nez, and was laid off a tranversely-mounted, 4·57 m wide cable drum carried on the tug *Goliath* in 1850. From that time, submarine telegraph cables proliferated in many parts of the world. Nearer home, the Government, under the leadership of W. E. Gladstone in 1870, created the first form of Nationalization Bill, when the then Postmaster General took over the operation of a great number of privately-owned telegraph companies working within the UK, along with several which owned and operated certain cables between the UK and Europe. Mr. R. S. Cully of the Electrical and International Telegraph Company became Engineer-in-Chief of the new Department in the British Post Office (BPO), and a colleague, Mr. D. Lumsden, became the first Submarine Superintendent.

At the same time, the BPO took over 2 paddle steamers which had been adapted to carry out submarine cable repairs: the *Monarch* and the *Lady Carmichael* (later renamed *Alert*). This started the long line of BPO cable ships that have borne those names with pride, culminating in CS *Alert* IV (6500 t) and CS *Monarch* V (3500 t), the latter recently named by Lady Ryland and launched at Messrs. Robb Caledon's yard at Dundee.[1] The BPO also own and operate 2 other cable ships CS *Iris* and CS *Ariel* (1440 t) and each is now about 36 years old. It is to replace these elderly cable ships that *Monarch* V and No. 565, as the second new ship is still called, are being built at a total cost of about £8 M.[2] They will be the most modern cable-repair ships in the world and will be the first to incorporate the new pan-loading concept.

The new Engineer-in-Chief's Department also inherited a small cable depot at Dover, close to the present railway ferry terminal, and during the 1939–45 War, larger premises were obtained in the Eastern Camber of the same port. The BPO Marine Division has recently relinquished this site back to the Dover Harbour Board, and it now provides the foundation for the third roll-on/roll-off ferry terminal. The land had been leased to the BPO for a peppercorn rent.

After taking over the various cable companies, the new Engineer-in-Chief's Department purchased part of the ground of Woolwich Arsenal in 1878. On this site was constructed the depot that has served so well, in spite of ships having to lie off at dolphins in the river and requiring stores and men to be transported between the depot and the ships by small craft. This Woolwich depot is now quite untenable due to the building of the Thames barrage wall to prevent flooding.

The BPO Marine Division also has, and will retain, a third depot on the north bank of the river Clyde at Dalmuir. The cable-tank capacity of this depot is approximately 2800 m^3; equal to that available at Dover and Woolwich combined. Although the berth is very small, Dalmuir has effectively been the depot for *Alert*, which has berthed at nearby Rothsey Dock about 625 m up river.

As will be appreciated from the foregoing, the BPO Marine Division has been fragmented, with one ship being effectively based at each depot; this served the needs of submarine telegraph network maintenance admirably, but now gives rise to quite considerable inefficiencies.

THE CENTRAL MARINE DEPOT

In about 1960, it became very evident from the growth of the submarine cable network, especially to Europe, and the resultant cable fault statistics, that a central depot could represent a very great saving. It was obvious, however, that such a central depot must be situated in an area convenient to the main growth area of the submarine cable network. Fig. 1 of reference 2 shows the submarine cables around the British Isles.

Choice of Site

A number of locations were considered and possible sites surveyed, from the river Clyde on the west coast of Scotland round the east coast to the English Channel area. Some sites had very good deep-water berthing facilities, but had serious and unacceptable drawbacks in other respects; other sites, whilst not too far from the main operational areas (cable ships generally have a maximum speed of 11–15 knots), had insufficient water-side development ground available, or else would require massive civil engineering works before they could be made operational.

Eventually, a site that fulfilled all the criteria was selected; this was the Marchwood site on the south bank of the river Test. The deep and broad estuary of Southampton Water is one of the finest natural harbours in the country. With the Isle of Wight forming a natural breakwater at its entrance, it has sheltered deep-water approaches right up to the quayside, and with a tidal range of only 3·9 m, there is no need for enclosed docks with their attendant delays to shipping owing to locking operations. Furthermore, with 4 h slack water in each period of 24 h, when there is little or no tidal movement, navigation in and out of the harbour is made easier.

Even in 1966, the cost of the Marchwood site was estimated as at least £1·5M, and would require quite extensive dredging.

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† Network Planning Department, Telecommunications Headquarters.

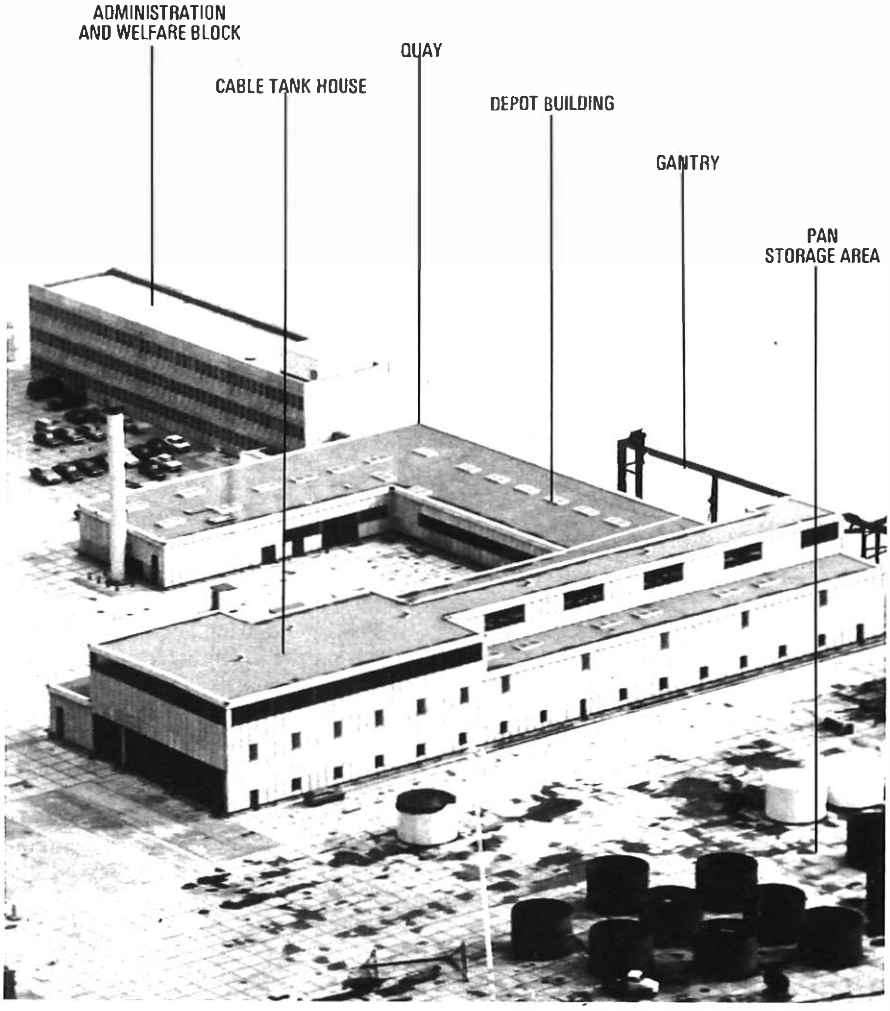

FIG. 1—The Central Marine Depot

At the same time, the British Transport Docks Board (BTDB) were planning to reclaim some 0·4 km² of the north bank of the river Test, opposite the Marchwood site. It was this latter point which led the BPO to abandon its Marchwood project, especially as the negotiations with the Southampton BTDB were proving fruitful. It was eventually decided to lease a 20 235 m² site with a 274 m waterfront from the BTDB.

DESIGN OF NEW DEPOT

With the advent of the new cable-pan concept for the new cable ships, it was quite obvious that a completely new approach to the design of the depot would have to be made (see Fig. 1). At the same time, advantage was taken of the opportunity to modernize completely the time-honoured techniques of loading and unloading cable to cable ships by using roller-equipped gantries and linear-type cable-handling machines (Fig. 2).

The first criterion was, therefore, to have a space to store the pans of cable, remembering that about 50 of these would be required to provide at least 50% of the depot storage volume, and to take account of the fact that there are approxi-

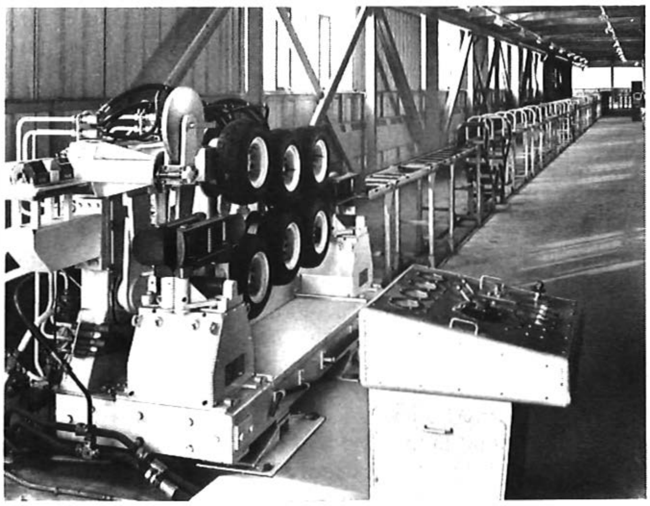

FIG. 2—Linear cable engine

FIG. 3—AeroGo tug and pan

mately 50 different types of cable to be stored. The original intention was to move these pans about the storage area by means of a travelling crane. This crane would also be used to place the pans on board the new ships, but here was a difficulty. The conventional crane was quite unable to plumb the entire pan storage area (approximately 8000 m^2) and, also, plumb the 4 points in the ships where the pans were to be placed. At the same time, the crane idea was being quickly overtaken by the economic circumstances of the time. The estimated crane costs in 1973 were £0·25M and would have required considerable resources for adequate maintenance to meet the very severe safety regulations.

The AeroGo System

It was about this time that the BPO Marine Division quite fortuitously learnt of the AeroGo system[3] of moving large loads over flat areas (see Fig. 3). Numerous demonstrations and tests were carried out by the Division with a prototype cable pan. These tests proved that, provided the area was suitably treated and kept clean, this system could be used and quite easily adapted to meet the BPO's requirements. In addition, it required only a small extension of the treated area to allow the pan to be "floated" into the end of the tankhouse for replenishment with cable from the main stock, which is contained in massive fixed tanks, each able to contain 311 m^3 of cable, generally in longer lengths than can be carried in pans. When coiling cable into pans or tanks, it is necessary to have adequate headroom between the top of the tank and the point of application of the cable (see Fig. 4). This has been proved over the years to require at least 6·1 m. Therefore, at the new depot, all cable is hauled up to the first floor by the linear cable engine and conveyed from tank to tank or pan, or to and from the ships, on the roller gantry system mentioned earlier.

Workshop Facilities

The upper floor also provides an excellent working area for maintenance cable jointing to be carried out, thus eliminating the necessity for cable ends to be manhandled out onto the tankhouse floor. It was then logical for the jointing equipment and jointing workshops group to be also placed on this upper floor, and it is here that all shipboard jointing equipment is overhauled periodically and fully tested before being reissued to the ships. This group also carries out cable-fault investigatory work, and to this end, has been provided with a jointing laboratory and a small temperature-test area.

With the greatly increased complexity of radio, navigational aids and other electronic equipment carried on board cable ships, it has been necessary, due to economic and operational circumstances, to provide a suitable repair workshop/laboratory facility on this same upper floor. The members of this group have received various training in radar, satellite navigation[4], closed-circuit television and high-powered shipboard transmitter maintenance, as well as LORAN and other navigational aids.[5]

Stores Facilities

The introduction of the pan-loading technique should result in a much faster turn-round time for the cableships, requiring that all other facilities of the Division be improved in efficiency. Not the least of these is the stores complex, where the ships can now, on demand, obtain anything from a needle to an anchor on the production of one piece of paper. Thus a considerable reduction has been effected in the amount of

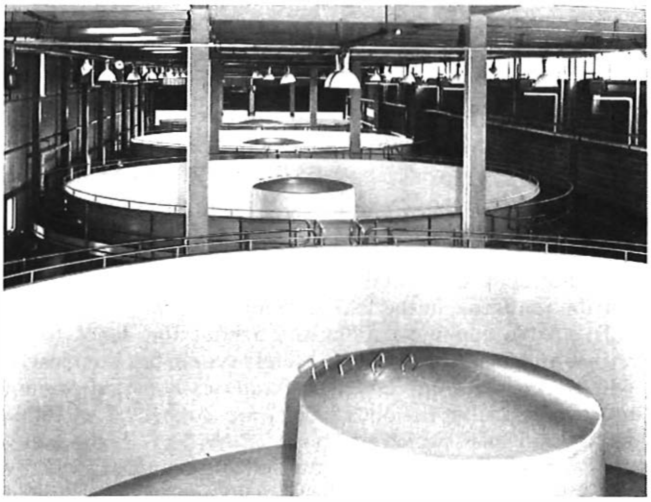

FIG. 4—Tank house

paperwork that was previously necessary on board ship, quite apart from the significantly reduced time required to return the B-copies of stores ordering forms when the ship was at sea.

Storage of spare submersible repeaters requires an amount of space which increases as the distance between repeaters decreases because of increased bandwidths; room is available for up to 300 repeaters to be stored at the depot using much the same principle as is used for bottles of wine.

Repeater Repair Facilities

Adjacent to the repeater store, there is a submerged-repeater repair facility, where faulty repeaters and equalizers can be opened. The internal units can then be taken into a clean area, which is temperature and humidity controlled with filtered air fed in at slightly above atmospheric pressure to ensure the very minimum of contamination to the internal unit undergoing repair. On completion of the repair, and the generally lengthy confidence-testing period, the internal unit is rehoused and then subjected to a further confidence trial in a water tank in the repeater store, before being restored to its position on the storage rack. A maintenance workshop is also provided, and this is being equipped with machinery to enable prototype and small maintenance work to be effected.

Services

Heating and domestic hot-water supplies are provided by 2 fully-automatic oil-fired 2·64 GJ ($2 \cdot 5 \times 10^6$ Btu) boilers for the heating, and a small 264 MJ oil-fired boiler is used for the domestic supply when the main system is not in service.

Adequate supplies of electricity are an essential requirement of any modern complex and there is a sub-station on the site with a capability of 500 kW which supplies all needs.

Ship-to-Shore Connexions

It is necessary to be able to supply power to the cable ships when they are alongside and out of commission, and for this purpose, mobile rectifier units have been supplied. These can be connected to special 440 V, 3-phase supplies at 2 points on the quayside with the d.c. outputs—110 V for the small ships and 220 V for *Alert*—being connected to the ships by heavy-duty flexible leads. The new ships (*Monarch* and No. 565) will be connected directly to the 3-phase supply, as they are basically a.c. operated ships. If this facility of shore power were not made available, certain ship's engine-room staff would have to remain on duty, even when the ship was out of commission, to provide essential basic power and emergency services.

Telephone facilities are also available at similar quayside points, allowing up to 10 lines to be connected to the ships by the simple expedient of plugging into the appropriate socket. Additionally, a continuous supply of fresh water can be made available from quayside hydrants.

Communications Facilities

The telephone system for the complete depot and administration building is provided by a PABX No. 7[6] with 20 exchange lines. The telephone lines from the ships do not go through this PABX, although facilities have been made available for certain extensions to be connected to the ships on the same interconnecting cable and these lines go through the main distribution frame in the PABX room.

To enable communications throughout the depot to be carried out efficiently, a public-address system has been installed covering the entire complex. Strategically-placed column and exponential-horn loudspeakers are connected to 100 V distribution lines, which are powered by 50 W high-quality amplifiers. By using 3 separate systems, coupled only by microphone input switching, the whole system can be operated from low-impedance, plug-in, hand-held microphones at certain points. This enables a full talk-back system to be used for cable handling and, at the same time, enables the telephonist/receptionist to override the whole system for important announcements or paging calls.

To facilitate more rapid communication between inward-bound or outward-bound cable ships of the BPO fleet and the depot, a very-high-frequency (VHF) radio facility has been installed using the Marine Division's private VHF maritime-band frequency. A 10 W frequency-modulated transmitter/receiver is mounted at the top of the adjacent Docks Board navigation tower at the east end of the site. It is enclosed in a specially constructed weatherproof housing, and is remotely powered and controlled from the depot's telephone exchange. The 3-element Yagi aerial array is positioned to give maximum output towards the Solent entrance to the harbour.

ADMINISTRATION AND WELFARE BUILDING

With the amalgamation of the marine and ship-operating facilities of the BPO Marine Division at one place, it was adjudged to be more economical in the long run to provide the headquarters of the Division with office accommodation at the same place. This has already considerably reduced the amount of travelling time and expense in the staff interchange between the ships and the office. Decision taking and transmission of instructions have also been considerably speeded up.

The building is of 3 storeys, constructed on a prefabricated basis, and resembles a small version of the Stock Exchange extension in London. The top floor is given over entirely to staff welfare, having a large catering area, suitable for dealing with up to 300 people, and a quiet room. The catering is carried out by the South Western Telecommunications Region Catering Service, who advised on the kitchen fittings. A small goods hoist was provided to enable foodstuffs to be more easily brought to the kitchen area, and facilities were also provided to enable the drawing office to use the same hoist for raising its supplies of paper from the delivery vehicles.

CONSTRUCTION OF THE DEPOT

The site is built on reclaimed land, requiring that both buildings be suitably piled. In addition, the 4 main cable tanks were also built on piles and this enables them to carry up to 800 t of cable each. The Southampton BTDB Authority have now reclaimed the entire 0·4 km^2 area on north bank of the river Test, and this is in the vicinity of an area called Millbrook.

Almost all this reclaimed area is covered by some 99 000 concrete slabs. Each slab is made of 2 m square and approximately 150 mm thick reinforced concrete panels, bounded by an angle iron reinforcing to prevent breaking of the edges. The slabs are laid onto a specially laid and graded shingle bed up to approximately 1 m depth, on top of the original greensand sub-soil. The great advantage of this method of construction for open areas is that any subsidence of the sub-soil can be corrected cheaply and easily by removing individual slabs from the affected area, infilling by additional shingle and relaying the slabs. The harbour authorities have specially adapted a fork-lift truck to raise and replace the slabs.

The whole of the area has a gradient of approximately 1 in 250 towards the river and land drainage is supplied by 600 mm square bar drains let into the surface. Each drain has its own concrete covers thus preserving the continuity of the complete surface. This method of drainage is quite effective in all but the heaviest rainfalls, when the inadequacies of the bar drains to clear the rain water immediately are noted for short periods.

The entire complex was designed by the Property Services Agency (PSA) of the Department of the Environment to a schedule of requirements provided by the BPO Marine Division in consultation with the BPO's Operational Programming Department (OPD). The contracts for the 2 buildings and ancillary works were placed by the PSA and progressed by them. The whole project was carefully controlled and vetted by a joint PSA/OPD/Marine Division team, with representatives from the PSA and Marine Division on site throughout the entire operation. It speaks well for this method of control that the entire building work was completed on schedule and to a total cost of under £1M. This at a time when the 3-day week and rapidly escalating costs were wreaking havoc with many other similar-sized building projects. A large measure of help was also given by the various contractors who appeared to want to demonstrate that, no matter what the difficulty, they could overcome any setbacks.

The site was made available to the project team in September 1972 and the entire complex completed and ready for occupation in September 1974, this schedule being attained only by close co-operation between the authorities concerned. The complete electrical installation was designed and installed by the Southampton Telephone Area electric-light and power staff, working as sub-contractors to the 2 main building contractors, and this method appears to have worked very well.

Visits have been made by several overseas administrations who have expressed great interest in the ideas incorporated in the new depot.

TRANSFER OF STAFF TO SOUTHAMPTON

For the purposes of control within Network Planning Department, the Director of Network Planning set up a Southampton Working Party. On this were represented all the BPO departments and divisions who had some concern with the project because, quite apart from the depot provision, there was a very great problem in logistics concerning the transfer of up to 300 people from various parts of the UK to their new base in Southampton. This therefore required the formation of the Transfer Terms Sub-Committee which included representatives from the national bodies of the 5 main unions and staff associations involved. However, there were many bodies represented on the Main Committee who were required to attend the Sub-Committee only occasionally as expert advisers. This Sub-Committee completed its work in mid-1974, and has now been superseded by the Redeployment Sub-Committee since there are a great number of staff who do not, for many and varied reasons, wish to transfer their homes to Southampton. These people have to be found other suitable employment within the BPO, and it is only by working in the closest co-operation with the various unions and staff associations involved that this work can be successfully completed. A second sub-committee of the Main Committee was formed to deal with accommodation problems, and this Sub-Committee is still in existence. Once again, the unions and staff associations are members of this Sub-Committee, and the degree of co-operation is full and entire.

Housing

One of the greatest problems in moving the entire staff of the Marine Division to a place like Southampton is the sad lack of suitable rented accommodation available on the market. This affects both the private and local authority sectors. For instance, the Southampton Area housing waiting list is over 3000 long, whilst that of the local New Forest District Council is over 4000. Although this problem is still with the Division, it is expected that a locally-formed housing association will be able to meet the housing needs of the staff.

CONCLUSIONS

From the time that the original decision was taken to centralize the BPO Marine Division's activities, the strongest emphasis has been placed on the need to make the whole transaction economically viable within the restrictions of safe-working practices.

Now that the Division's 3 ships are able to berth, albeit only 2 at a time, alongside the new depot, and are, therefore, able to take advantage of the improved facilities, it means the virtual elimination of the long communication links that previously existed between Headquarters and the ships at berth. This saves many man-hours of delay and travelling expense in getting to and from the ships, with a consequent increase in efficiency.

When the difficulties with resettling the ships' crews have been resolved, this, coupled with the pan-loading concept to be introduced on the new cableships, will mean that a ship could be turned round in, say, 24 h, rather than the days it takes at present due to the antiquated cable-handling methods used. This will represent a great saving, since it will enable the much higher capacity submarine cables now coming into service to be repaired sooner to reduce out-of-service time.

ACKNOWLEDGEMENTS

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A New Grading Design for Access to Stored-Programme-Controlled Register-Translators in Director-Area Local Exchanges

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This article describes how a grading problem, which was foreseen with the introduction of stored-programme-controlled register-translators into director-area local exchanges, has been resolved.

INTRODUCTION

The new register-translator equipment for director-area local exchanges is based on the Mark 1C stored-programme-control (SPC) processor,[1,2] developed by GEC Telecommunications Ltd. The equipment is designed to form a complete replacement unit for the existing electromechanical A-digit selectors, directors and local registers. Simplified diagrams of the trunking arrangements for the electromechanical and SPC systems are shown in Figs. 1 and 2 respectively.

Each of the SPC processors has up to 60 inputs available for carrying traffic, each input being individually interfaced with the Strowger equipment via a signal-conversion circuit (SCC) and trunked into the A-digit-hunter grading. This article is concerned with the design of this grading and the reasons for deviating from the grading practices normally used at this point.

INSTALLATION SIZE

For reliability reasons, it was decided that the minimum size of any installation would be a group of 3 processors and, for practical dimensioning reasons, the largest group would be of 10 processors. Any installation requiring more than 10 processors would consist of 2 or more groups, suitably sized in the range 3–10 processors.

THE GRADING PROBLEM

In Strowger-type director exchanges, an O'dell grading[3,4] is used to interconnect the A-digit-hunter banks, which have an availability of 24, to the A-digit selectors. The failure of any one A-digit selector has a minimal effect on the overall grade of service given by that grading.

However, in SPC-type exchanges, because the failure of a processor results in all the SCCs served by that processor being placed out of service, it was realized that such a failure would have a much greater effect on any grading to which that processor was trunked. For example, if a standard A-digit-hunter grading were trunked to a 3-processor system, the failure of a processor would result in the loss of one third of the trunks serving that grading. Similarly, with a 4-processor system, one quarter of the trunks would be lost, and so on. It was foreseen that, if an O'dell grading were used to interconnect the A-digit-hunter banks and the SCCs, then, under

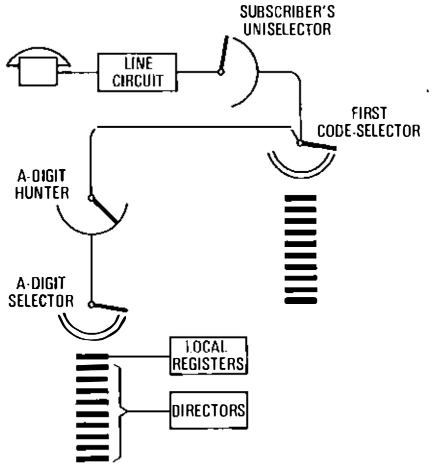

FIG. 1—Trunking diagram for a director-area local exchange using electromechanical A-digit selectors, directors and local registers

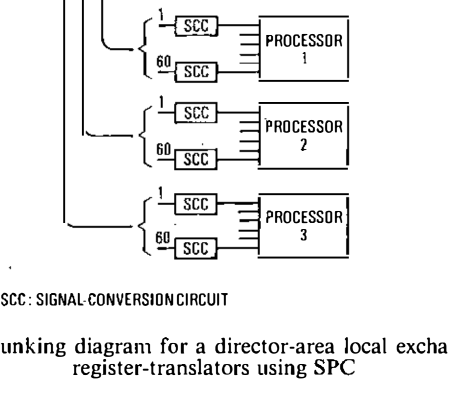

FIG. 2—Trunking diagram for a director-area local exchange with register-translators using SPC

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a processor-failed condition, the loss of a large number of trunks would, in effect, leave gaps in the grading, giving an uneven availability of the remaining circuits with respect to the input grading groups. Besides this weakness, it was also realized that, with one processor failed, the resulting configuration would not represent an O'dell grading. Therefore, the grade of service could not be determined from the standard dimensioning tables, which are for use only with O'dell configurations.

In addition, regardless of which processor fails, the resulting grades of service should, as nearly as possible, be equal. The practical results of this condition could not be determined without resorting to computerized traffic-simulation checks on the behaviour of the multitude of O'dell grading formations that could exist for each of the 3–10-processor systems. It was, therefore, decided to use another form of grading design which would eliminate some of the difficulties and, at the same time, reduce the amount of traffic-simulation effort.

THE NEW GRADING DESIGN

The new grading formations that have been selected are based on a homogeneous concept, a homogeneous grading being defined as a grading in which the outlets of an identical number of grading groups are connected to each outgoing trunk. Such a grading can be formed by the techniques of "skipping" and "slipping"*.

Because of the necessity to expand gradings to cater for traffic growth, it is not practical to retain the homogeneous character throughout their growth. The new gradings are, therefore, better described as *pseudo-homogeneous fully-skipped gradings*. Fig. 3 shows the basic interconnexion pattern of a 6-group fully-skipped grading, and the outlets on which the pattern is repeated. It can be seen that the basic grading consist of all pair-type commons. The maximum number of trunks, n, that can be connected to such a grading is given by the formula $n = gk/2$, where g is the number of grading groups, and k is the availability.

To obtain the correct configuration for the required number of trunks, straps are inserted to interconnect the pair-type commons. The principle of the strapping technique is illustrated in Fig. 4, in which the dashed lines indicate where straps are inserted on the basic pattern. The number beside each strap indicates the number of trunks which can be connected to the grading when that strap is cut, the straps being cut in ascending order. Hence, the configuration in Fig. 4 can be expanded from 5–15 trunks over the 5 outlets shown. It can be seen that, when straps 6–10 are cut, each outlet has a 4-group common and a 2-group common and, therefore, the grading is not homogeneous. This apparent imbalance tends to be smoothed out by the skipped character of the grading.

The new grading concept, in itself, does not overcome the difficulties outlined earlier, but, in conjunction with a new allocation technique for the trunks, offers many advantages over an O'dell grading.

ALLOCATION OF TRUNKS

Under a processor-failed condition, to ensure the remaining serviceable trunks are evenly available to each grading group, it was decided to allocate to any one outlet of the grading those trunks served by the same processor. For example, all trunks from outlet 1 are connected to SCCs served by processor 1, all trunks from outlet 2 are connected to SCCs served by processor 2, all trunks from outlet 3 are connected to SCCs served by processor 3, and so on. Thus, for a 3-processor system, by repeating these allocations across the 24 outlets of the grading, each processor serves 8 outlets and, with any one processor failed, 16 outlets always remain in service. This arrangement is ideal for systems having 3, 4, 6 or 8 processors, where the number of processors is a factor of 24. Special arrangements have been made for systems having 5, 7, 9 or 10 processors, and these are described later.

It was also decided to allow each grading to grow by adding an equal number of trunks to each processor and, therefore, the number of trunks serving each grading is always a multiple of the number of processors in that system. This ensures that an equal number of trunks remain in service regardless of which processor fails.

TRAFFIC SIMULATION AND DEVELOPMENT

Gradings were developed for 4, 6, 8, 10, 12, 14, 16 and 18 grading groups, for use with each of the 3–10-processor systems. Throughout the development, the performance of each grading was checked by computerized traffic simulation. Initial checks were made to determine the best order in which to cut the strapping during the growth of the grading and, also, the effectiveness of the new allocation technique. It was found that, regardless of which processor was assumed to have failed, nearly equal grades of service were achieved when the processors serving outlets 1–24 were arranged in the order

$$1, 2, 3, \ldots n, n, \ldots 3, 2, 1, 1, 2, 3, \ldots n, n, \ldots 3, 2, 1,$$

where n is the number of processors in the system. This arrangement has been adopted for the gradings for systems having 3, 4, 6 or 8 processors.

Traffic-simulation checks were also made to determine the best method of allocation for systems having 5, 7, 9 or 10 processors. The method adopted follows the principle outlined above, and uses as many $1, \ldots n, n, \ldots 1$ sequences

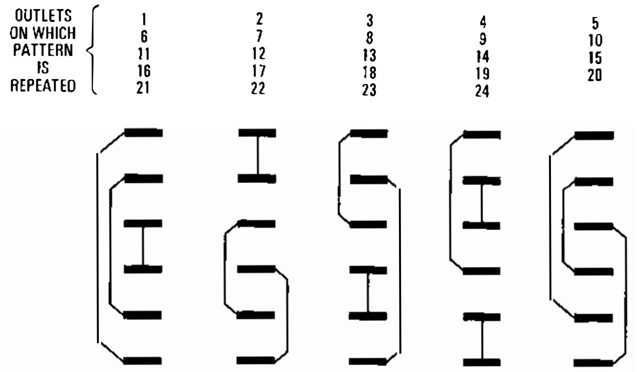

Fig. 3—Basic pattern of a 6-group homogeneous fully-skipped grading

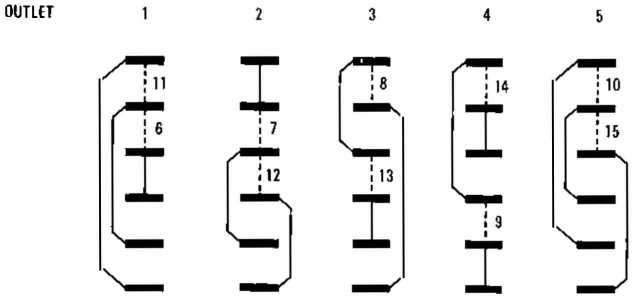

Fig. 4—Principle of the strapping technique

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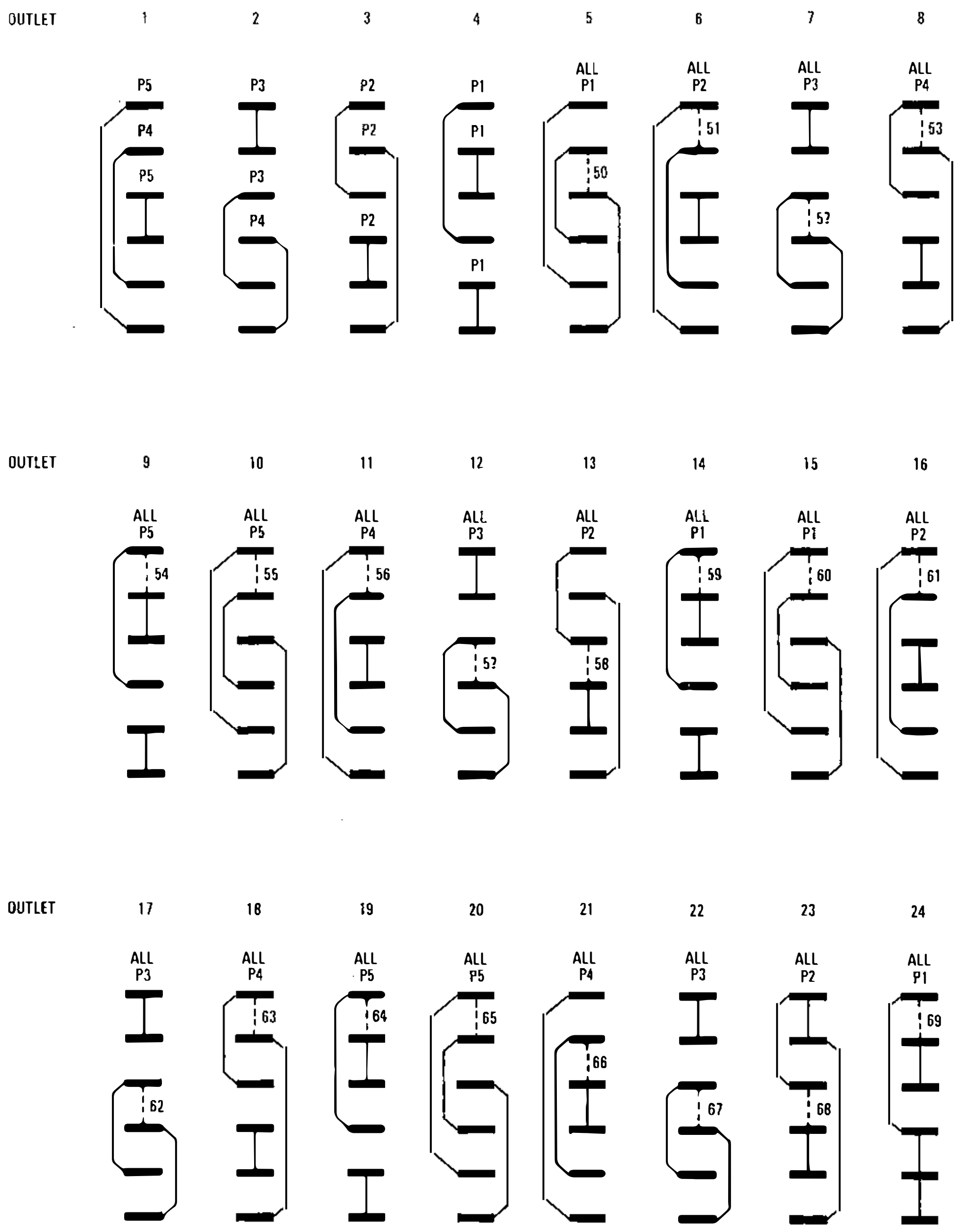
* Skipping is the interconnexion of identically numbered choices of non-adjacent grading groups. Slipping is the interconnexion of differently numbered choices of grading groups.



Note: P5 indicates that the associated trunk is connected to processor 5. ALL P1 indicates that all the trunks associated with that outlet are connected to processor 1

FIG. 5—Complete grading for a 6-group, 5-processor system, with provision for 50–70 trunks

as is possible across the 24 outlets. The residual outlets are then provided as all pair-type commons, with a predetermined allocation for each grading, and are used as the early choices of that grading.

In some of the fixed-allocation gradings, the number of pair-type commons (that is, trunks) serving the residual outlets is not always a multiple of the number of processors serving that grading and, therefore, an unequal allocation of trunks to each processor occurs. This is compensated for by omitting one strap on each subsequent outlet throughout the grading, with the exception of the last few outlets served by the processors which are allocated one extra circuit in the predetermined pattern; on these outlets, one strap is always left uncut. This can be seen in Fig. 5, which shows the complete grading for a 6-group, 5-processor system. Outlets 5–24 are allocated to processors in the 1, . . . *n*, *n*, . . . 1 sequences, with one strap omitted on outlets 5–22. Outlets 1–4 are residual and are provided as all pair-type commons. Because the number of pair-type commons is not a multiple of 5, processors 1 and 2 are allocated 3 trunks each, while processors 3, 4 and 5 are each allocated 2 trunks. In compensation for this, outlets 23 and 24 each have one strap permanently connected. If the grading groups are considered to number 1–6 from top to bottom, the permanent straps are between groups 1 and 2 on outlet 23, and between groups 4 and 5 on outlet 24. (Note that, in Fig. 5, the straps are labelled such that those numbered equal to or greater than the number of trunks required need to be inserted.) As a result of the omitted straps, the minimum number of trunks possible is increased, but this is not expected to present any difficulties in practice.

TRAFFIC PERFORMANCE OF GRADINGS

The performance of each grading was checked, by traffic simulation, under 10% and 20% traffic-overload conditions, as well as under the one-processor-failed condition. The results showed that the worst performance, in terms of the permissible grade of service, was always given under the one-processor-failed condition. A graph showing a typical result is given in Fig. 6.

The permitted level to which the grade of service can worsen during a fault condition is determined by multiplying the normal-traffic-level grade of service by a degradation factor. The degradation factors used were derived from the formulae

$$y = 6{\cdot}84(x - 0{\cdot}03)^{0{\cdot}42}, \qquad \ldots\ldots \; (1)$$

or

$$y = 12x + 1, \qquad \ldots\ldots \; (2)$$

where y is the degradation factor, and x is the mean time between failures (years).

It is specified by the British Post Office Service Department that equation (1) shall apply where reductions in the grade of service occur less than 12 times per year. It is also specified that, where failure rates exceed 12 times per year, the grade of service shall not worsen beyond twice its normal value. To meet this requirement, in the case of systems having 8, 9 or 10 processors, equation (2) was used. This formula allows the degradation factor to approach unity as the mean time between failures approaches zero; that is, it tends towards the situation that one processor failed is the normal condition. The mean time between failures is calculated on the assumption that only a proportion of the estimated failures of a system will occur during a significant period, and it has been assumed that only one fault in 4·2 will have a significant effect upon the grade of service.

Table 1 shows the degradation factors and the resulting grades of service with one processor failed, that were used to determine the traffic capacities for each of the systems.

When designed to the one-processor-failed standards, the grades of service given when all the processors are in service are better than the normal standard value of 0·005, as illustrated in Fig. 6 for the 9-processor system.

TABLE 1

Degradation Factors and Resulting Grades of Service with One Processor Failed

Number of Processors in System	Degradation Factor	Designed Grade of Service with One Processor Failed
3	3·2	0·016
4	2·755	0·0138
5	2·48	0·0124
6	2·17	0·0108
7	1·98	0·01
8	1·90	0·0095
9	1·80	0·009
10	1·72	0·0086

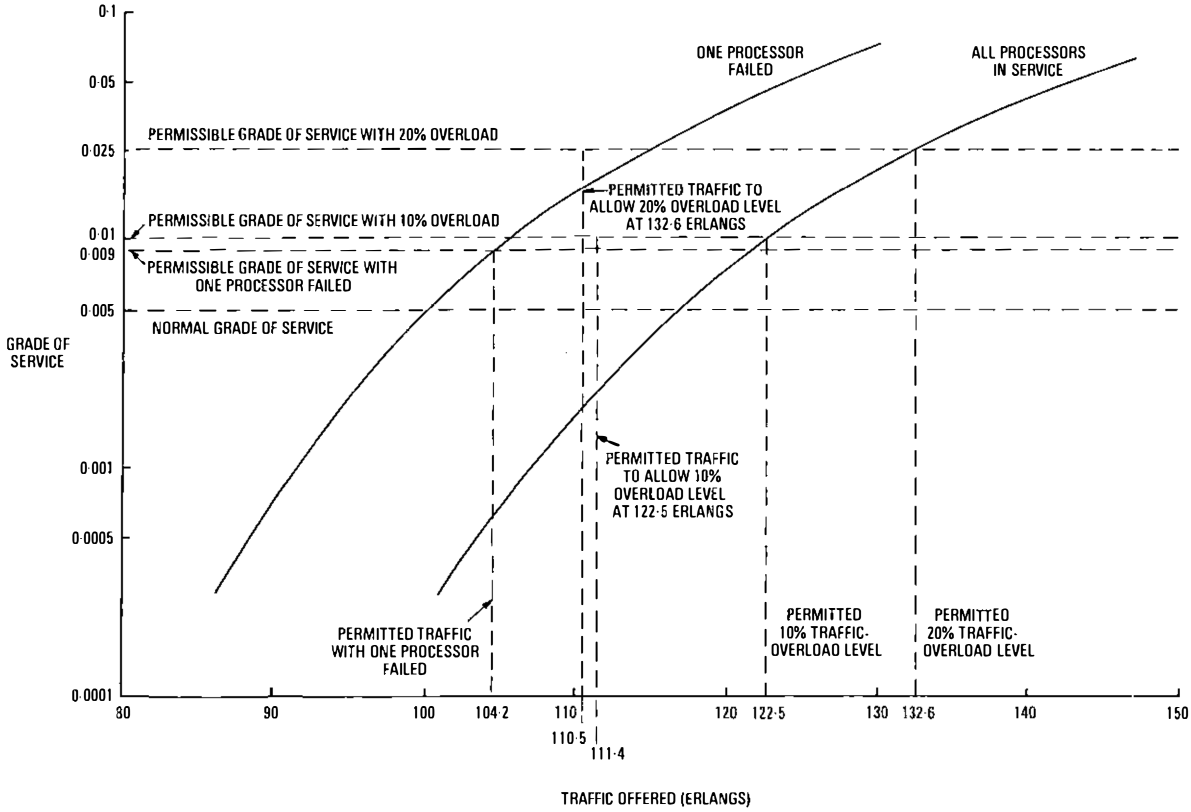


FIG. 6—Graphical representation of traffic-simulation results for a 14-group, 144-trunk, 9-processor grading under 10% overload, 20% overload and one-processor-failed conditions

FINAL DIMENSIONING ARRANGEMENTS

As a result of the studies made, traffic tables have been compiled for each of the 3–10-processor systems. The traffic capacities, which assume one processor to be failed, are stepped in circuit sizes that are in multiples of the number of processors in the system. Grading designs for 4, 6, 8, 10, 12, 14, 16 and 18 groups, suitable for any of the systems having 3, 4, 6 or 8 processors, have been produced, each grading indicating by numbers those straps that are to be inserted. These gradings all use the 1, . . . n, n, . . . 1 allocation technique.

The same range of grading designs has also been produced for each of the systems having 5, 7, 9 or 10 processors, each grading showing the predetermined allocation of trunks to processors for the residual outlets and, again, indicating by numbers those straps that are to be inserted. Fig. 5 is an example of a complete 6-group, 5-processor grading as presented for design purposes.

To meet future traffic growth, it is desirable that any one grading group should serve only one first-code-selector rack. This will generally result in more than 18 grading groups being required and, hence, 2 or more grading divisions will be needed. Should an odd number of grading groups be required, the next even number of groups is provided, leaving the spare group unconnected at the growing end of the grading. This procedure has been found, by simulation, to have an insignificant effect on the performance of the grading.

On the rare occasions when a single-group or 2-group configuration is required, special arrangements are made to provide full-availability groups of trunks to the processors, using the degradation factors given in Table 1 to achieve the desired grade of service under a one-processor-failed condition.

CONCLUSION

The use of computerized traffic-simulation techniques has aided the relatively rapid development and testing of new grading and allocation procedures for an environment where the use of standard grading practices would have led to a large number of difficulties. The probable over-provision of equipment to meet desired grades of service under equipment-failure conditions was also avoided.

A number of the new gradings are now in use in the field, and are giving satisfactory service.

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Book Review

Theory of Waveguides. L. Lewin. Newnes-Butterworths. 346 pp. 78 ill. £9·00.

The development of electromagnetic theory continues towards improved mathematical models to explain observed phenomena and, occasionally, to uncover new facets of operation that are hidden by a lack of knowledge. A point in the development of a model is reached when any further attempt at an analytical solution becomes impossible. Invariably, a computer is used to obtain a numerical solution, so that a device can be built. Some of the techniques being investigated at present will, in the future, become common tools for the engineer to apply to obtain solutions to specific problems.

In this book, Professor Lewin has brought together a number of techniques that have been developed over the past decade, the intention being to provide a direction for investigation in applying these new methods. One recognizes that, in the space of one chapter, there is a limit to the amount of knowledge that can be conveyed on a particular method. The reader is then directed to the original papers to obtain more information.

The book is aimed at engineers in the field of waveguides and, particularly, at post-graduate students. The content is necessarily of an advanced nature. A prospective reader should have a sound knowledge of vector algebra, integration techniques (including residue theory), Fourier and Hankel transforms, and conformal transformations. Some degree of tenacity would also be an advantage, as the author tends to leave to the reader the task of filling in a number of intermediate steps, the nature of which is not always obvious.

The first chapter is a brief review of some basic theory, which is intended to refresh the reader's memory. The remainder of the book can be subdivided into 3 main headings: propagation in waveguides, obstacles in waveguides, and waveguide junctions.

There are 3 chapters on propagation, which cover a wide range of the various forms of waveguide configurations. In general, solutions are produced by setting up Maxwell's equations in the appropriate co-ordinate system and applying the boundary conditions of the lossless waveguide. The usefulness of the surface-impedance technique is demonstrated in some examples, particularly where the impedance is anisotropic.

In the 3 chapters on obstacles in rectangular waveguides, there are a number of techniques that are pursued. For cylindrical posts in a waveguide, techniques include the normal first-order and second-order theories, as well as a variational method and transformation formula. For the case of diaphragms and gratings in the waveguide, the important single-integral method is expounded, which is, in general, applied to the transverse field. Explanations of how some of the very complex integrals generated could be solved analytically are given. Another form of solution is shown—the Weinner-Hopf technique—which generates an integral equation for the field along the whole of the waveguide's axis.

Finally, there are 2 chapters on waveguide junctions where there is a change of shape (that is, a step discontinuity) or a change of media (that is, into a ferrite or a dielectric). The techniques given include those previously mentioned, as well as solutions by conformal transformations.

In conclusion, any engineer in the field of electromagnetic theory applied to waveguide or antenna design, should inspect this book. It is possible that some benefit may be obtained by an introduction to a new technique.

C. R. S.

Evaluation of a British Post Office Scheme for Producing Professional Engineers and Scientists

P. M. NEWEY, M.A.†

UDC 378.001.4: 331.053.5

This article begins with a brief description of the Post Office Studentship Scheme, the scheme is then compared with other means of recruitment and, finally, details are given of an evaluation of the performance of former Post Office Students in relation to that of Executive Engineers obtained via the 4 other channels.

HISTORY

The British Post Office's (BPO) undergraduate apprenticeship scheme, known as the *Post Office Studentship Scheme*, is designed to supplement the intake of good honours graduates to higher engineering posts. The scheme was started in 1960 when graduate engineers were in particularly short supply and BPO requirements could not be fully met through existing recruitment methods. The initial number of awards was 20, rising to 47 in 1970 and declining to 18 in 1972, at which level it has since been maintained. The number of studentships offered each year is related to the total engineering and scientific graduate recruitment requirements, bearing in mind that students will not be available to fill posts for some 4–5 years.

THE SCHEME

To qualify for a studentship, candidates must be school-leavers aged 17–20 years and must have, or expect to get, 3 passes of at least grade C in the General Certificate of Education examinations at A-level (H-level in Scotland); these must include Mathematics and Physics and be obtained at one sitting. Each October, applications are received from students in their final A-level or H-level year, in response to publicity directed at schools with science sixth forms. Applications are submitted via headmasters, who add their assessment of each candidate's potential. Those successful remain at school to sit their examinations, obtaining their university place through normal Universities Central Council on Admissions or other procedures; entry then has to be deferred for a year, to allow the Post Office Students (POSs) to serve their first year in the BPO. This raises no problem; all universities accept this, and many are particularly keen on students who have had a pre-university industrial year. New-entrant POSs undergo 12 months of special training within the BPO, followed by a 3-year honours course, or a 4-year course in the case of Scottish universities. The universities at which POSs are currently studying are shown in Table 1.

Specialist training is given for a further 12 months after graduation, thus completing a "thick" sandwich of vocational and academic training. The first year of BPO training of POSs consists of a series of training courses at the BPO College of Engineering Studies (Horwood House, Milton Keynes) interspersed with field and practical training. Much of the work of the formal courses is of first-year university standard and beyond, and prevents any falling-off of academic ability during the break between school and university. During the long vacations, POSs work on research or development projects for about 10 weeks. On successful completion of the course, POSs are normally regraded as Executive Engineer (EE) on the graduate scale of pay, and it is on this grade that their final year of specialist training is undertaken, after which pay is advanced to an appropriate point on the full EE pay scale. Those who do not reach the required standard may be regraded as Assistant Executive Engineer (AEE). After regrading as EE or AEE, BPO career progress is entirely dependent on individual ability and determination.

The pay of POSs is on a scale of £1086/annum at 17 years to a maximum of £2145/annum at 24 years of age, plus London Weighting where appropriate. The BPO pays all college fees, university union dues and examination costs, plus half the cost of text books. In addition, travel and subsistence costs are paid for training courses and visits. This scheme is popular and, with a large number of very able applicants, the BPO can choose to award its limited number of studentships to those whose academic ability and proven technological interest makes them likely to make rapid progress in professional work after graduation. It must be remembered that, after their initial regrading, former POSs will encounter strong competition from engineers and scientists who have some years of BPO experience; it is important, therefore, that the selection process should give special weight to evidence of ability on the part of applicants to hold their own in subsequent years.

TABLE 1

Universities at which POSs are Studying

University/College	Number of POSs Studying	University/College	Number of POSs Studying
Birmingham University	5	Manchester University	1
Bristol University	2	Oxford University	2
Cambridge University	13	Queen Mary College	2
City University	1	Sheffield University	2
Dundee University	1	Southampton University	8
Durham University	5	Strathclyde University	1
Essex University	1	Sussex University	2
Heriot Watt University	1	Reading University	1
Imperial College	3	Westfield College	1
Loughborough University	2	Total	54

Figures represent intake period 1972–74

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† Telecommunications Personnel Department, Telecommunications Headquarters.

COMPARISON OF BPO STUDENTSHIP SCHEME WITH OTHER MEANS OF RECRUITMENT

Apart from the Studentship Scheme, there are 4 other channels of entry to the EE grade. These are

(*a*) direct entry from outside the BPO,
(*b*) Internal Scholarships awarded to BPO staff,
(*c*) Limited Competitions open to BPO staff, and
(*d*) normal in-line promotion.

Direct entry is open to graduates only, these normally being recruited straight from university. Internal Scholarship Awards are designed to enable current employees with at least 2-years' service to be sponsored on degree or institution courses, thereby providing a source of recruits to higher engineering grades. Award holders receive full pay throughout the course and training is given during long vacation or industrial training periods. Since 1974, these awards have been re-named *Major Awards*, and an additional Minor Award Scheme has been introduced. BPO employees granted Minor Awards are expected to obtain local-education-authority grants. The BPO pays an award of £160 per full academic year, plus the normal National Insurance contribution, and provides industrial or vacation training on full pay. On successful completion of their course, award holders are automatically considered for regrading to EE or AEE. The Limited Competitions, which are held annually, are open to all BPO employees between 23 and 45 years of age, who have at least 5-years' continuous service (3 years, if service is in the AEE grade) and hold certain academic qualifications in an appropriate subject. Normal in-line promotion is from the AEE grade using an appraisement and boarding system. An appraisement, including an assessment of suitability for promotion, is completed every other year by the AEE's supervisor and countersigned by a senior manager. After fulfilling certain service requirements on the grade, those AEEs marked "suitable" have the opportunity of an interview with a 3-man promotion board. These boards are held periodically according to staffing requirements. Those successful are assigned to EE posts as vacancies arise.

REASON FOR REVIEW

In the late-1960s, the number of graduates available for direct recruitment to the EE grade began to outstrip BPO needs and, although there has been a more balanced situation in recent years, the comparative dearth of engineering graduates which originally led to the introduction of the Post Office Studentship Scheme, seemed a thing of the past. For this reason, and because the BPO has several other schemes for obtaining engineering graduates, a comprehensive review of the Studentship Scheme was undertaken.

THE REVIEW

The first phase of this review was a survey of the relative performance of the EEs recruited from the various channels. Additionally, up-to-date costings were obtained of the various entry methods in terms of numbers of engineers produced. The probable future demand and supply for graduate engineers, both within Post Office Telecommunications and in the market as a whole, were also considered.

The survey of the comparative performance of EE recruits was split into 2 parts: a Telecommunications Headquarters (THQ) departmental enquiry and a regional enquiry. The majority of graduate EEs appointed in 1968–70 had been assigned to 4 departments in THQ in London, and samples of these were, therefore, selected to form a basis for a detailed enquiry. The THQ sample included both graduate and non-graduate EEs from all channels of entry appointed during these years, and totalled 119. Managers were asked to complete an enquiry schedule on each of the sample EEs in their departments, giving managerial and technical performance ratings, and present potential ratings. An indication of the number of "months to acceptable effectiveness" was also requested. A rough guide to assist in the quantification of these assessments was supplied, and it was asked that they be made on the following basis.

(*a*) For managerial performance, the EE's ability should be assessed in respect of devolving responsibility, written work, communication with and handling of staff, judgement and output.

(*b*) For technical performance, the assessment should be of the EE's knowledge as related to experience and education, initiative and the suggestion of new ideas.

(*c*) For present potential, the assessment should be of speed and ability to learn, desire to self-improve, motivation and ambition.

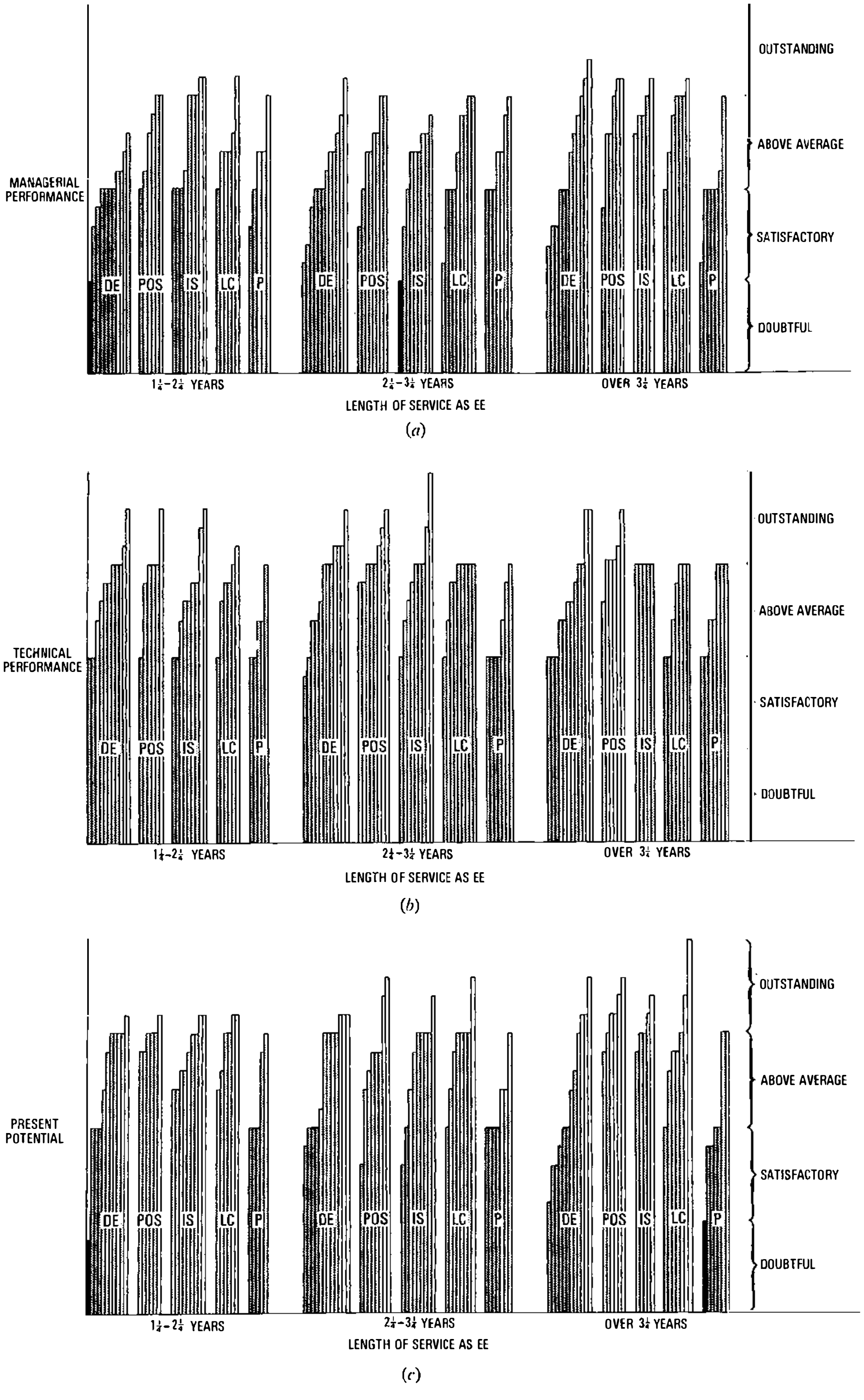
In addition, managers were asked for general comments and a comparison of the different types of entrant, particularly graduates, in the light of the sponsorship and recruitment costs. A general request for information was also sent to the 10 telecommunications regions to cover the smaller number of graduate EEs appointed there.

An analysis of the enquiry schedules completed by THQ departments can be seen in Fig. 1. The 3 ratings—*managerial performance*, *technical performance* and *present potential*—are divided into length-of-service classes; namely, 1¼–2¼ years, 2¼–3¼ years, and over 3¼ years, corresponding approximately to the 1968, 1969 and 1970 intakes, and these are further sub-divided by type of recruit. The ratings are displayed in pillargraph form, each vertical column representing an individual EE. The number of each type in the sample, which was as large as possible, is not consistent and this should be borne in mind when interpreting these diagrams.

Fig. 1(*a*), on managerial performance, shows consistent ratings generally well above the *satisfactory* level for POSs, and also for the other type of graduate entrant with previous BPO experience, the Internal Scholar. Both the direct-entrant and Limited-Competition-entrant ratings improve with length of service. From Fig. 1(*b*) on technical performance, it can be seen that the ratings of the POSs are consistently high, a good proportion showing *above-average* markings. The Internal Scholar and Limited-Competition entrants also show consistently high markings. Fig. 1(*c*) shows that POSs have consistently high potential ratings. The graduate entrants taken as a whole have the highest potential ratings. Entrants with previous BPO experience are the most consistent. When all 3 diagrams are taken into account, the POS scores better overall than any other type of entrant. The differences, however, are small and the diagrams broadly indicate that graduate EEs, particularly the POS and the Internal Scholar, have the edge on other types of entry to the grade.

The regional enquiry also showed that EEs recruited from the Post Office Studentship Scheme were highly regarded.

Although the marginally higher scores of former POSs would, of themselves, provide some justification for the continuation of the Scheme, the survey participants were also asked for their comments, in the light of the summary of their total response, on the future of the Scheme. The majority felt that the Scheme should be retained. As can be seen from the analysis of the enquiry schedules in Fig. 1, POSs and Internal Scholars received more or less equal ratings. A more interesting finding, however, was the clear preference on the part of users for Internal Scholars graduating via sandwich courses rather than full-time degree courses. This results from the former having had more BPO experience during their course, allowing them to become effective sooner and to settle down to work more quickly. This finding had implications in the context of POSs and, when referred back to the survey participants, the view was expressed that the Studentship Scheme should make provision for a "thin" sandwich course of alternate periods at college and in BPO employment, thus enabling a closer watch to be kept on the progress of these award holders. It was recognized that there would be a



DE—Direct Entrants
POS—Post Office Students
IS—Internal Scholars
LC—Limited-Competition Entrants
P—Normal In-Line Promotees
Each vertical column represents one individual

(*a*) Managerial Performance (*b*) Technical Performance (*c*) Present Potential

FIG. 1—Performance of EEs of various classes of entry

problem in that the number of courses open to POSs would be limited and there would have to be close liaison between the BPO and the colleges to integrate BPO training with the academic content. An unexpected outcome of the survey has, therefore, been the commissioning of an in-depth study to ascertain how such courses could be organized to introduce a thin sandwich course scheme alongside existing arrangements. It was known that, during recent years, the cost of running the Studentship Scheme had been increasing. The costings shown in Table 2, however, indicate that POSs do not cost more than Internal Scholars on sandwich courses when success rates (measured as regradings to EE) are taken into account. Furthermore, in view of the consistent rating and high reputation of EEs who entered through the Studentship Scheme, the cost seems well justified.

TABLE 2

Estimated Average Costs per EE Appointment

Type of Entrant	Estimated Average Cost per Appointment (£)
Direct Entrant—Assigned to THQ	1600
—Assigned to Region/Area	2300
POS	8100
Internal Scholar—Full-Time Degree Course	5900
—Sandwich Course	8100
—Council of Engineering Institutions, Part 2, Full-Time (Full sponsorship for 1 year)	4500

Costings done in 1973

FUTURE SUPPLY OF ENGINEERING GRADUATES

Although the recruitment of graduate engineers on the open market became far easier during the 1960s, the market has hardened in recent years. There are also strong indications that the recruitment market will become even more competitive in the foreseeable future. In 1971, for example, the recession in graduate employment was a deterrent to entering higher-education courses, particularly engineering and science courses. In 1973, the University Grants Committee took a decision to cut back on engineering and science places at universities, when faced with a possible 5000 unfilled vacancies over the next 5 years.

The rapid improvement in graduate opportunities in the private sector during 1973 attracted many potential graduate engineering recruits, and the recent economic difficulties have not changed this. This brings out the importance of internal schemes, which can guarantee a reasonable proportion of eventual graduate EE recruits who will stay with the BPO.

As far as future needs of the Business are concerned, with accelerated technological change, it is clear that the BPO demands for graduates with specialized technical knowledge will continue, and this also applies to other industries with whom the BPO is in competition on the engineering graduate market.

CONCLUSIONS OF THE ENQUIRY

As a result of this evaluation of the Studentship Scheme, and in the light of the consideration of supply and demand factors, it has been decided to continue the scheme. The training arrangements require a minimum intake of 12 students to operate efficiently and, as long as there is a reasonable prospect of obtaining the required number of open entrants, 12 is likely to be the annual intake of students. Admittedly, forecasting the BPO requirements 4 years ahead will present difficulties. Forecasts can so easily be upset by rapid technological changes, and the demand of outside industry is a big factor which cannot be predicted. However, a stable recruitment policy, in this small sector at least, in periods of fluctuating demand elsewhere should stand the BPO in good stead in lean times for the future. The Studentship Scheme will also continue to serve the valuable functions of maintaining links with the schools and promoting the image of the BPO as an employer.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the assistance of Mr. R. J. F. Johnson for the original enquiry, Miss M. Coates and Miss C. M. Richards for the cost investigations, and Mrs. C. D. Hill for invaluable help in compiling the article.

Book Review

Key Papers in the Development of Information Theory. Editor: Professor D. Slepian, M.A., PH.D., F.I.E.E.E. IEEE Press, distributed by John Wiley & Sons Ltd. 463 pp. 202 ills. Cloth £7·95, paper £3·75.

This volume, one of the IEEE Press Selected-Reprint series, comprises 48 papers from 38 authors, beginning with Shannon's historic July 1948 paper *A Mathematical Theory of Communication*, and covering the next 25 years, up to July 1973. All the papers originally appeared in American literature (half of them in *IEEE Transactions on Information Theory*), and all the authors, with the exception of 3 Russians, are American, or were working in the USA when the papers were written.

The papers are divided into 3 groups, entitled "The Classical Source and Channel", "Rate Distortion Theory", and Many-Terminal Channels". They deal with information theory proper—not the wider subject of statistical communication theory—with only a few basic papers on coding theory, for the latter is the subject of a companion volume in the series.

Although there is a certain attraction in having these papers in one volume, its usefulness is not so evident. Beginners will be better served by a conventional textbook, and advanced workers would have no difficulty in getting papers such as these through a library.

W. E. T.

Traffic Characteristics of the TXE4 Electronic Exchange

A. F. PAIS, M.SC., M.B.C.S.†

UDC 621.395.345: 621.395.31

A previous article[1] described, in general terms, the traffic evaluation of the TXE4 exchange system. This article describes in greater detail some of the more important traffic aspects of the system which are reflected in its performance under normal and overload traffic conditions and when equipment faults occur. The methods of devising and testing traffic models to assess performance are described and discussed.

INTRODUCTION

Fifty TXE4 exchanges have already been ordered. These are mainly replacement director exchanges, but also include some new director exchanges and some replacement non-director exchanges. Previous articles in this *Journal*[1,2] have outlined the teletraffic techniques used to evaluate the system, and described the historical development of the TXE4 system. The joint British Post Office (BPO)/Standard Telephones and Cables Ltd. (STC) project-control organization for managing the execution of the TXE4 contract has also been previously described.[3] Whilst dimensioning of the system is a BPO responsibility, there is a regular interchange of information and ideas with STC on teletraffic matters. The traffic studies to date have been aimed at providing general rules for dimensioning of TXE4 exchanges to meet BPO standards and, therefore, have been carried out using normal traffic load, 10% and 20% overloads and specific failure conditions.

To this end, traffic models have been devised which can be adapted to study a wide spectrum of exchanges with different parameters. The details included in the models, and the traffic inputs used to test the system, have been influenced by the traffic environments in which the exchanges are expected to work. Thus, most of the studies have been done on director exchanges with approximately equal incoming and outgoing traffic loads, and about 10% local traffic. For the non-director exchanges, similar traffic quantities have been used, but a small amount of through traffic is also included. This article describes only the director studies.

Thus, while the traffic model and its inputs are quite adequate for the main stream of exchanges, allowance must be made for those exchanges that have significantly different features, such as very high traffic on PBX lines or very low bridge-link traffic. The studies to ascertain the traffic implications in such cases are outside the scope of this article.

TXE4 SYSTEM DESCRIPTION

The TXE4 system is best considered as comprising the following 4 main areas:

(*a*) the switching network, and the interrogators and markers which organize the setting-up of paths through the exchange,

(*b*) the cyclic stores and scanners,

(*c*) the main control units and their associated registers, and

(*d*) the supervisory processing units, which are responsible for call supervision.

The block diagram of the system (see Fig. 1) depicts, in broad outline, the lines of communication between the different areas mentioned above.

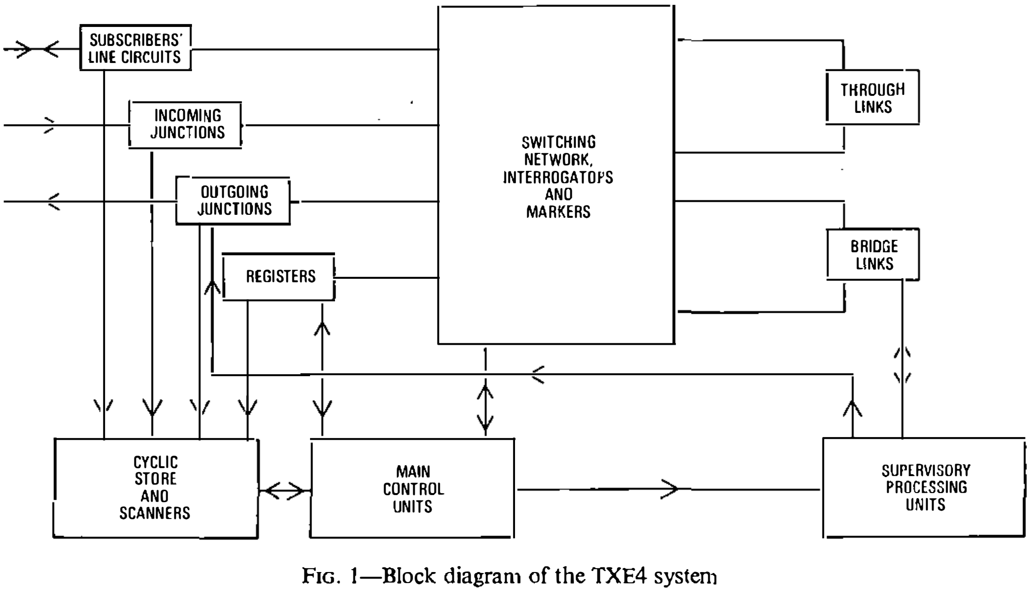


FIG. 1—Block diagram of the TXE4 system

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† Telecommunications Development Department, Telecommunications Headquarters.

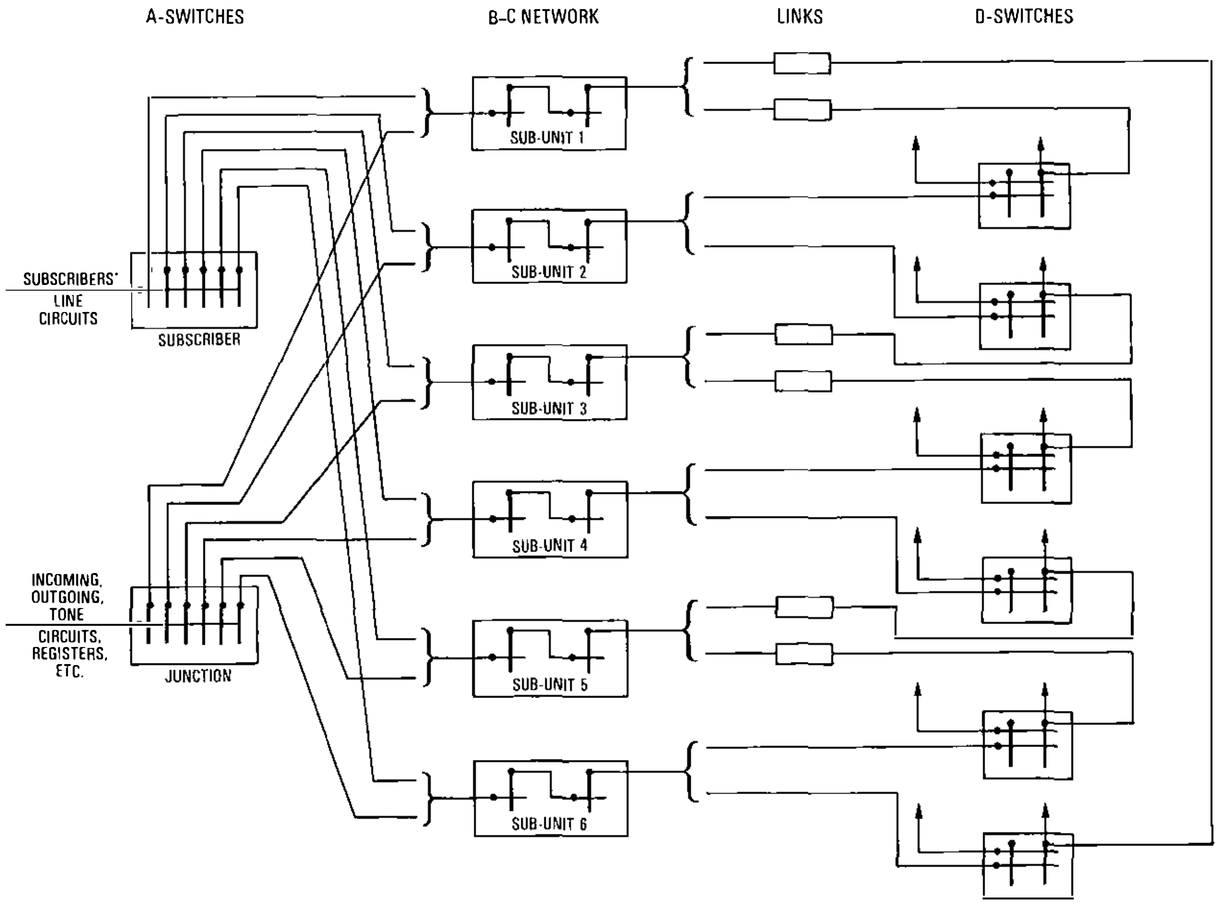


FIG. 2—Trunking diagram of the TXE4 switching network

Switching Network

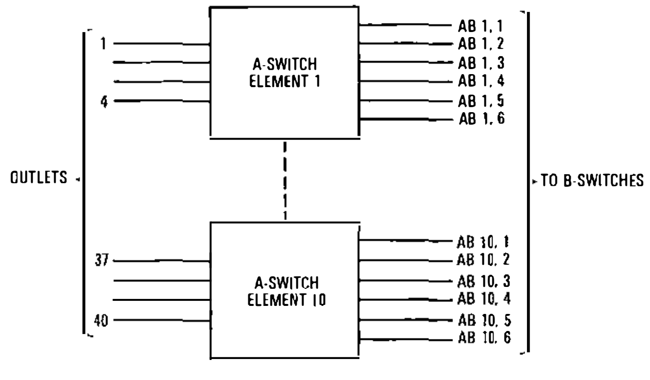
A trunking diagram of the switching network is shown in Fig. 2. The network consists of reed-relay matrices, arranged as a 3-stage link system (A-, B- and C-stages), folded on itself via the D-stage. Thus, 7 crosspoints must be used to complete a connexion between the 2 terminals. The network is composed of a number of identical units. Each unit includes standard B–C networks, or sub-units, their number being equal to the number of planes in the exchange. Connexion to the B–C network is made via the A-switches.

A-Switches

The A-switches on a unit have access to all sub-units and are of 2 types: subscriber and junction. Subscribers' lines appear on the outlets of the subscriber A-switches, while such items as junction circuits, registers and tone circuits are connected to the outlets of the junction A-switches.

A fully-equipped unit contains 18 A-switches. In the director exchange, there are approximately equal numbers of subscriber and junction A-switches. The basic A-switch is constructed of 10 elements, each element having a number of crosspoints equal to 4 times the number of planes, and the inlets are connected to the B-switches, as shown in Fig. 3 for a 6-plane exchange.

Concentration on the A-switch is achieved by increasing the number of basic A-switches and multipling inlets, and traffic mixing is introduced by slipping multiples on the even-plane links.



AB$x, y \equiv$ A-B LINK No. x ON PLANE y

FIG. 3—Basic A-switch for a 6-plane exchange

B-C Network

This network (Fig. 4) comprises 18 B-switches and 8 C-switches. Each B-switch has a 10 × 8 interconnexion matrix and is associated with either a subscriber A-switch or a junction A-switch, and each C-switch has an 18 × 12 matrix.

D-Switches, Bridge and Through Links

Each D-switch is connected between the inlets of C-switches on adjacent planes in the same unit and in different units. The bridge links and through links are located on the C-switch inlets of the odd planes; interconnexions between the planes

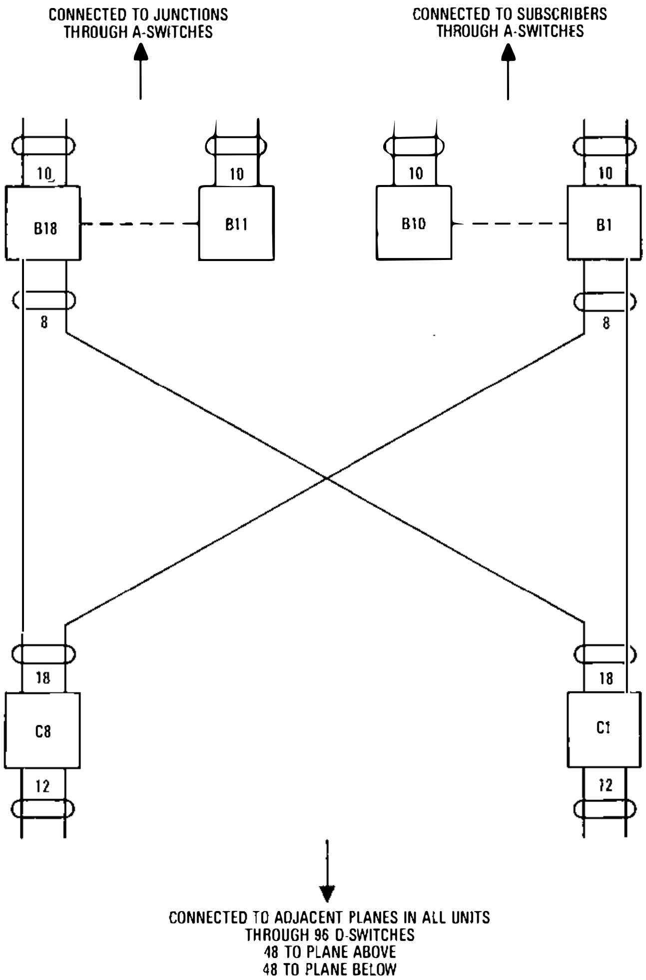


FIG. 4—Single plane of switching with 10 subscriber A-switches and 8 junction A-switches

are made through D-switches. Of the 96 C-switch inlets on each plane, half connect to the plane below and half to the plane above. A 6-plane exchange has 288 D-switches. The number of crosspoints on each D-switch is u^2, where u is the number of units in the exchange. There is full accessibility between the inlets and outlets of the D-switch, as indicated in Fig. 5, thus enabling interconnexion between units and between outlets on the same unit.

Interrogators and Markers

Each sub-unit is associated with an interrogator which operates in conjunction with a marker. The interrogator interrogates the states (free or busy) of the required switch outlets. The odd-plane markers select free paths and communicate to the main control unit the appropriate C-switch numbers. The main control unit then selects the preferred path, which is always the one with the lowest C-switch number, and instructs 2 markers to set up the connexion.

Cyclic Stores and Scanners

Cyclic stores provide a library of information about every exchange termination. Associated with each store is scanning and line logic equipment which provide state-of-line information. The whole store is addressed cyclically.

Main Control Units and Registers

Terminal hardware functions are provided in each main control unit for

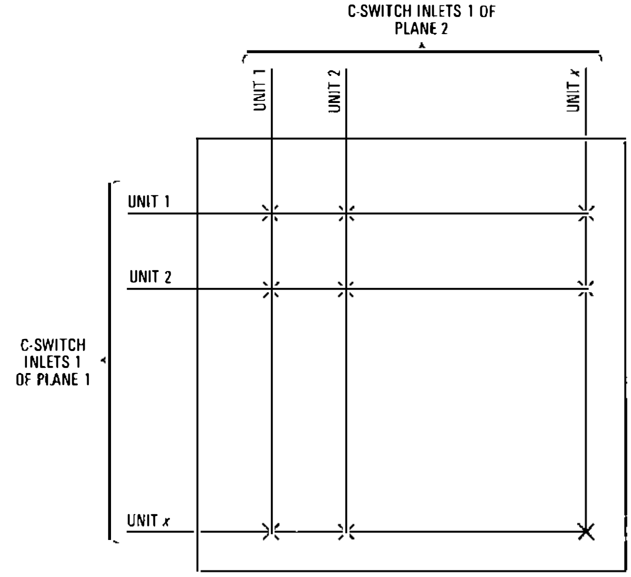


FIG. 5—D-Switch connecting C-switch inlets 1 of plane 1 to C-switch inlets 1 of plane 2

(*a*) the selection of new call conditions and data search from the cylic store,

(*b*) processing the registers associated with the main control unit, and

(*c*) interchange of control data with markers and supervisory processing units.

The main control unit operates on a set of instructions which is contained in the main control unit programme. This programme is stored in a read-only memory that permits programme changes to be readily made. On the Rectory-type of TXE4 exchange, each main control unit is associated with a maximum of 36 registers (on some main control units, all registers are not available for traffic as some positions are used for maintenance equipment).

Supervisory Processing Units

Bridge links, outgoing-junction relay-sets and tone circuits are processed for call supervision by a set of supervisory processing units. The state of each supervisory circuit is periodically monitored and appropriate instructions are sent to it by the supervisory processing unit.

METHOD OF STUDY

Two basic methods by which the traffic capability of a system can be assessed are

(*a*) theoretical techniques, which in the case of TXE4 entail very sophisticated mathematical concepts associated with such topics as queueing theory and link system theory, and

(*b*) system simulation, which for TXE4 has involved considerable computing resources and programming expertise.

These methods are used in a complementary manner when analysing a large system. For the TXE4 system traffic studies, whilst most results were obtained by simulation, theoretical methods were used to ascertain sensitive areas and were instrumental in reducing the number of computer simulation runs actually carried out. The exclusive use of theoretical methods, however, was ruled out, as it was believed that the mathematics would be intractable unless very simplifying assumptions about system operation were made.

The simulation of the system was implemented on an Elliott 503 digital computer,[1] which has a main store of 8000 words, a backing store of 128 000 words and a word

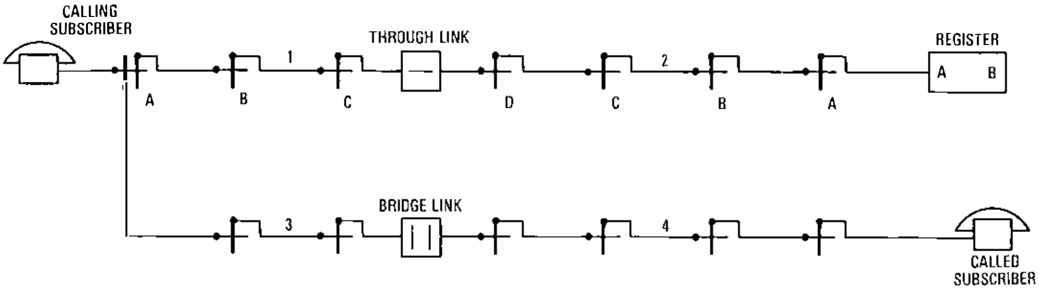


FIG. 6—Subscriber-subscriber call (without planar transfer circuits)

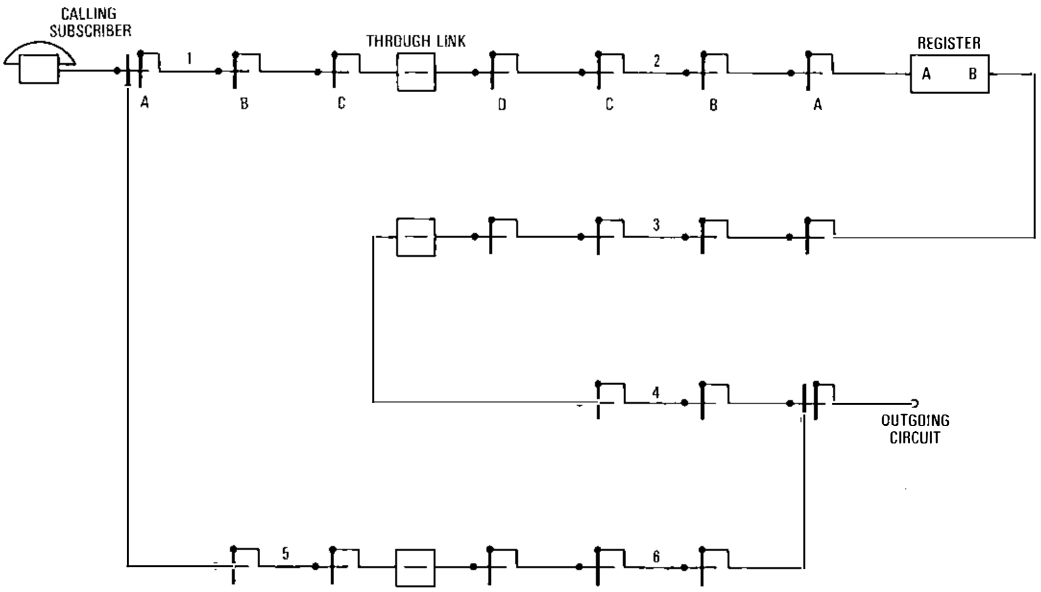


FIG. 7—Subscriber-outgoing call (without planar transfer circuits)

length of 39 bit. The entire exchange could not be adequately simulated on this machine and so part simulations have been done. Two traffic models were, therefore, prepared: one to represent the switching network, and the other to represent the control area. The main reasons for dividing the system along these lines were as follows.

(*a*) These 2 areas tend to have rather distinct traffic features. The switching network is associated with the longer conversation holding times, whose distribution is negative exponential, and its performance is closely related to system traffic. The control area, on the other hand, has a traffic which is built up from short holding times, generated by the processing of each call, the holding times normally being constant or varying uniformly about a mean value. Thus, control equipment must be provided on the basis of calls rather than on system traffic. This means that, for system traffic associated with a mean conversation time of 2 min, more control equipment is required than when it is associated with a 3 min conversation time. The switching equipment required, however, is substantially the same in both cases.

(*b*) The traffic characteristics of these areas tend to be comparatively independent. Thus, is it easier to assess overall exchange performance from the results obtained by studying each part separately, when the exchange is divided in this way.

(*c*) The differences in traffic models of these 2 areas are apparent in the structure of their simulation programmes. Thus, the switching network comprises only a small number of simulation blocks, but requires immense storage to hold the current states of the links. The control area, however, has several programme blocks to follow the various stages of call processing, which is done by a series of interactions between the register and control equipment. A minimal amount of storage is required to hold the busy/free states of the control equipment and registers.

(*d*) It is possible for separate teams to be engaged in the study of each part, thus enabling the work to proceed in parallel.

TRAFFIC EVALUATION STANDARDS

The performance of the system was assessed in the light of the grade of service (GOS) stipulated for the own-exchange, outgoing and incoming call types. In director exchanges, the GOS laid down at normal traffic load for these call types is 0·025, 0·01 and 0·015, respectively. To meet the BPO standards, it is necessary that, in addition to the performance at normal load, system behaviour at 10% and 20% overload must also be taken into account. For 10% and 20% overloads, the GOS performance requirements are generally relaxed to 2 times and 5 times the normal-load value, respectively.

The degradation of the normal-load GOS allowed by the BPO requirements when equipment failure occurs, is also related to the normal-load GOS, but in a far more complex way. Briefly, the permissible degradation factor is calculated as a function of the mean time between failures of the equipment concerned. This degradation factor is then applied to the normal-load GOS specified for the call type in question. If the failing equipment is deemed to affect any particular group of subscribers, the degraded GOS must be applied to the worst affected subscribers. In the TXE4 system, 2 items

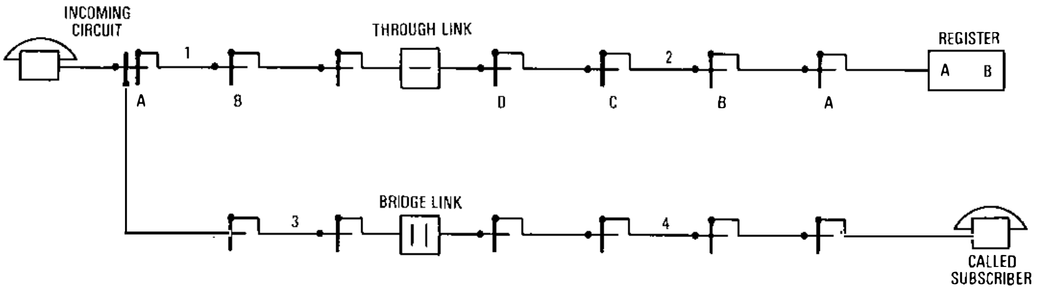


FIG. 8—Incoming-subscriber call (without planar transfer circuits)

of equipment failure have been identified as important, and system performance has been assessed in the light of these: marker failure, which removes from service the switching equipment of those sub-units associated with it, and main control unit failure, which takes a main control unit and its associated registers out of service. The GOS is, of course, specified across the whole exchange and the apportionment of GOS to the control and switching areas has been made to enable each part to be evaluated as an entity.

SWITCHING-NETWORK SIMULATION

The switches and their interconnexions are represented precisely, and so is the *path-choice* algorithm which decides the path to be used for any specific connexion. The activities of the control unit associated with path setting are included only to the extent that they could affect the switching-network traffic capacity. Thus,

(*a*) interrogator markers were engaged for a constant period of 30 ms whereas, in practice, this time varies about a mean value of 30 ms,

(*b*) point-to-group connexions (for example, subscriber–register) were allowed up to 4 routing attempts, all effectively made at the same point in time whereas, in the system, there is inevitably a small time lapse between successive attempts, and

(*c*) registers were treated as a single group and calls unable to route to registers were abandoned from the system. In practice, registers are in groups, each group being associated with a specific main control unit, and originating calls queue for service.

In the director-exchange simulation, 3 call types were studied: own-exchange, outgoing and incoming terminating. The successive paths to be set up through the network are known as *serial trunking sequences*, and are shown in Figs. 6, 7 and 8. When setting-up successive paths from a terminal, the second path may overlay the AB-link of the previous path for certain call types. This is shown in the diagrams by double lines.

Loading of the Switching Network

A path between any 2 terminals in the TXE4 system entails the use of very specific types of links. For example, the subscriber–register connexion uses a subscriber AB-link and a subscriber BC-link, a junction AB-link and a junction BC-link, and a through link. The subscriber–subscriber path, however, uses 2 subscriber AB-links, 2 subscriber BC-links, and a bridge link. Thus, each call type generates very specific quantities of traffic on the different link types. This allows loading criteria to be formulated in terms of link traffic; the criteria used for the studies described was equal subscriber and junction AB-link occupancies, and equal bridge and through-link occupancy.

The traffic capacity can, therefore, be conveniently described in terms of A-switch capacity. From a knowledge of the mean register and call holding-times, a traffic mix was chosen which satisfied the above conditions, and had approximately equal quantities of originating and terminating traffic with a very small amount of own-exchange traffic. This was the principle underlying the selection of traffic inputs to the system.

Organization of Simulation Runs

Exchange configurations of different sizes were now studied by simulation. Between 5 and 7 runs were carried out on each configuration, different traffic levels being chosen to straddle the critical GOS values for each call type. Graphs relating GOS and traffic were then plotted. From an analysis of these graphs, it was established that the outgoing call produced the most onerous requirement and that the traffic capacity of the exchange would be limited by its performance on this call type.

A useful representation of system performance is to establish the traffic capacity of the system with respect to each of the requirements under consideration. Thus, if T_N, T_{10} and T_{20} are the traffic quantities giving the GOS values specified at normal, 10% and 20% overload, respectively, then T_N, $T_{10}/1 \cdot 1$ and $T_{20}/1 \cdot 2$ represent the traffic capacity of the system with respect to normal, 10% and 20% overload requirements, respectively. The traffic capacities obtained for 6-plane exchange configurations, ranging from 2–10 switching units, with markers fully provided, are shown in Fig. 9. The simulation runs were repeated under marker-failure conditions. This was achieved by holding the faulty marker busy

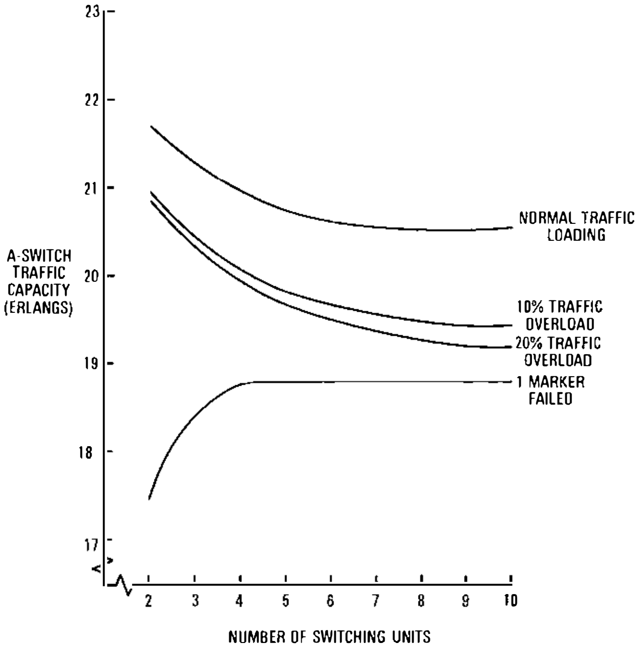


FIG. 9—A-switch capacity (6-plane without planar transfer circuits

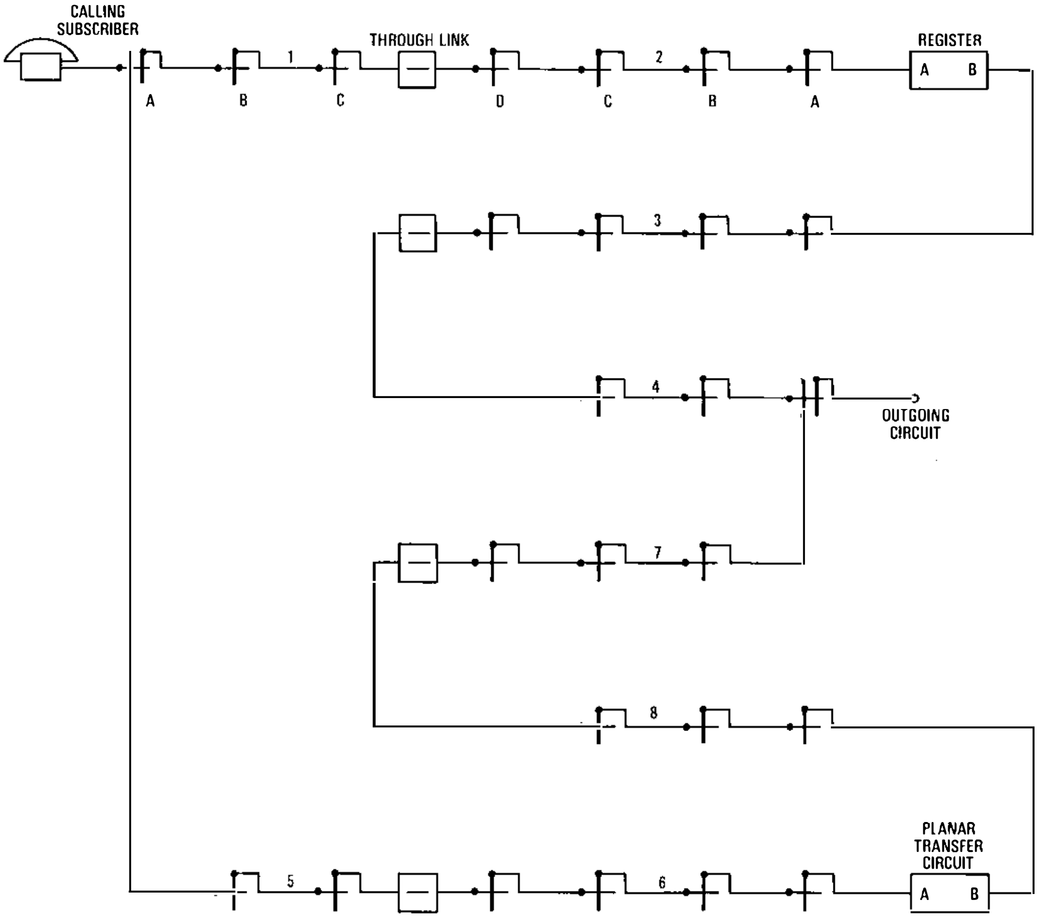


FIG. 10—Subscriber-outgoing call (with planar transfer circuits)

throughout the simulation and measuring the GOS given to subscribers loaded on the unit with the busy marker. These results are also shown in Fig. 9.

Planar Transfer Circuits

The planar transfer circuits act as an overflow device, and provide an alternative path for own-exchange and outgoing calls that fail to route on their final point–point connexion.

The serial trunking sequences for an outgoing call using planar transfer circuits are shown in Fig. 10, and the traffic capacities for the above range of exchange configurations are shown in Fig. 11. It was originally intended to use planar transfer circuits on own-exchange calls only, but, when it was realized that the outgoing call was the limiting case and that planar transfer circuits were very effective in improving the response under marker-failure conditions, it was decided to use them on outgoing calls as well.

General Comment on Results

It is clear from Fig. 9 that a faulty marker has a significant effect on traffic capacity, particularly for the smaller sizes of exchange; on the other hand, the use of planar transfer circuits improves the traffic capacity very considerably; nearly 8% for a 2-unit exchange.

Under marker-failure conditions, the performance improves with exchange size because a smaller proportion of the exchange is affected by the fault. Planar transfer circuits are very effective under failure conditions, and also improve the performance at normal and 10% overload. At 20% overload, however, the extra paths and traffic introduced by the use of planar transfer circuits tend to offset their advantages. This effect is being investigated at present, and it is believed that the effect may be overcome by the use of a more accurate provisioning method. However, this does not detract from the usefulness of planar transfer circuits, the main purpose of which is to overcome the effect of marker failure; this is adequately achieved.

The decrease of normal and overload traffic capacities as exchange size increases is due to D-switch blocking. A full discussion of the mechanism of D-switch blocking is beyond the scope of this article. However, in general terms, this arises due to a C-switch inlet to the D-switch being unable to connect to a corresponding inlet because the latter is engaged to some other unit. This blocking does not, therefore, arise in a single-unit exchange, but it increases with the number of switching units, more or less exponentially, reaching a constant value for exchanges above a certain size.

These configurations very clearly elucidate the exchange traffic characteristics, but are unrealistic for the larger number of units as these will normally have shared markers. This would mean that the marker-failure performance of the larger numbers of units would be somewhat similar to that depicted for the smaller exchanges in Fig. 11 since, when marker faults occur, all units served by the faulty marker will lose a plane of switching and affect a large proportion of the exchange. This is a further justification for using planar transfer circuits over the complete range of exchanges.

CONTROL-AREA SIMULATION

For the control-area simulation study, it was necessary to have extensive details of the operation of the system, with these details being translated into system flow charts describing the processing of calls in terms of the traffic generated on the main control units and registers. The system flow charts

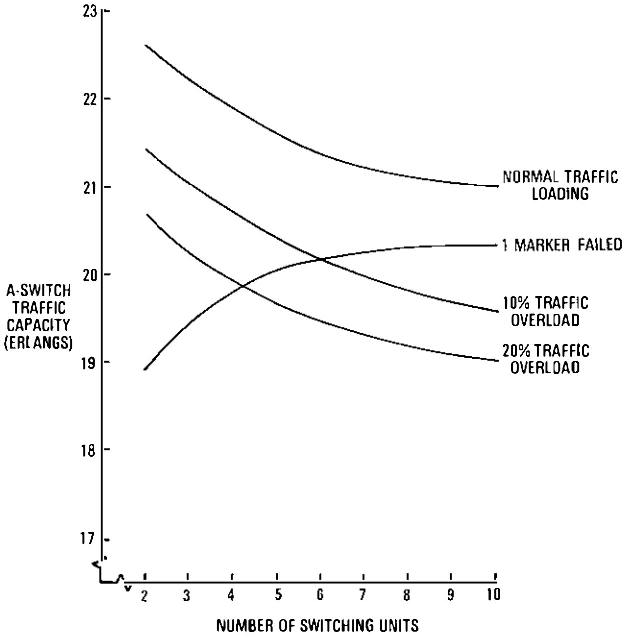


Fig. 11—A-switch capacity (6-plane with planar transfer circuits)

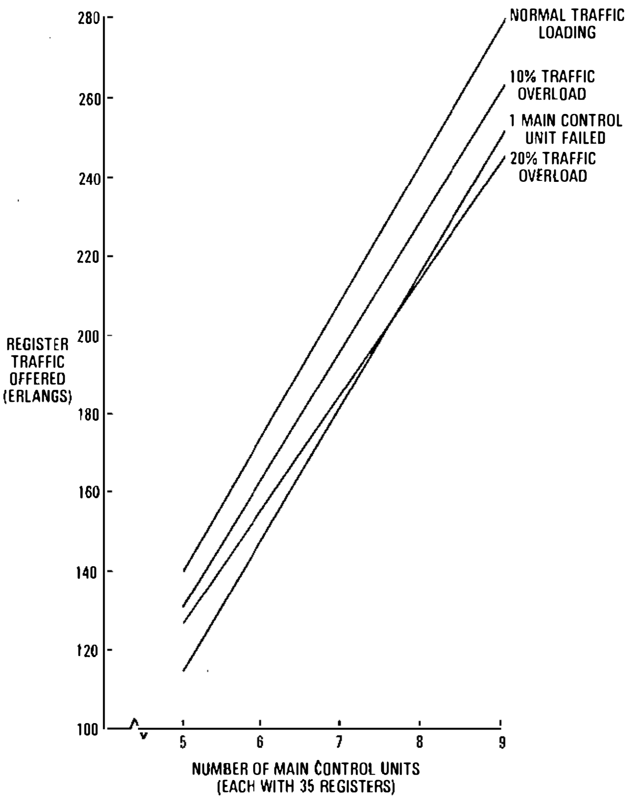


Fig. 12—Capacity of TXE4 control

were then coded into the computer simulation programme. The switching network and paths were not included, but the control traffic generated in the process of path setting was estimated and included for each call type. In collaboration with the Operational Programming Department of Telecommunications Headquarters, a traffic mix comprising 25 call types was selected as being representative of a director exchange, and this traffic mix was used as the standard input to test the system.

The object of the control-area study was to determine the number of main control units and registers required for a given register traffic. This level of provision was determined predominantly by the GOS given to incoming calls. These calls suffer losses in the switching network and so the control configurations were evaluated against the GOS apportioned to them. The originating calls queue for service in the control area and the resulting delays in the application of dialling tone were measured in the simulation. These delays require further study and are beyond the scope of this article.

As in the case of the switching network, a batch of 5–7 simulation runs was carried out for each configuration, at different traffic levels chosen to straddle the GOS of interest. Unlike the switching network, it was not necessary to organize separate simulation runs to examine performance under equipment-failure conditions, as this could be readily interpolated from a configuration having one less main control unit; that is, 9 main control units with 35 registers/main control unit under a fault condition perform identically to 8 main control units with 35 registers/main control unit.

Fig. 12 depicts the traffic capacity of control configurations ranging from 5–9 main control units, each having 35 registers/main control unit. The trend is very similar to that of the switching network when planar transfer circuits are used. Thus, the equipment-failure requirement is the most critical for exchanges with up to 7 main control units, above which the 20% overload becomes the controlling requirement.

CONCLUSIONS

The material presented in this article constitutes only a very limited part of the traffic studies undertaken on the TXE4 exchange system. The aim has been to provide an appreciation of the problems involved in the study, the assumptions that have had to be made, the scope of the study and the central traffic characteristics of the system. The effect of reliability on the exchange performance has set in train a lot of effort to reduce the likelihood of equipment failure. However, the derating of traffic capacity due to overload and exchange equipment failure will obviously ensure a very high standard of performance at normal traffic loads.

ACKNOWLEDGEMENTS

The author wishes to thank his colleagues for their help in the work described and for suggestions on the presentation of this article. The continuous interchange of ideas and information with STC Ltd., and other TXE4 development groups in the BPO, has been of invaluable assistance in the work described.

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Further Considerations of Optical-Fibre Transmission Systems

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UDC 621.391.63: 621.395.4

This article commences with a discussion of the potential areas of application of optical-fibre transmission systems. Detailed aspects such as power-feeding, supervisory and speaker facilities are then discussed as well as some preliminary views on optical-fibre cables.

INTRODUCTION

Optical-fibre transmission systems are versatile in terms of capacity and areas of application in a telecommunications network. The basic system design configuration for a digital system is shown in Fig. 1.

There are prospects that the use of a laser working into monomode fibre, or into graded-index fibre, will enable digital bit rates of 140 Mbit/s, or higher, to be transmitted. These will find primary application on the inter-city trunk routes, where route lengths can be considerable and the use of optical-fibre repeaters spaced at intervals along the route will be necessary.

Light-emitting diodes can be used in conjunction with multimode fibres, but the digital bit rate that can be readily transmitted is, for practical purposes, limited to the range 2–35 Mbit/s. Such systems are probably best suited to applications in the junction network between exchanges and, to a limited extent, for special customer requirements; for example, closed-circuit television. Analogue systems are also a practical proposition for specialized services such as community-antenna television.

The relationship between modulation rate and section length for digital systems has been discussed in detail in a previous article in the *Journal*.[1]

Optical-fibre transmission systems are potentially suitable for application in all parts of a telecommunications network. Possible applications in the British Post Office (BPO) network can be conveniently categorized as shown in Table 1.

A study of the statistics of the BPO network shows that, if the spacing between intermediate repeaters can be made to be about 5 km or greater, then 98% of applications in the local network and 50% of applications on junction routes would not require repeaters. The advantages of not needing to install repeaters, repeater housings and power-feeding equipment are highly significant in terms of financial savings in the local and junction networks, where cost is all important. The lengths of trunk routes vary considerably, and intermediate repeaters are required at intervals along these routes.

POWER-FEEDING ASPECTS

On longer routes, where intermediate repeaters have to be provided, the repeaters must be supplied with power to enable them to function. BPO transmission systems have to meet defined reliability criteria, this being one of many reasons that rule out the use of local mains supplies for energizing intermediate repeaters. The type of power-feeding arrangement to be used will depend on the power requirements of the intermediate repeaters.

At present, it appears that the repeaters for an 8 Mbit/s system might require about 1 W for each direction of transmission. This can conveniently be supplied by a conventional 50 mA direct-current series power-feeding system, having maximum voltages of ±75 V. With a power-feeding current of this magnitude, the voltage drop across each repeater will be nominally 20 V, although there is every hope that, in time, this will be reduced to 15 V or possibly even 12 V. The arrangement envisaged is very similar to that already used on existing pulse-code-modulation (PCM) line systems.

The power requirements for higher-order systems are likely to be such that the arrangement described above will not provide adequate spacing between power-feeding stations. Accordingly, a remote power-feeding system, based on that used on the 60 MHz analogue systems,[2] and to be used on high-speed digital systems on coaxial cables, may be used.

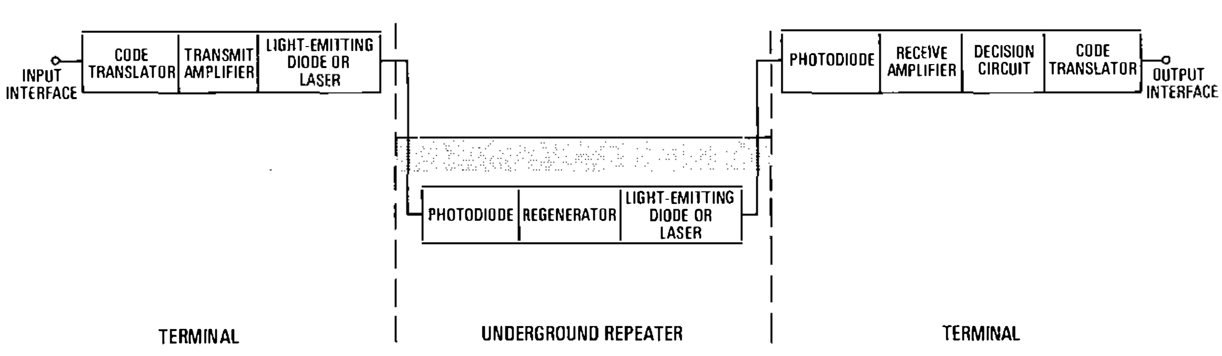

FIG. 1—Block diagram of a typical optical-fibre digital transmission system

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TABLE 1

Possible Areas of Application of Optical-Fibre Transmission Systems in Telecommunication Networks

Network Application	Route Length (km)	Transmission Capacity (Mbit/s)	Need for Repeaters and Spacing (km)	Need for Power Feeding
Local (exchange to subscriber)	Up to 5	Up to 35	Not required	Not required
Junction (e.g., exchange to exchange)	Up to 5	Up to 140	Not required	Not required
	Over 5	Up to 140	Required (2–10)	Required
Trunk (e.g., main switching centre to main switching centre)	Up to 280	Up to 500	Required (2–10)	Required

This would be capable of supplying a power-feeding current of up to 300 mA with a total line voltage drop of 1000 V. The power-feeding current, which is fed to all the repeaters in one direction of transmission in a series configuration, can be carried inside the same cable sheath as the optical fibres, either on metallic interstitial pairs, on metallic tensioning wires, or on both. Alternatively, a separate multi-pair power-feeding cable can be used. This type of system permits dependent repeaters to be sited in buried equipment housings, as is the current practice on existing analogue and digital line systems.

A simplified block diagram of a power-feeding system for supplying a current of up to 300 mA is shown in Fig. 2. The power-feeding stations at each end of the system are surface buildings and, for economic reasons, it is desirable to achieve as large a spacing between them as possible. The power-feeding station spacing is, however, a function of the repeater spacing, the voltage drop across each repeater, and the size of conductor(s) used to carry the power-feeding current. The relationships between these factors are shown in Table 2.

Reliability of Power-Feeding Arrangements

Studies have shown that a power-feeding system in which a pair of conductors is allocated to each both-way optical-fibre transmission system is preferable to one that has one pair of large-diameter conductors allocated to a number of both-way optical-fibre transmission systems. The reason for this is that, although the reliability of each optical-fibre transmission system is the same for each method, the availability of the former is much greater than the latter. Also, greater security of service is obtained using the former, because the failure of a power-feeding equipment at one terminal affects only one optical-fibre transmission system; in the latter case, failure of the power-feeding equipment causes the failure of all the systems.

Consider, for example, 9 both-way optical-fibre co-terminal transmission systems that can be power fed in either of the following 2 ways:

(*a*) one power-feeding system for each both-way optical-fibre transmission system, and

(*b*) one power-feeding system for all 9 optical-fibre transmission systems.

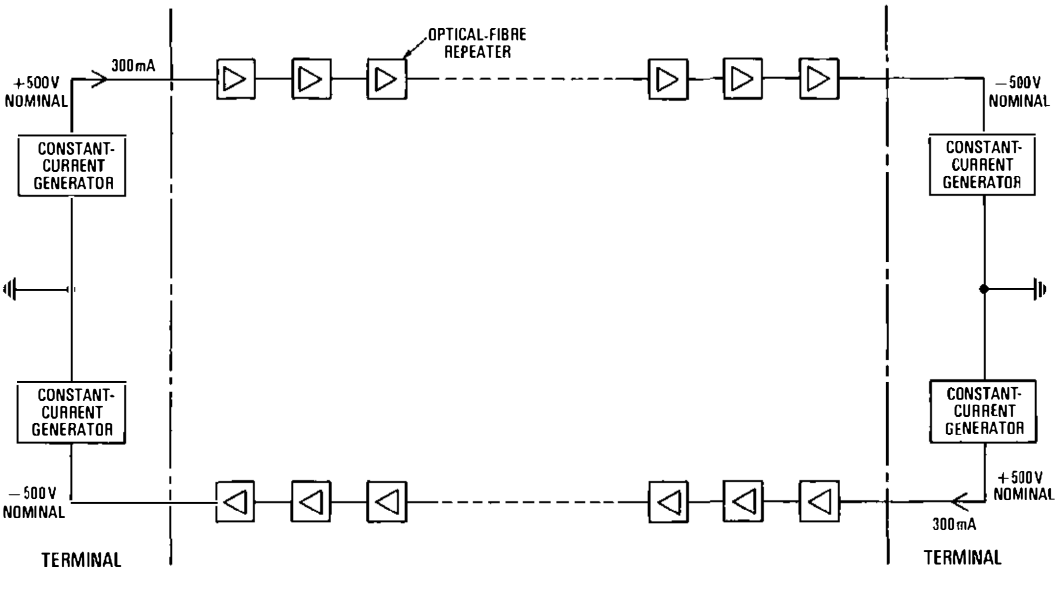


FIG. 2—Simplified block diagram of a 300 mA power-feeding system

TABLE 2

Maximum Power-Feeding Station Spacings

Assumed Voltage Drop/Regenerator (V)	Conductor Diameter (mm)		Regenerator Spacing			
			2 km		10 km	
	Copper	Aluminium	Number of Regenerators	Maximum Power-Feeding Section Length (km)	Number of Regenerators	Maximum Power-Feeding Section Length (km)
25	2·6	—	37	76	28	290
	1·2	—	28	58	13	140
	0·9	—	23	48	8	90
	0·63	—	17	36	5	60
	0·5	0·7	13	28	3	40
10	2·6	—	83	168	50	510
	1·2	—	51	104	17	180
	0·9	—	35	72	10	110
	0·63	—	23	48	5	60
	0·5	0·7	17	36	4	50
6	2·6	—	125	252	$\gg 50$	$\gg 510$
	1·2	—	64	130	18	190
	0·9	—	42	86	10	110
	0·63	—	25	52	6	70
	0·5	0·7	18	38	4	50

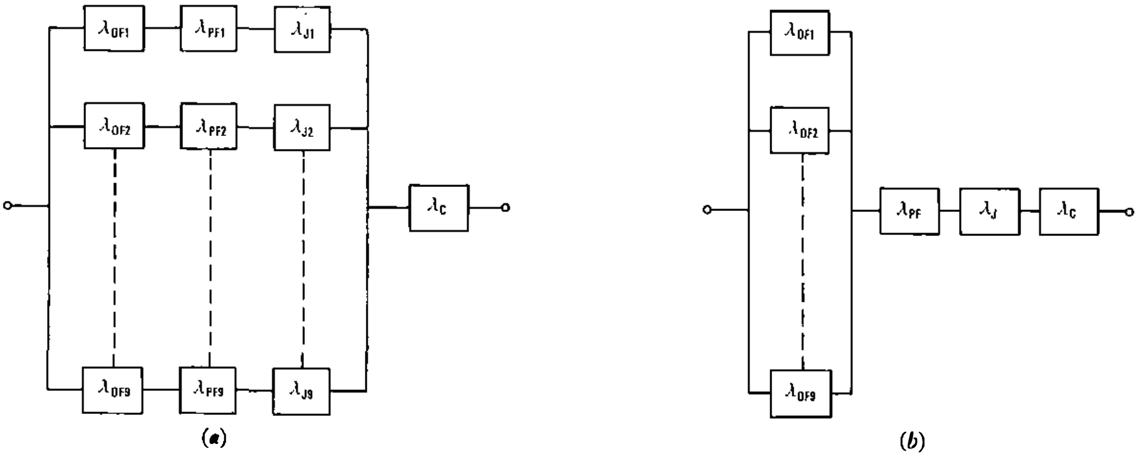
TABLE 3

Reliability Calculations for Different Methods of Power-Feeding

Parameter	Symbol	Single Power-Feeding System for each Optical-Fibre Transmission System	Single Power-Feeding System for 9 Optical-Fibre Transmission Systems
Failure rate of a single optical-fibre transmission system	λ_S	$\lambda_{OF} + \lambda_{PF} + \lambda_J + \lambda_C$	$\lambda_{OF} + \lambda_{PF} + \lambda_J + \lambda_C$
Typical mean time between failures for single optical-fibre transmission system	$MTBF_S$	1·3 years	1·3 years
Defect rate for all 9 optical-fibre transmission systems	λ_D	$9\lambda_{OF} + 9\lambda_{PF} + 9\lambda_J + \lambda_C$	$9\lambda_{OF} + \lambda_{PF} + \lambda_J + \lambda_C$
Typical mean time between defects for all 9 optical-fibre transmission systems	MTBD	0·24 years	0·36 years
Failure rate for all 9 optical-fibre transmission systems (simultaneously)	λ_T	λ_C	$\lambda_{PF} + \lambda_J + \lambda_C$
Typical mean time between failures for all 9 optical-fibre transmission systems	$MTBF_T$	3·0 years	1·96 years
Availability of all 9 optical-fibre systems		$\frac{MTBF_T}{MTBF_T + MTTR}$	$\frac{MTBF_T}{MTBF_T + MTTR}$
Typical availability (equipment, optical-fibre cable and power-feeding cable)		99·998%	99·996%

Notes:

λ_{OF} = failure rate of optical-fibre equipment (MTBF assumed to be 4 years/160 km)
λ_{PF} = failure rate of power-feeding equipment (MTBF assumed to be 100 years/power-feeding section)
λ_J = failure of joints in power-feeding conductors (MTBF assumed to be 6 years/160 km)
λ_C = failure rate of complete power-feeding cable (MTBF assumed to be 3 years/160 km)
MTTR = mean time to repair (assumed to be $6{\cdot}85 \times 10^{-5}$ year = 36 min)
MTBF = 1/failure rate
MTBD = 1/defect rate



(*a*) For arrangement having one power-feeding system for one optical-fibre transmission system
(*b*) For arrangement having one power-feeding system for all 9 optical-fibre transmission systems

FIG. 3—Reliability models

The reliability figures for each arrangement are shown in Table 3.

The figures given in Table 3 were derived using series/parallel reliability models that took account of the failure rate of each constituent item (see Fig. 3(*a*) and (*b*)). The calculations made assumed a route length of 160 km, that there were no stand-by systems, and that the probability of simultaneous failures occurring in the parallel path of the failure model is insignificant. For each individual optical-fibre transmission system (including power-feeding equipment), the number of potential failure mechanisms is the same. Thus, the mean time between failures, or the failure rate, of a single optical-fibre transmission system is also the same. However, there the similarity ends; for the potential failure rate and the overall availability of all 9 systems is much superior where there is one power-feeding system allocated to each optical-fibre transmission system.

Economic Aspects of Power Feeding

It is expected that one of the main advantages of optical-fibre systems will be their low cost/circuit-kilometre. The cost of provision of a power-feeding cable is not expected to increase the cost/circuit-kilometre significantly, since each pair of power-feeding conductors will be energizing repeaters which carry, for example, 1920 circuits for a 140 Mbit/s system. Thus, the increased cost per circuit will be only 1/1920 of the cost of the power-feeding pair and is, therefore, unlikely to be significant, especially since this pair need only cater for power feeding (and possibly some supervisory signals) with a consequent low cost. The metallic pairs used for power feeding would not, of course, be capable of carrying more than one audio circuit, or, at the most, 30 channels by means of PCM.

It appears, therefore, that the cost of provision of power-feeding conductors is probably not as significant as was once thought; accordingly, power-feeding systems, as described above, seem to be feasible on both economic and technical grounds.

SUPERVISORY FACILITIES

The supervisory facilities can be conveniently categorized into the following 3 distinct functions.

Within-System Digital Supervision

Such a supervisory system would monitor the digital error rates at the electrical interfaces and give indications of the performance of the optical-fibre link at any point in time. The precise method of monitoring the performance is a function of the digital-coding scheme used and is, therefore, outside the scope of this article.

Cable-Fault Location

The optical-fibre cables and equipment housings (if of the buried variety) may need to be pressurized, to prevent the ingress of water if a fault develops in the cable sheath or in the equipment housing, Cable-pressure fault-location equipment is already used on existing high-capacity coaxial line systems, and it is expected that similar systems could be used on optical-fibre cables. Such systems monitor the operation of air-pressure contactors located at cable joints and in buried equipment housings, and the time taken for them to operate as the air pressure along the route falls from the normal 160 kPa (1600 mbar) to 120 kPa (1200 mbar)—the contactor operating pressure. The operation of each contactor causes a tone to be transmitted on low-loss metallic cable pairs back to the terminal, where they are monitored. The frequency of the tone, in the range 0·92–14·2 kHz, is specific to a particular contactor. Using this system, cable-fault locations can be made from a terminal station to within ±100 m of the fault.

Laser Shut-Down

Some authorities have suggested that high-speed optical-fibre transmission systems (140 Mbit/s and above) using laser light sources, although producing coherent light of relatively low power (1–2 mW typically), might conceivably cause damage to the eyes of staff working on optical-fibre cables if special precautions are not taken. The BPO is particularly safety conscious and takes all reasonable steps to prevent accidents.

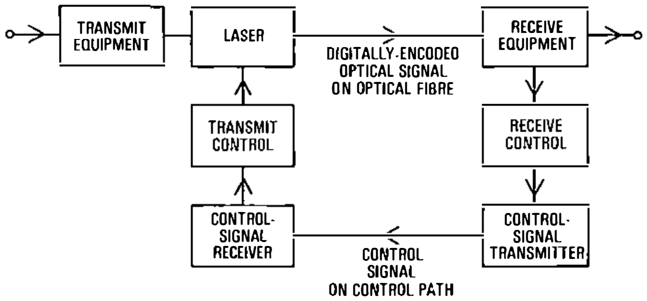


FIG. 4—Block diagram of a possible laser shut-down control system

Whilst it may be possible to issue suitable optical filters that could be worn as spectacles, a possible better solution is to arrange for the instantaneous shut-down of the laser light source whenever the optical fibre is disconnected, be it purposely or accidentally. A suitable control system is shown in Fig. 4.

The laser light is detected in the receive equipment of each power-feeding section. Absence of light for a predetermined period inhibits a tone that is normally transmitted from the receive equipment back to the transmit equipment by suitable means, for example on the power-feeding pair. Inhibition of the tone causes the laser to shut-down, thus rendering the system safe. This principle is fail-safe because absence of the tone causes the laser to shut-down. Thus if, for instance, the return path is disconnected, the laser still shuts down.

SPEAKER FACILITIES

Whenever cables are laid in underground ducts, with electronic equipment spaced at intervals along the route, it is necessary to provide facilities to enable maintenance personnel to communicate with the surface stations and sometimes with other points along the route. It is also necessary for surface stations to be able to intercommunicate. Exchange lines are not normally used as engineering speaker circuits because they may well be routed over the very system that has failed. Current practice is to use metallic interstitial pairs that are normally made available for this purpose. The speaker systems are usually 4-wire audio-frequency circuits, routed on 0·63 mm or 0·9 mm cable pairs loaded at appropriate intervals, with audio amplification at surface stations. Signalling between surface stations, and between surface stations and intermediate points along the cable route, is achieved in various ways. The standard system, in current use on 12 MHz[3] and 60 MHz[4] analogue and 120 Mbit/s digital coaxial line systems, involves digital signalling in which the number of 800 Hz pulses transmitted after an appropriate guard signal corresponds to the code of a particular surface station. Up to 20 stations can be coded with this system.

NEED FOR METALLIC PAIRS

Metallic pairs are essential for power feeding. For a given repeater and surface-station spacing, the metallic pairs should be designed to meet the power-feeding and other requirements at minimum cost. Parameters to be taken into account are d.c. resistance and size. The requirement for the speaker is that there should be an adequate transmission performance over the audio band of nominally 0·3–3·4 kHz. Supervisory facilities can be provided either on the same pair or by other means.

Consideration of these various requirements and reference to Table 2 suggests that 0·63 mm conductors might be suitable in terms of size, cost, d.c. resistance and transmission performance.

CABLE ASPECTS

The number of fibres constituting an optical-fibre cable will vary according to its usage. Economic studies have indicated that there should be a range of cable sizes, much the same as the existing coaxial-cable range, to cater for all types of routes with both high and low growth-rates. It is expected that about 25 % of fibres might be provided as spares.

Experimental cables being developed in the UK will initially contain about 6 fibres, and effort will be concentrated on ensuring that mechanical strength and flexibility are adequate for normal cabling operations. Metallic pairs, required for power-feeding, speaker and supervisory purposes on trunk routes, will not be incorporated in the optical-fibre cable immediately, but will probably be provided separately in relaxed-standard audio cable; typically, a 28-pair/0·63 mm cable for an 18-fibre cable carrying 9 both-way systems. However, there is little doubt that interstitial wires will be incorporated in the optical-fibre cable, in due course, once sufficient practical experience with an all-fibre cable has been obtained.

It is desirable to minimize the number of joints, not only to keep the attenuation to a minimum and reliability to a maximum, but also to avoid the necessity for making the joints in inclement environments. This implies that manufactured cable lengths should be as long as possible, and it is hoped that lengths of up to 2 km will be manufactured and pulled into ducts without undue difficulty in due course.

One of the major causes of service failure, particularly on trunk routes, are cable faults due to civil engineering works. Cables on trunk routes are normally laid in ducts at depths of around 0·9 m, but greater security of service can be achieved by increasing the depth to 1·2 m, as on 60 MHz analogue systems.

Means of identification of the different fibres within a cable may be considered desirable in some, if not all, applications. It is envisaged that this could be achieved by either colour-coding or providing numerical indications on the protective coating surrounding each fibre.

The effect of the ingress of water into an optical-fibre cable on the transmission performance has still to be studied in detail, but it may well be desirable to pressurize the cables as on existing metallic-conductor cables, these being pressurized to 160 kPa (1600 mbar). Pressurization will be particularly important if metallic interstitial wires are incorporated in the optical-fibre cable.

CONCLUSIONS

There are no simple answers to transmission system design, and the design of optical-fibre transmission systems is no exception. System design is a compromise of all the factors involved, not least of which are economic and reliability criteria. The power-feeding problems may not be the obstacle that many at one time thought, and the introduction of optical-fibre transmission systems does not seem likely to be inhibited by the need to provide power-feeding arrangements.

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A Survey of Recent Test-Equipment Development in the British Post Office Factories Division

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This article describes some recently-developed test-equipment, the essential object of which is to assist the British Post Office Factories Division to discharge its responsibilities to the Telecommunications Business at a reasonable cost, and with acceptable quality and delivery times.

INTRODUCTION

The British Post Office (BPO) Factories Division is responsible for the repair, servicing and manufacture of a wide range of telecommunication equipment. This work, which is carried out at 8 factory sites by a staff of about 4000, has an annual value of over £25M. Cost, delivery times and quality are factors of paramount importance in the Factories Division's activities, and these activities involve many types of equipment having differing technologies, complexities, shapes and parameters. The factory managers are responsible for meeting commitments to customers, and maximizing production efficiency. In this, they are supported by specialist Headquarters groups, having expertise in such disciplines as work study, quality assurance, production and mechanical engineering, factory services and test-equipment development. The corporate efforts of the whole assist the Factories Division to achieve its business objectives.

Test equipment is necessary to support the Factories Division's activities for several reasons; in particular, that customers (that is, the Supplies and Contracts Divisions of the Purchasing and Supply Department, and users in the field) need to be assured that, when equipment is repaired, serviced or manufactured, it meets its performance specification. This assurance is provided within Factories Division by a 2-stage inspection scheme, involving both production and quality-assurance staff. Test equipment is required to assist production; for example, in ensuring that sub-assemblies, such as printed-circuit boards, function correctly prior to being assembled into complete equipments. Test equipment is also helpful in the diagnosis and rectification of faults. By a careful definition of the testing requirements, in conjunction with work study and process and quality engineering, the basic hardware for efficient and economical production processes can be designed and provided. The choice of the testing system depends upon many factors, such as capital cost, estimated development time, and production, delivery-time, quality and cost objectives.

The range of items requiring test equipment includes customer items, such as telephones, teleprinters and Datel modems, and system equipment, such as Strowger relay-sets, 2-motion selectors, mobile-non-director-exchange and PABX equipment, pulse-code-modulation (PCM) and video units, and automatic routine testers (Testers TRT), to name a few examples of the 1500 products with which the Factories Division is presently concerned. Whatever the product, the provision of efficient test equipment, with stable circuitry, robust connexions, and displays that quickly provide test-status information, together with efficient testing methods, are of fundamental importance to the organization of work and its quality and cost.

The basic requirements, which must be satisfied in providing test equipment for the Factories Division, are

(*a*) to test an item in such a way that its performance specification is satisfied,

(*b*) to provide consistent and reliable test results to the satisfaction of the Factories Division's production and quality-assurance groups,

(*c*) to provide test equipment having short test-cycle times, which is simple to use and easily maintained and calibrated,

(*d*) to provide ergonomically-designed portable test equipment, which can be easily moved and incorporated into factory processes,

(*e*) to provide a method of connexion to the unit under test, involving the design and construction of jigs and fixtures,

(*f*) to provide training to enable factory staff to maintain and use the test equipment, and to supply documentation and handbooks, and

(*g*) to satisfy requirements (*a*)-(*f*) economically.

The following sections briefly describe a few of the test equipments recently developed in the Factories Division.

PROGRAMMABLE AUTOMATIC TESTERS

The range of work within the Factories Division concerned with the renovation, repair and construction of different types of Strowger equipment emphasizes the need for a programmable automatic testing system that can carry out both functional and diagnostic tests on any electromechanical equipment, and can be easily transported either between different working positions or, if necessary, between different factories. A wired-programme tester, using electromechanical-routiner principles, was initially designed to establish the feasibility of the programmed-tester approach. The second phase of the development, using modular-construction principles and integrated-circuit techniques, provided a family of 3 basic programmable automatic testers (PATs). The 3 testers, PAT 1, PAT 2 and PAT 3, are all controlled from 8-track punched paper tapes, and their functions are described below.

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PAT 1

PAT 1 is a diagnostic tester, designed to check printed-circuit-board tracks, or wiring continuity, and component values. The tester provides GO/NO-GO information of resistance and capacitance values; that is, it indicates either that conditions are correct or that they are not, but gives no additional information. Diodes and transistors are checked as resistances for forward-bias and reverse-bias conditions. The main use of PAT 1 in the Factories Division is in the repair of Telephone No. 722 and Telephone No. 746 printed-circuit-board assemblies, and in testing printed-circuit-board sub-assemblies, connexion strips, and plugs and cords for Testers TRT.

PAT 2

PAT 2 has additional capabilities, including that of the dynamic measurement of transistor gains on energized printed-circuit boards. Its initial use in the Factories Division is in the repair of printed-circuit boards for Loudspeaking Telephones No. 4 and Tone Callers No. 8A. Future applications for electronic-device servicing work are being investigated.

PAT 3

PAT 3, illustrated in Fig. 1, is the largest of the range, and is designed primarily to carry out functional or diagnostic testing of Strowger-type selectors and relay-sets. About 50 different controlling programmes have been written to date, and the library is being increased continually.

Principle of Operation

All the PATs are similar in principle and use the same types of printed-circuit-board modules, which are interchangeable for maintenance purposes. The essential differences between them are concerned with the provision of test facilities, and switching and test-access capacities, these being determined by the economics of providing functions that might be used only occasionally.

The PATs are controlled from a pre-programmed 8-track paper tape. Each instruction, consisting of an 8 bit word, is sensed by a tape-reader and decoded to control the switching of a relay matrix, consisting of an assembly of plug-in modules on which Type 23/16 Relays are mounted to provide a one-inlet-to-30-outlets switch. A range of switching configurations can be assembled into a PAT system by the addition of matrix modules; in PAT 3, for example, a 45-inlets-to-90-outlets switch has been found to be the most suitable. The matrix, in switching under the control of the paper-tape programme, routes the test function required to the unit under test via a connecting jig. A route is also set up to measuring circuits, enabling GO or NO-GO decisions to be made.

A range of test facilities has been developed on printed-circuit-board modules, including oscillator, filter, attenuator and window-discriminator circuits, these being voltage-controlled devices using summing-amplifier techniques, set up automatically from the paper-tape programme. Also available as printed-circuit-board-module facilities are a range of 50 V battery and earth test conditions, no-tone detectors and dial-pulse generators, the last providing standard-line, long-line and leaky-line impulsing conditions. Repeat-test facilities are included in the testers, and PAT 3 also has a self-test capability, using a special test-routine programme. Failure of any test is indicated by a TEST-FAIL condition, and the test at which the failure occurred is identified by a number.

The PATs are not difficult to programme using instructions identified by 8 bit words, but work is now proceeding on a simpler programming technique, using a mnemonic language that can be translated into the tester code using a time-sharing computer terminal.

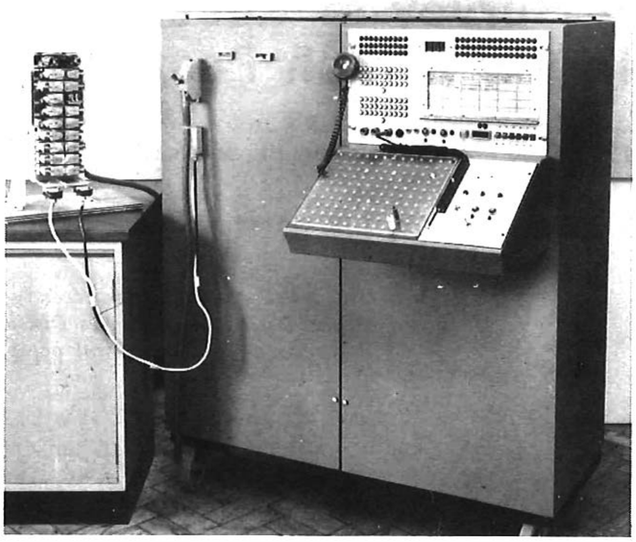

FIG. 1—PAT 3

Range of Use

The use of PATs on all the main processes in the Factories Division is now established. Of special note is their use on telephone-instrument printed-circuit-board repair, automatic-routine-tester manufacture, relay-set manufacture and repair, mobile-exchange construction, and 2-digit-sender construction. The range of work on which they will be used will increase significantly, and the experience gained so far indicates that they are simple and reliable to use, and enable a much greater degree of testing flexibility to be simply obtained by means of changes to the paper-tape programme. Fast test-cycle times are possible within the restrictions imposed by relay operate and release times, enabling improved production rates to be obtained at an acceptable quality.

PROGRAMMABLE AUTOMATIC CONTINUITY TESTER

Continuity testing of large wiring multiples and forms is very time consuming when carried out by traditional buzzing-out methods. To reduce the problem, a special form of PAT, called a *programmable automatic continuity tester* (PACT), was developed. This tester is controlled from a paper-tape programme and, as before, connects test facilities to test outlets. In this case, the outlets consist of uniselector banks, arranged to enable the continuity of up to 8 wires to be checked simultaneously. The test capacity of the PACT enables up to 1800 wires to be tested in 1–2 min. The test functions provided include continuity tests (for a maximum resistance of 5 Ω), 50 V battery and earth facilities, and window-discriminator circuits. The PACT will facilitate the repair of PABX Nos. 1, 5, 6 and 7, and PMBXs No. 4/1. Connexion to the units under test is made via special jigs inserted into relay-set and selector jacks and connected to termination blocks. Operating and programming procedures are similar to those of the PATs.

10-DIGIT-DISPLAY AND CALL-SENDER UNITS

As part of the PAT development and, in particular, for the functional testing of mobile exchanges, digit-display and call-sender units were designed, to extend the PAT 3 testing facilities.

The digit-display unit enables 10 pulses/s pulse trains, of up to either 10 or 16 digits length, to be monitored at any point in an exchange-trunking network. It includes automatic resetting facilities, and recognizes inter-train pauses.

The call-sender is designed to check the performance of exchange equipment during the transmission of a selected test call and, by means of a key pad, up to sixteen 16-digit numbers can be programmed into the tester's metal-oxide-semiconductor memory. The unit can be connected to any appropriate part of the exchange-trunking network; for example, the subscriber's uniselector circuit at the intermediate distribution frame. When the required pulsing-out conditions have been selected, pulsing-out proceeds automatically on receipt of dial tone. The unit monitors the conditions returned to it, both during the setting-up and completion of the call, including the positive-wire, negative-wire and P-wire conditions, metering conditions, and number-unobtainable and ringing tones, and provision is made for a meter-recording of successful and failed calls. Calls can also be audibly monitored. Continuous cycling of the test-number sequences, or single operation, can be selected.

Both units use the 50 V exchange supply, d.c.-d.c. converters being used to derive the logic-circuit supply voltages. High-impedance input circuits are used. A gating technique, using light-emitting devices, very effectively minimizes interference from extraneous pulses coupled into the signal leads from the Strowger environment.

TELEPHONE AND DIAL TESTERS

The repair of telephone instruments of all types is one of the more important activities of the Factories Division. A previous article[1] has described the telephone-testing equipment, and this remains the principal testing method used. The introduction of new types of telephone instrument, however, and the possibility of using PAT principles to achieve more efficient and flexible testing procedures, have led to a development programme being initiated with the object of modernizing and improving the telephone-testing equipment. This work is still proceeding and is summarized below.

PAT 1

PAT 1 is used to test telephone-instrument printed-circuit boards. The board is located in a jig and, under the control of a paper-tape programme, the tester measures the values of all the components, as well as checking the continuity of the track. A test result outside specified tolerance limits is indicated as a fault, and rectification is then carried out by changing the appropriate component. After retesting, the printed-circuit board can be used as a piece-part in the assembly of refurbished telephone instruments. The testing principles previously outlined enable off-line repair to be readily carried out for a range of different printed-circuit-board sub-assemblies, such as those for the Telephone No. 746 and Telephone No. 722. A special feature of the test procedure is a check of the handset microswitch sequence.

Dial Testers

The testing of telephone dials is an essential activity in both telephone-instrument and dial repair processes. Accurate measurements of dial speed and pulse ratio, check of the off-normal spring-set operation and release, check of the pulsing-contact resistance, and tests for framing (that is, contacts between the circuitry and the frame) are important factors. Dial testers, based on integrated-circuit techniques, have been developed and are now in use, enabling the above and other parameters, such as the number of pulses generated, to be measured during one operation of the dial. A later design, using a large-scale-integrated-circuit arithmetic device, enables pulse-ratio measurements to be automatically derived from the dial-speed measurement by counting clock pulses during the dial-return period. Displays for either tester can be provided as GO/NO-GO indications or as a digital read-out.

Telephone Testers

New testing methods for measuring the transmission characteristics of telephone instruments are under development, and will include calibrated standard-signal sources and level-measuring facilities. These, and other facilities, together with the electronic dial tester, will be provided in a new functional tester, which will be used in an improved Telephone No. 746 repair process at Cwmearn Factory.

ELECTRONIC EQUIPMENT REPAIR

A growing part of the Factories Division's activities is concerned with the repair of electronic equipment, such as video amplifiers, PCM apparatus, and telegraph equipment. This work is largely carried out as a direct service to regions and areas, and forms the third-echelon repair-stage, as defined under the Service Department's electronic-equipment-repair policy. (The first echelon is on-site repair at the exchange or repeater station, and the second echelon is repair at a regional electronic repair centre.) The Factories Division's involvement at the third-echelon repair-stage is decided in consultation with the Service Department and users in the field, and is determined by equipment populations, complexities and mean times between failure. The range and complexity of the items the Factories Division has been requested to repair has required the development of specialized test equipment, enabling the efficient repair of complex electronic units to be carried out at low cost and high quality. A few of the test equipments developed for this work are briefly outlined in the following paragraphs.

TEST EQUIPMENT FOR VIDEO AMPLIFIERS

The testing of video amplifiers involves pulse-and-bar measurements[2] to very precise limits, and the difficulties resulting from the use of conventional measurement methods in a situation involving a considerable number of amplifiers led to the development of a simpler and more precise measuring technique using integrated-circuit devices. A simplified block diagram of the new test unit is shown in Fig. 2.

The circuit measurements are referenced to the synchronizing-pulse-separator output. These pulses are used to derive strobe pulses, the width and position of which can be adjusted such that measurements can be made at any point on the test waveform. By using the Z-modulation facility on an oscilloscope, means can be provided for indicating the position of the strobe pulses as a "bright-up" display on the test waveform. The synchronizing pulse is also used to derive timing pulses which ensure that the test waveform is clamped to black level between the pulse and the bar, all measurements being referenced to black level.

The clamped waveform is taken to pulse-measuring and bar-measuring circuits, which are similar, except that the pulse-measuring circuit can measure positive or negative peaks. Both circuits measure peak voltage using special diode-pump techniques. The voltage derived at the output of the pump circuit is recorded by a digital voltmeter, which can be made to read pulse and bar heights and ratios by the operation of appropriate push-buttons.

The clamped waveform, the peak-amplitude measurement and the strobe-pulse waveform are used in additional circuitry to enable accurate measurement of the half-amplitude duration[2] of pulses. By gating the outputs of 2 comparator circuits, a square-wave pulse, whose duration is equal to the

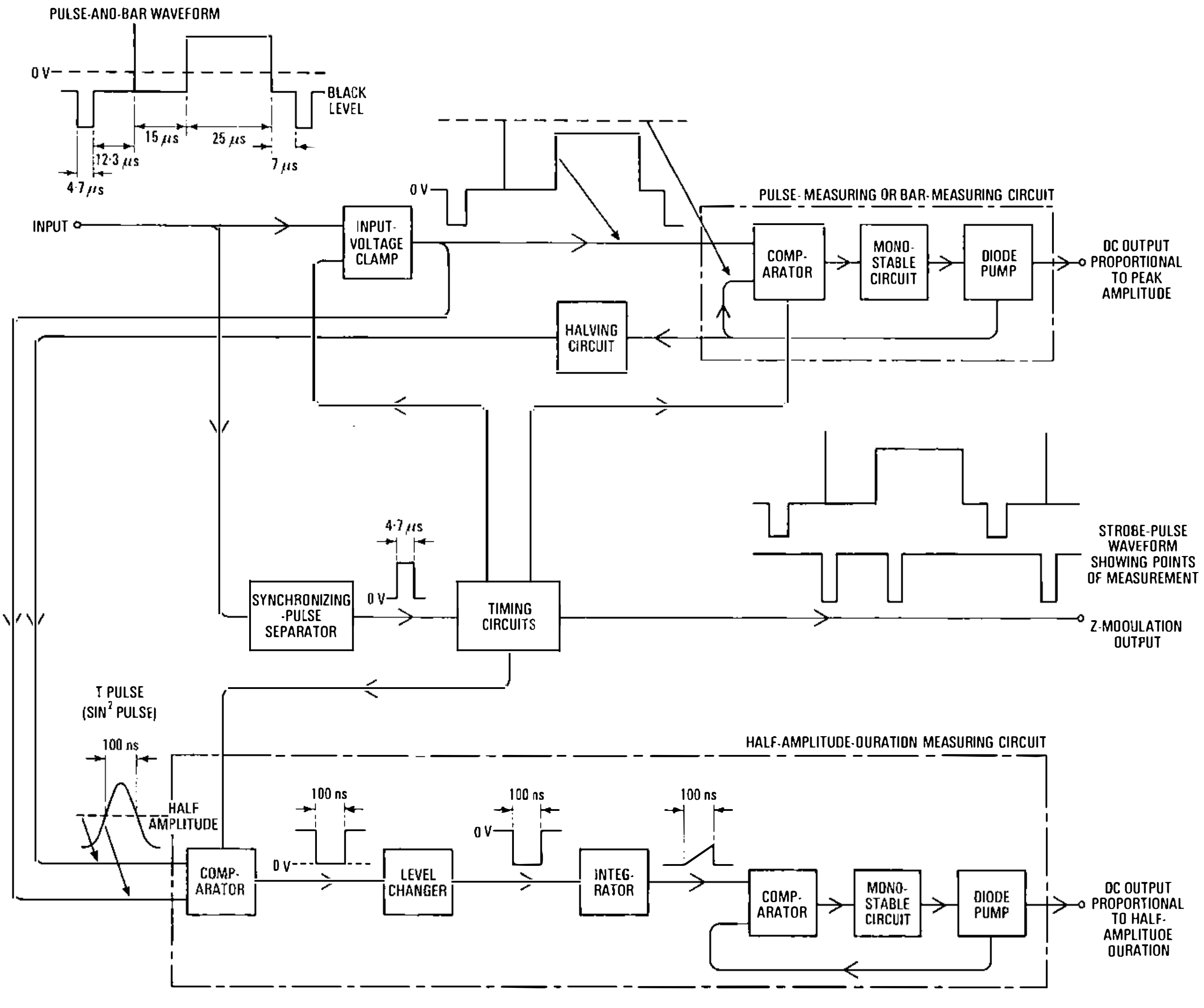

FIG. 2—Block diagram of the video-amplifier test unit

half-amplitude duration, is derived. This pulse is used to drive a field-effect-transistor integrating circuit having an extremely linear ramp characteristic, the integrating capacitor being discharged at the end of each pulse. By feeding the ramp waveform so derived into a comparator and diode-pump circuit, a direct voltage, proportional to the half-amplitude duration, is obtained, and is displayed directly as a time measurement on a digital voltmeter where 1 mV ≡ 1 ns. This technique enables the half-amplitude duration of T and 2T pulses[2] to be readily measured to an accuracy of ±1 ns.

The use of similar techniques enables the test unit to provide also direct measurements of non-linearity of the luminance channel,[3] by comparing the minimum and maximum riser voltages for a 5-step waveform, and of differential gain and differential phase,[3] each measurement being selected as required by operating an appropriate push button.

The development of this testing system has enabled the Factories Division to repair and calibrate video equipment to new standards of accuracy ($K = 0{\cdot}1\,\%$, where K is the rating factor[2]), both economically and at high quality.

PCM TEST EQUIPMENT

All the London Telecommunications Region's PCM unit repair is now carried out at Enfield Factory. At the start of this work, it was decided, for technical and organizational reasons, not to test PCM units within the multiplex, but to design test equipment that would automatically apply system conditions to the unit under test, make measurements, and show the presence of a fault by means of a NO-GO indication. By deriving the test conditions from a crystal-controlled clock, oscilloscope displays can be readily phase-locked and compared at different parts of the circuit. The testers display information to indicate the area of the circuit in which the repair technician should seek the fault. Faulting schedules, together with the use of an oscilloscope or a logic probe, then aid the identification of the faulty component. Experience has shown that the testing philosophy adopted has been successful in enabling PCM equipment to be repaired quickly at low cost and high quality.

The test equipment is briefly described in the following paragraphs. Each item, in common with all other items repaired by the Factories Division, required the preparation of detailed repair specifications. This presented some problems, because PCM specifications, in general, apply to the complete multiplex and not to individual units.

Channel-Card Tester

The channel-card tester automatically tests cards in a test-cycle time of either 2·5 s or 25 s. The occurrence of a fault is indicated by a lamp display, one lamp being related to each specific test on a particular part of the circuit. A 768 kHz crystal-controlled oscillator is used to generate clock pulses, signal frequencies and stepping signals for sequenced switching of the controlling logic. Level-detector and comparator circuits are used to measure gains, filter responses and adjacent-channel crosstalk. The tester includes a facility for heating the cards under test to approximately 46°C, and can also apply continuous-routine tests.

Different contractors' units are catered for by changing a wired-programme plug, which modifies the tester's connexions and conditions as necessary.

Signalling-Card Testers

Separate test equipments have been developed for outgoing and incoming signalling cards. Fig. 3 shows the incoming-signalling-card tester. Each tester can be sequenced manually or automatically, the test-cycle time in the latter case being between 40–60 s; the number of tests applied is dependent upon the signalling direction of the unit. The tests simulate normal and extreme operating conditions, and provide timing, transmission and extra-facility tests as detailed in the relevant BPO specifications. During the tests, timer displays and lamps indicate correct or incorrect circuit conditions. Any fault detected is displayed on a lamp until reset. The card-heating facility is also provided.

Regenerator Tester

The regenerator tester requires manual operation, and incorporates a Tester No. 168A and a modified Generator Pulse No. 2000A, as well as additional pattern-generating and pattern-measuring circuits. The pattern generator enables pseudo-random and manual word patterns, and sequences consisting of 17 marks (binary 1) followed by 15 spaces (binary 0), known as *17/15 patterns*, to be selected. Pulse-height, pulse-width and delay measuring circuits are included. The occurrence of an incorrect positive or negative pulse height, or pulse width, is indicated on a lamp display and, with the aid of lamp displays, the clock circuit in the regenerator can be aligned using the 17/15 pattern. Terminals on the front panel of the tester enable a digital voltmeter to be used, if required, when measuring pulse heights, widths and delays.

Encoder/Decoder Tester

The encoder/decoder tester produces all the clock and timing pulses necessary to drive an encoder or decoder card. The test system is based upon comparison measurements between standard encoder and decoder units and the unit under test. A 3·072 MHz crystal-controlled oscillator is used to derive clock and timing pulses, from which 128 × 8 bit words are generated in a sequence corresponding to the quantizing levels. A lamp display is used to indicate the generated 8 bit words.

Decoder units are tested by feeding the generated bit stream into the inputs of a standard decoder and the decoder under test. By comparison of the serial-to-parallel converter stages, and of the analogue outputs, any disparities are readily detected. Bit errors are indicated on a lamp display, and errors in the analogue output signal are identified using an oscilloscope. From the information obtained, rapid fault diagnosis to a small area of the circuit is possible. Faulty components can then be detected by comparison techniques, using an oscilloscope or logic probe.

Encoder units are tested using similar methods. The serial-to-parallel converter stage is checked by applying the generated serial bit stream to the input, and comparing the parallel word output with the parallel word input, itself derived from the serial bit stream. Magnitude comparators are used to localize faults in the control logic. Analogue circuitry is checked by breaking the encoder feedback loop, enabling the analogue transfer characteristics to be examined on an oscilloscope.

STORED-PROGRAMME AUTOMATIC LOGIC-CIRCUIT ANALYSER

Test equipment to check timing and clock cards in PCM systems, is now under development. A tester having a programmable and universal capability in detecting logic faults has now reached the laboratory-prototype stage, and is

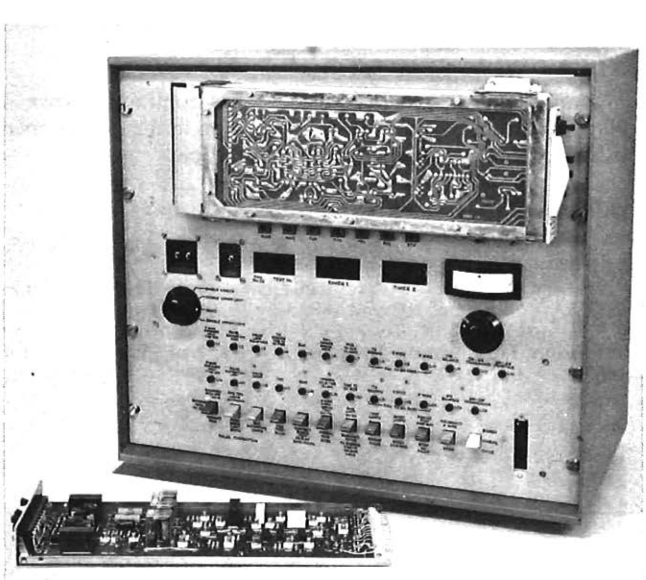

FIG. 3—PCM incoming-signalling-card tester

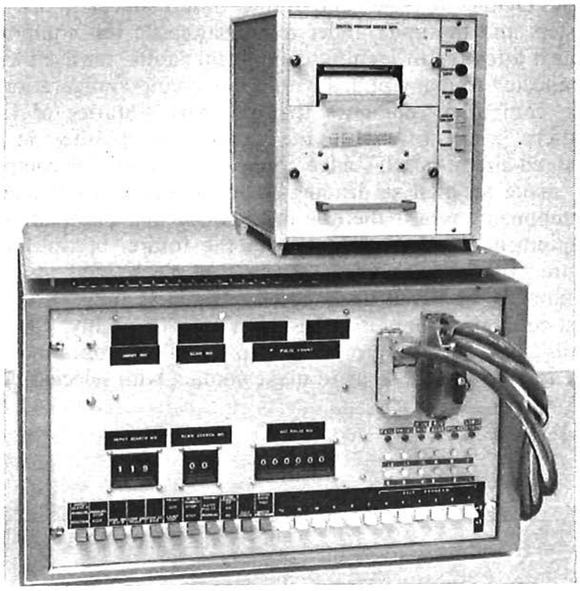

FIG. 4—Prototype stored-programme automatic logic-circuit analyser

briefly outlined below. It will be used extensively on PCM repair work and in the general repair of other equipments using logic designs.

The stored-programme automatic logic-circuit analyser, shown in Fig. 4, uses comparison techniques to check logic states on the unit under test against programmed logic conditions held in a metal-oxide-semiconductor store. Any differences detected cause a print-out to be given which provides information enabling the faulty logic devices to be identified and changed.

Programming the tester requires an analysis of the circuit diagram and the circuit functions involved. From the analysis, a programme is prepared which defines the logic states to be set on 12 inputs to the unit under test. The logic-state combinations on the 12 leads can be changed up to 90 times to form a programme. The programme is written into a memory and, under the control of a 3 MHz clock, is used to operate a standard unit via a special jig which is connected to the outputs of each logic element. Up to 128 connexion points are available, these being taken to a 128 × 90 bit metal-oxide-semiconductor monitoring store. Thus, all the logic-state changes occurring under the control of a programme sequence of a known "good" unit are identified and stored. Testing subsequent units is carried out by connecting the tester to the necessary inputs and logic elements, and allowing the programme to run through its scan routine. By comparing the logic states occurring on the unit under test in each scan period with those contained in the monitoring store, a print-out is given; this indicates at which of the 128 connexion points an error state was detected, together with the associated scan-period number. The tester has a built-in routine which can indicate faults in jig connexions and leads, and has a self-checking facility. Provision is also made to provide pulse trains, the bit length of which can be pre-programmed, to occur during any required scan period.

The first indications are that the stored-programme automatic logic-circuit analyser will make a very significant contribution to the repair of logic-unit assemblies. Programmes have been written for the PCM receive-clock, timing and gating cards, and for Datel Modem No. 8 units. Programmes to assist the repair of logic units for miniaturized Signalling System AC No. 9 signalling units are in the course of preparation.

JIG DEVELOPMENT

Fundamental to any testing system are the jigs and fixtures that enable reliable and rapid interconnexion between testers and the units under test. Diagnostic test equipment, which attempts to identify component faults, must either be connected to many points within the circuit configuration, or use computer techniques that compare libraries of fault-pattern sequences with the conditions existing at the printed-circuit-board's edge connector, enabling a computer to make an analysis leading to identification of the faulty component. Whilst there is little doubt that automatic-test-equipment developments will, in the future, become much more computer oriented, the use of such methods must ultimately be based upon cost-effectiveness judgements and test-equipment-mobility considerations. Currently, "bed-of-nails" jigs, consisting of a series of metallic probes mounted on a plane surface so as to make contact with selected points on a printed-circuit board, are preferred for the cheaper portable test equipments.

Developments are in hand to examine 2 possible methods of connexion. The first involves moving connexion points in an X-Y co-ordinate plane to any part of a printed-circuit board, under the control of a PAT paper-tape programme used to activate stepping motors. The second involves the provision of a standard holder into which different probe assemblies can be located. Vacuum techniques will be used to effect the connexion between the probes and the unit under test. With this method, one jig can be used to test many different kinds of printed-circuit-board unit by means of simple changes of the probe assembly. Further work is to be considered, to investigate the possibilities of a variable-pitch matrix, into which probes can be inserted as required by the printed circuit's configuration.

It is hoped that both these developments will lead to programmable jigs, that will complement the programmable testers.

FUTURE TEST-EQUIPMENT DEVELOPMENT

It is essential that the Factories Division keeps abreast of the developments now occurring in both system and customer equipments, to maintain its repair capability in the context of the rapidly changing technologies. Test equipment is an important part of this capability, and consideration is being given to future development work. It is considered that test systems such as the PATs and stored-programme automatic logic-circuit analyser, together with the complementary jigs, can be developed further, and are likely to satisfy a large proportion of the Factories Division's testing requirements for several years to come. The falling costs of micro-processors, however, and the new possibilities provided by this technology, must increasingly direct attention to computer-based automatic test equipment. Initial studies indicate that, to repair or service the digital systems of the future, testing will need to be based upon computer techniques.

CONCLUSION

This article has outlined some recent test-equipment developments undertaken by the BPO Factories Division to assist in discharging its responsibilities to the Telecommunications Business at the right cost, quality and delivery times. The range of work undertaken, as well as present technological changes, requires continuous development effort to maintain efficiently the capabilities of the Factories Division.

ACKNOWLEDGEMENT

The author wishes to acknowledge the continuing work of many colleagues in the Factories Division in the development of the test equipment described in this article.

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A Local-End Line System

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UDC 621.395.743

A low-capacity line system, operating over quad-type cable, is in use for the local ends of customers' private wideband circuits. This article discusses the design principles that make the system easy to order, install and operate.

INTRODUCTION

The increase in demand for group-band and supergroup-band private circuits has prompted the British Post Office (BPO) to offer, on rental terms, channel translating equipments of standard design, for installation in customers' premises. The customer can use the private circuit for speech or data, and wideband cable links are provided to connect the customer's equipment to the local repeater station. The first wideband links were provided by coaxial cable pairs, amplified and equalized at suitable points. Later, a cheaper quad-type cable of proved reliability came into use. The amplifiers (Amplifiers No. 184 and 185) developed for use on these links were installed in BPO buildings and energized by local power supplies. The apparatus used 51-type piece parts and the speed of provision depended, to some extent, on the availability of recovered stores items.

Provisioning has now been simplified by developing and stocking a standard amplifying equipment suitable for direct-labour installation using simple planning and commissioning procedures.

Since the local-end line system is used to extend a main line-circuit into the customer's premises, the standard CCITT* objective of 3 pW/km was set for the noise performance of the local end.

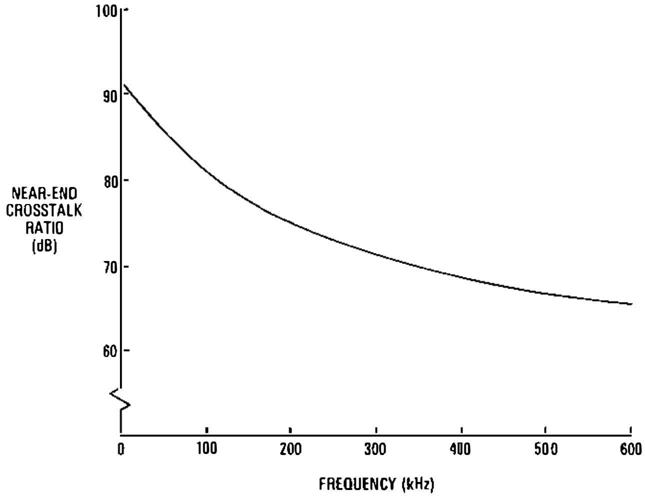

FIG. 1—Near-end-crosstalk-ratio/frequency characteristic between pairs 10 km long

CABLE, EQUALIZERS AND TERMINATIONS

Cable, Polyethylene, Quad No. 4, which has proved reliable in service over the years, has been specified for the new system. The cable contains a single quad and has an overall diameter of about 15 mm. It is flexible, easy to handle and store, and eminently suitable for long-length cabling techniques; up to 1 km of continuous cable can be drawn into duct if required.

To meet the needs of the majority of private customers, it was estimated that system lengths ranging from 1–30 km were required.

The insertion-loss/frequency distortion and the near-end-crosstalk-attenuation/frequency characteristic between pairs of the cable were determined for frequencies up to 552 kHz. The decision was then taken to satisfy the planning requirements by catering for up to 3 sections of cable, each up to 10 km long. The crosstalk performance of 10 km of cable and the insertion loss of 1 km of cable are shown in Figs. 1 and 2. The GO and RETURN transmission paths are in the same

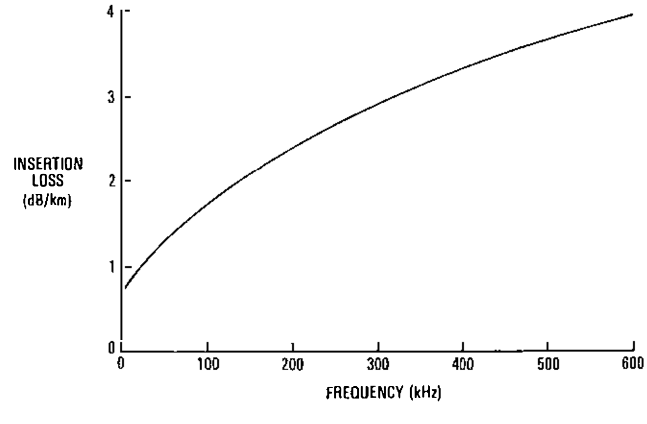

FIG. 2—Insertion-loss/frequency characteristic

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† Telecommunications Development Department, Telecommunications Headquarters.

* CCITT—International Telegraph and Telephone Consultative Committee.

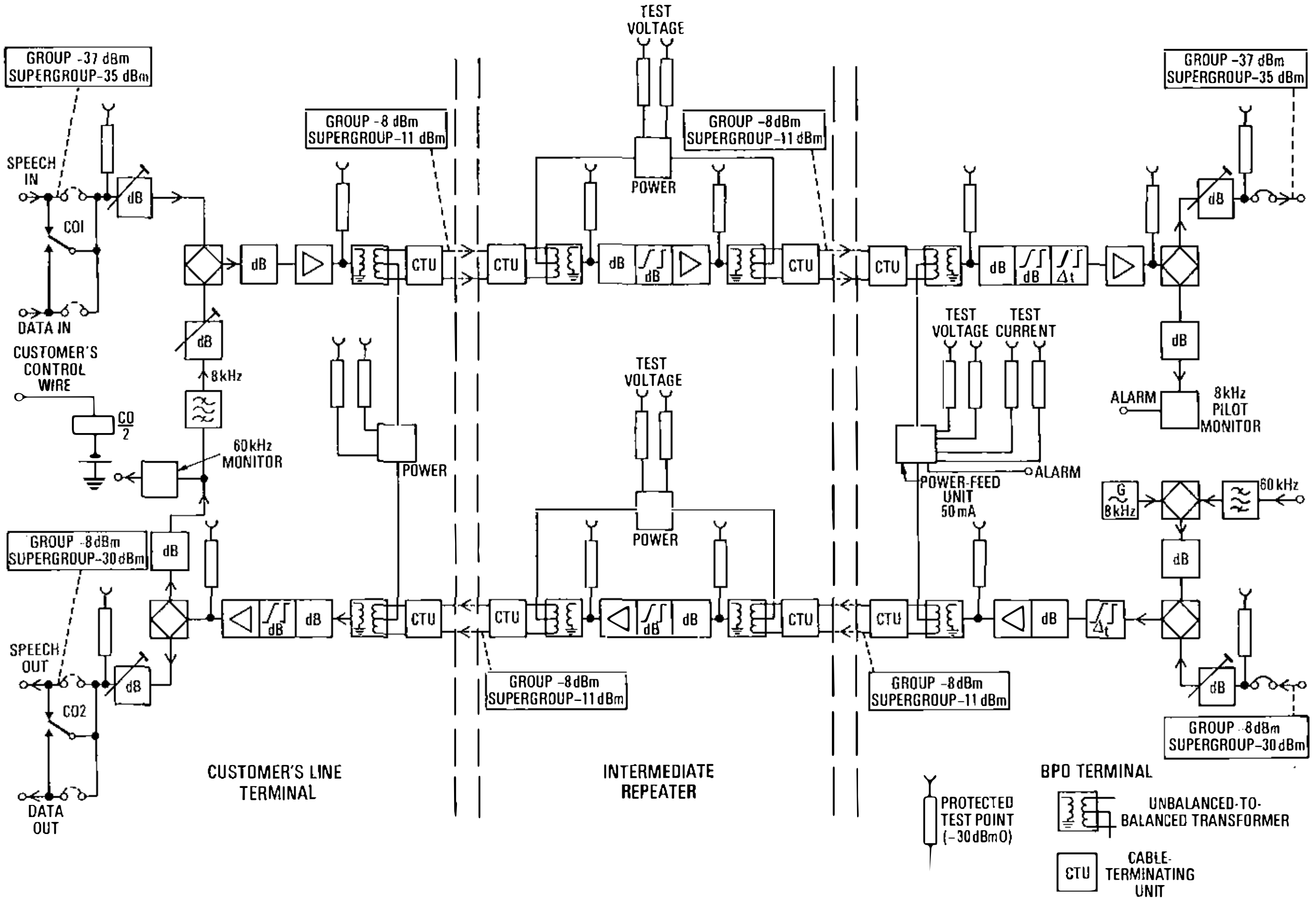


FIG. 3—Simplified block diagram of the line system

quad and a crosstalk ratio of 70 dB can be approached, without cable balancing, for the band of frequencies up to 552 kHz for one 10 km section. It was planned to accommodate intermediate repeaters in BPO buildings along the route, and since repeater points could not be provided at fixed intervals, flexibility of equalization was essential. Because the distance between the intermediate-repeater accommodation sites are known at the planning stage, it is feasible to equalize the attenuation/frequency distortion introduced by the cable on a prescriptive basis. A range of 10 coded equalizers (Equalizer No. 1011A) was specified for lengths of cable in the range 1–10 km in 1 km steps. Exceptionally, for group-band working up to a length of about 40 km, the equalizer range is extended in 2 km steps to 20 km. This method of prescriptive equalization is well suited to stores ordering and direct-labour installation, and accurate equalization results if the cable section length is an exact multiple of 1 km. The steps in the range are small enough to avoid the need for additional mop-up equalization for all but the longest route. On these longest routes, mop-up equalization can sometimes be avoided by selecting equalizers that do not exactly match the section being equalized, thereby giving a measure of pre-equalization to the following section. The line amplifier is designed with an adequate overload margin to permit this degree of misalignment.

The insertion loss of a 10 km length of cable at 552 kHz, the highest frequency in the band, determines the nominal gain required at each intermediate-repeater point. Each 10 km section of cable, plus its appropriate attenuation equalizer, builds out the insertion loss of the combination to about 40 dB. An extra 2 dB is added for the insertion loss of line transformers and equalizer sections, resulting in an overall loss/section of 42 dB. If the equalizer design for a short section of cable requires the inclusion of an attenuator, this precedes the equalizer to reduce the signal level and improve the harmonic performance of the equalizer.

The cable is equalized down to a frequency of 12 kHz. This reduction of the low-frequency cut-off of the transmission path improves the group-delay distortion in the transmission band. The cable attenuation equalizers are responsible for most of the overall group-delay distortion of the system, and because they are fixed equalizers, their group-delay performance is well defined. Group-delay-distortion equalization is also provided on a prescriptive basis. A 3-section group-delay equalizer, supplied with the terminal equipment, is strapped at the repeater station, as required, to reduce the group-delay distortion to less than 1·5 μs for the group or supergroup band.

Cable sections can be isolated from the equipment for test purposes by means of U-links provided in a Cable Terminating Unit No. 9A developed for the purpose; this unit can be mounted at a convenient height on a wall or at the top of the equipment rack. The crosstalk attenuation of the terminating unit is about 10 dB better than a 1 km section of cable. This standard of crosstalk performance also sets the crosstalk requirements of the equipment.

THE EQUIPMENT

The equipment (Equipment, Carrier No. 1001A) features 3 options: a BPO terminal, a customer's line terminal and an intermediate repeater. A simplified block diagram of the equipment is shown in Fig. 3. Appropriate combinations enable any length of line in the range 1–30 km to be set up, and the same equipment is ordered for group or supergroup working. A filter equipment (Equipment, Filter, Frequency No. 1009A) is fitted at the repeater station to select the band required. The BPO terminal is supplied complete with power units and is mounted on two 62-type shelves. The shelves are supplied fully wired. Inter-shelf power wiring is carried out as part of the installation. The intermediate repeater is accommodated on half a 62-type shelf, and the customer's line terminal requires one 62-type shelf.

The adoption of a zero-loss circuit between the customer's premises and the repeater station results in channel test levels at the system TRAFFIC-IN and TRAFFIC-OUT points, corresponding to the standard levels at the group and supergroup distribution frames. Adjustable pads are provided to set up the required levels. Transmission to line is at the BPO standard level of −8 dBm for group working; the level to line for supergroup working is −11 dBm. Pre-emphasis of the line frequencies is not used for normal line lengths.

A regulating pilot is not provided over the comparatively short system of 30 km for economic reasons, but a low-frequency pilot at 8 kHz is injected at the BPO terminal to monitor the continuity of the traffic path around the customer's loop. Failure of the traffic path results in an alarm at the repeater station and initiates the repair procedure. The large difference in level between the receive and transmit line levels at the customer's line terminal enables the incoming 8 kHz pilot to be extracted via a filter and re-injected back into the return path towards the BPO terminal. This pilot is injected and extracted using hybrid transformers and protecting pads, thereby effectively isolating the monitoring apparatus from the traffic path. To meet service requirements at the customer's terminal, a 60 kHz comparison pilot can be injected at the repeater station via a filter. The filter is necessary to improve crosstalk between systems connected to the pilot distribution network.

By means of signals applied to a control wire, the customer can select, from appropriate points on his premises, one of two inputs—SPEECH or DATA—to the line. The change-over switch is biased in favour of the speech input if the control wire fails. Solid-state change-over switches are used, the switches being energized from the customer's power supply.

The intermediate repeaters and the customer's line amplifiers are energized from the BPO terminal, using the phantom circuits. The standard power-feeding current of 50 mA is adopted to take advantage of the well-proved designs of power-feeding units developed for coaxial line systems.[1] The series power-feeding system, at 20 V/amplifier, meets all the safety requirements specified by the BPO for power transmission over pair-type cable, and the equipment is protected against lightning and power surges. Protected test points are available to check the voltage and current sent to line. The BPO terminal derives its power from the repeater-station battery supply.

AMPLIFIER DESIGN

The design of amplifiers to meet system performance requirements has been discussed in a recent issue of the *Journal*.[2] The design procedure for a short system of 4 amplifiers can be simplified to calculations for basic noise and intermodulation noise.

Basic Noise

Consider a lightly-loaded system with, say, one channel only in use. Intermodulation noise can be safely ignored, and the noise impairment is due to the basic noise performance of the amplifiers. The noise objective of 3 pW/km totals 90 pW for the 4 amplifiers, representing a signal-to-noise ratio of about 70 dB. Random noise adds on a power-addition basis; so that, for a system with 4 amplifiers, a signal-to-noise ratio of $70 + 10 \log_{10} 4 \simeq 76$ dB is required for each amplifier in the system. The insertion loss of a cable section and its appropriate equalizer reduces the signal level at the input of the amplifier to $(-11 - 42) = -53$ dBm. Subtracting 76 dB from this sets the level of noise at the input of the amplifier at −129 dBm. The noise contributed by the amplifier consists of thermal noise generated in the input termination of about −139 dBm/4 kHz bandwidth, and also active-device noise. The noise factor required for the amplifier (that is, active-device noise) is, therefore, $-129-(-139) = 10$ dB.

It is good engineering practice to design with a margin, and a noise factor of 7 dB was specified to take care of seasonal variations in line levels and misalignment. A noise factor of 7 dB results in a noise level at the output of each amplifier of $(-139 + 7 + 42) = -90$ dBm for each 4 kHz channel.

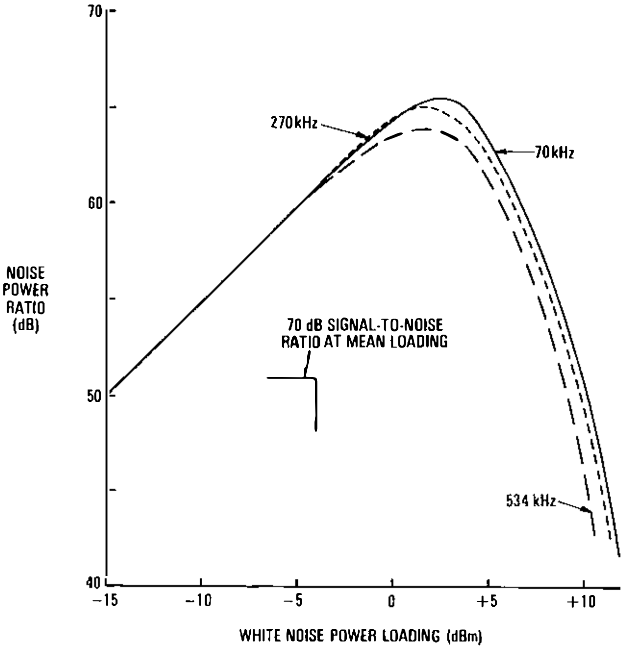


FIG. 4—Noise performance of 4 amplifiers in tandem

Intermodulation Noise

The second parameter of intermodulation noise and harmonic performance is difficult to specify accurately. Since intermodulation distortion is proportional to the harmonics generated by the amplifier, and this can be designed such that its output is inverted relative to the incoming signal, some of the harmonics generated by the previous amplifier can be cancelled and the level of intermodulation noise reduced. Quad-type cable is of balanced-pair construction and an inverting amplifier results in the reduction of intermodulation noise only if the A-wire and B-wire of the pair are connected in a particular way at each amplifier point. This is known as *phasing*. To reduce commissioning time, however, the system is required to operate within limits, at the first attempt, with the minimum of setting-up. Therefore, the following criterion for harmonic performance of the amplifier was set, such that phasing of the amplifiers is unnecessary.

During service, it is likely that test tones will be applied to the 2-wire which will appear on the line system at channel test level. The performance of the line should be good enough, without phasing, to prevent harmonics of the tone interfering with the user of any other channel of the system; that is, it should not be possible to detect the effects of the harmonics when measuring basic noise signals in any channel on the line with a selective level measuring set. The performance limit is set by the highest system test level of -8 dBm for group working. At the output of the system, basic noise appears at $-90 + 10\log_{10} 4 = -84$ dBm. The level of harmonics should be about 15 dB lower than this if they are to go unnoticed; that is -99 dBm. Therefore, in the worst case, where the harmonics generated by each amplifier add in phase, the level of harmonics produced at the output of the first amplifier is $-99 - 20\log_{10} 4 = -111$ dBm. As the maximum test level is -8 dBm, the harmonic margin required for each amplifier is thus 103 dB.

NOISE PERFORMANCE

Test results of a laboratory system of 4 amplifiers, loaded with white noise having a frequency band limited to 12–552 kHz, are shown in Fig. 4. The system was set up free of misalignment by fitting attenuators to simulate the loss of cable and equalizers. The amplifiers meet the design parameters of noise factor and harmonic performance discussed earlier, and were phased so that the harmonic distortion products added in phase to simulate the worst-case installation. The noise margin in excess of 3 dB arises because production amplifiers need to exceed the specification to pass the factory test limits set by the manufacturer for the amplifier.

Looping the laboratory system via a suitable attenuator to test 8 amplifiers in tandem resulted in a worsening of noise performance by 3 dB. Crosstalk contribution by the equipment is thus negligible, indicating that cable crosstalk will predominate when the system is installed for service. The full potential is unlikely to be achieved in the field, however, because a deterioration in noise performance can be expected when the equipment operates over the cable.

CONCLUSIONS

A low-capacity line system, meeting the requirements for stores ordering, direct-labour installation and ease of operation and service, is available. A high grade of performance is achieved over quad-type cable. The equipment assists the BPO in meeting the demand for the local ends of 12-channel and 60-channel private circuits without undue delay.

References

[1] Endersby, J. C., and Sixsmith, J. Coaxial Line Equipment for Small Diameter Cables. *POEEJ*, Vol. 55, p. 44, Apr. 1962.

[2] Davies, A. P., and Vincent, A. W. H. The CANTAT 2 Cable System: Evolution and Design. *POEEJ*, Vol. 67, p. 142. Oct. 1974.

Book Reviews

Delta-Modulation Systems. R. Steele. Pentech Press. x + 382 pp. 202 ill. £10·00.

Since the inception of delta modulation in 1946, there have been many variants devised of this type of coding technique, and this book is probably the first which is solely devoted to this most important topic. It has been said that delta modulation is a well-understood topic that only the experts do not agree on; if that is so, then this book, being one person's treatment of the whole subject, should help to produce a common basis of understanding. It is a book primarily for the expert or serious research worker in the field, although it should be valuable to the graduate student pursuing advanced studies, and might even be useful to final-year undergraduates. It is not, however, the sort of book where the non-expert can delve into its middle pages to seek enlightenment on some particular aspect of the subject. Rather, it is a comprehensive, coherent and ordered exposition of the whole topic.

The coverage of the book is extensive. Starting with a somewhat qualitative treatment of linear delta-modulation, the book proceeds on a more analytic footing to a consideration of noise performance in delta modulators and the treatment of some of the various coding strategies, including delta-sigma coders and syllabically-companded and instantaneously-companded coders. It achieves a useful uniformity in its treatment of the surprising variety and number of delta-modulation systems and, also, compares their performances with that of the standard segmented A-law pulse-code-modulation (PCM) coder. Conversion techniques from delta codes to PCM codes are also discussed. Finally, the application of delta modulation to digital filtration and instrumentation is considered.

With so much work still proceeding on delta modulation, it is inevitable that such a publication will miss a few of the most up-to-date advances in the field. Nevertheless, the author's broad knowledge of the field is clearly revealed in the almost 400 pages. Here is the strength and the weakness of the book; it is sufficiently comprehensive and detailed to provide a valuable text to the expert in this area, and yet somewhat more detailed than desirable for those seeking only a familiarity with one aspect of the rather broad topic of delta modulation.

G. W.

Magnetic Materials and their Applications. Dr. C. Heck. The Butterworth Group. xiv + 770 pp. 564 ill. £18·00.

The contents of this book can conveniently be divided into 3 main parts. The first part, 9 chapters in length, attempts to cover the basic magnetic effects, the definitions of magnetic parameters, and the magnetic, electrical and structural properties of magnetic materials. The second part, also 9 chapters in length, describes the applications of magnetic materials. The third part is a long chapter devoted to tables of the properties of commercially-available magnetic materials.

The book fails dismally as a reference book from which a non-specialist can obtain a straightforward description of magnetic effects and magnetic parameters. For example, the vitally-important magnetic parameters, namely the anisotropy constants, the magnetostriction coefficients and the magnetic polarization (magnetization), are given only a superficial treatment. The fundamental phenomenon of magnetic exchange, which is the basis of all magnetism, is covered in a single sentence, and superexchange—the origin of the magnetism in ferrites—is not even mentioned. The treatment of domain theory, which is the basis for an understanding of the properties of magnetic materials, is likewise weak and unhelpful. The final criticism of the first part of the book is the failure of the author to differentiate clearly between descriptions of the properties of single crystals and those of polycrystalline materials.

The second part of the book is more useful. The subjects covered include materials for permanent magnets, power transformers, magnetic amplifiers, relays (but not reed relays), inductors, microwave devices, storage devices, resonators, magnetic shielding, and temperature compensation, and the treatment of these subjects is quite good. The principles of operation of the various devices are, generally, clearly explained, and a newcomer to any of the above subjects should find enough information for an adequate introduction.

The third part of the book contains numerous tables of the magnetic properties, and the manufacturers, of a large variety of materials.

The book has a limited usefulness to an engineer seeking information either on a magnetic device or on the properties of a magnetic material, and is definitely not recommended as a source book of magnetic theory and effects.

R. D. E.

Regional Notes

LONDON TELECOMMUNICATIONS REGION

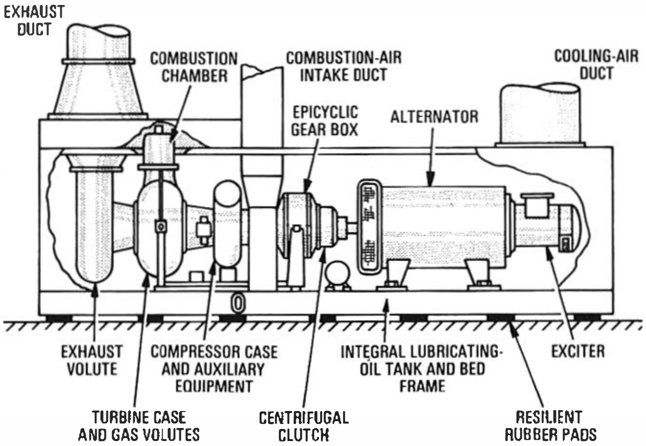
Balancing of a Gas-Turbine-Driven Stand-by Alternator at Faraday Building

The return of Faraday's No. 2 gas-turbine-driven alternator from the manufacturer draws to a successful close a saga that stretches back over a period of 1 year. This alternator is one of the stand-by units that take over Faraday's essential short-break and long-break supplies in the event of mains power failures.

The story began in May 1974 when, during routine maintenance, one of the alternator's main bearings was found to be deteriorating, and the whole machine bed was subject to considerable vibration. On investigation, it was discovered that the alternator's rotor was considerably out of balance statically; it always came to rest in the same position. As a result, it was decided to change the alternator bearing. This was done by local power staff, and an attempt was simultaneously made to balance the rotor statically by fitting lead weights to the alternator fan. It was found, with some consternation, that this required 0·24 kg at a radius of 330 mm. According to the manufacturer, units driven by gas turbines are balanced to within 0·72 kg mm; this alternator required 79·5 kg mm—over 100 times the manufacturer's figure. The alternator was then run at normal speed (1500 rev/min) to test the dynamic balance and vibration level. It was found that bed-frame vibration had been considerably reduced, from an amplitude of 0·15 mm to 0·05 mm. At this point, it was decided that local power staff could go no further without accurate instruments, and it was decided to call in a specialist firm to carry out tests and balance the rotor dynamically on site.

The firm carried out vibration tests as requested, but did not agree that the alternator was, in fact, out of balance. In their opinion, the trouble lay with resonance in the resilient pads on which the machine was mounted. The local power staff could not accept these findings, and further tests were made, but the specialist firm maintained their position. In the meantime, the gas turbine was put back into service, with the balance weights attached, for the critical winter period.

It was then decided that the complete alternator should be sent back to the manufacturer in Glasgow for accurate dynamic balancing. This was done in May 1975, and the entire operation of moving the alternator was carried out by local power staff at Faraday, in conjunction with the British Post Office Supplies Division who supplied the transport. This was no small feat, as the 3·5 t alternator had to be removed from a confined engine cubicle in the turbine room and placed on a Supplies-Division low-loader in the street, all this without cranes or lifting beams. The only possible way was to use 5 t vehicle jacks borrowed from the local motor-transport garage.



General layout of gas-turbine-driven stand-by alternator

The alternator was finally balanced in Glasgow by the manufacturer who, after fitting over 0·4 kg of lead to the rotor, agreed that the alternator had been badly out of balance. The origin of the fault is not clear, as no misalignment of the rotor windings could be detected. It can only be assumed, therefore, that this was an original fault which would not be readily apparent in a package unit such as this. There is no doubt that the high levels of vibration generated by this degree of imbalance were being absorbed by the resilient pads beneath the machine bed, to the detriment of the alternator bearings. It would seem that, had this alternator been connected to a Diesel prime mover, this condition would have been very difficult to detect.

P. WEEDON

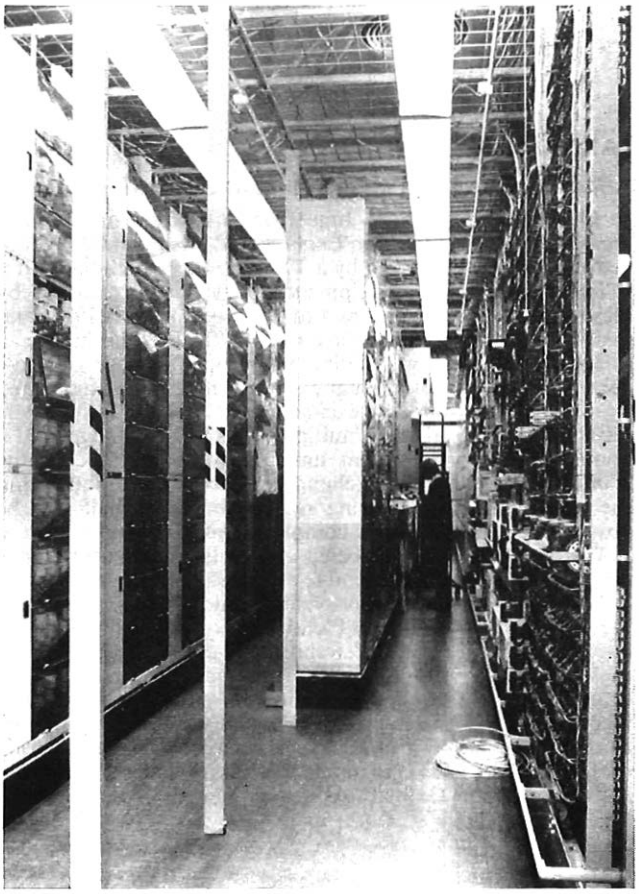
Redhill Clarendon TXK1

On 16 May 1975, a new TXK1 group switching centre (GSC), called Redhill Clarendon, was opened at Redhill, Surrey, followed on 14 June by a Cordless Switchboard System No. 1 (CSS1) auto-manual centre (AMC) in the same building. The crossbar GSC is an outgoing-only unit, and serves 37 250 subscribers on 9 exchanges. The incoming STD unit remains in the original non-director-exchange building.

The CSS1 is the assistance centre for the Merstham charge group, which includes all exchanges parented on the 2 GSCs, Caterham and Redhill.

The GSC had previously been accommodated in the same building as the local exchange, but the growth of both units, together with the need to introduce ISD and provide an AMC, made it necessary to erect a new building.

The switching equipment was installed by GEC Telecommunications Ltd., who started work on the 120 double-sided racks in July 1972. Completion of the contract was in



Part of the equipment area at Redhill Clarendon

December 1974, after a call sample showed the installation was giving a fault rate of less than 1 fault in 1000 calls.

The CSS1 consists of 60 positions, equipped with electronic key-sending. The access units to the switchboard are in Strowger-equipment practice, and this involved the provision of 54 racks of equipment. Outgoing routing to the local, STD and ISD networks is via the TXK1 equipment.

Power is supplied by a Power Plant No. 225, with 2 main batteries of 10·75 kA h capacity and a 367 kVA stand-by Diesel alternator. Use of a single common 50 V supply for the exchange and repeater station is on trial at Redhill. A 50 V modular-type plant provides power to the repeater station under normal conditions, and the main-exchange 50 V supply can be switched-in to take up this load.

The change-over was made in 3 stages. Subsequent to the installation and commissioning of the repeater station, the high-frequency, audio and pulse-code-modulation line systems were transferred to the new building. The incoming and outgoing circuits, although still in use by the Strowger GSC, were diverted via the new main distribution frame to terminations in the new building. They were then worked via tie pairs back to the old building. This stage was completed by November 1973.

Stage 2 was completed on 16 May 1975, when the TXK1 GSC was brought into service by simultaneously switching 780 incoming level-0 circuits and 681 outgoing trunk and junction circuits to the new unit. This was carried out at 24.00 hours to avoid high traffic levels during the change-over, and to allow time for a thorough check of all circuits after the change-over had been made. The opportunity was also taken to send a pattern of test calls from the local exchanges over the 255-circuit Toll-B route, the object being to prove the service given by this heavily-used level-01 route.

Stage 3 was completed on 14 June 1975 at 08.00 hours. This required the switching of all the assistance circuits from the old sleeve-control AMC at Purley. Some 300 circuits were involved.

Coincident with the opening of Clarendon AMC, ISD was made available to the Redhill charge group. STD access has been increased, and will be further increased by access to the transit network later this year.

B. A. Brand

EASTERN REGION

Abingdon: England's Last Manual Exchange

At 07.00 on Thursday 26 June 1975, after 79 years' service, the last manual exchange in England and Wales, at Abingdon, Oxfordshire, was replaced by a TXK1 group switching centre.

The installation of equipment for the new exchange, by Plessey Telecommunications Ltd., started in April 1972, and had been considerably delayed by difficulties in finding a suitable site, and by building problems. Because of these delays, the old CB10 manual exchange had to be augmented by 4 mobile non-director exchanges (MNDXs), 4 composite racks, an additional 2000-multiple expedient exchange, and a home-charge-group tandem unit. Half the multiple of the 2000-multiple expedient exchange was arranged to fall within the new TXK1's numbering range; the other half will be absorbed by the TXK1 on completion of extensions 1 and 2.

The change-over was effected in 2 parts: the first for trunks and junctions, and the second for the local exchange.

Temporary routes were provided from the manual board to the TXK1, and from the TXK1 to the home-charge-group tandem unit. All outgoing circuits were connected to the new exchange, with joint access for those circuits in the home charge group that appeared in the old exchange. The incoming home-charge-group junctions were then connected to the TXK1 one at a time. At this stage, home-charge-group exchanges had STD and tandem access via the TXK1, and assistance from Oxford assistance centre. Access to the Abingdon manual board was given via the temporary route. Incoming trunk circuits were then connected to the TXK1.

Part of Abingdon's manual board, before conversion

A month before the final conversion, the half of the 2000-multiple expedient exchange outside the TXK1's numbering range was connected to the new exchange. Access was given from the expedient exchange's line finders to calling equipment in the TXK1, and incoming routes were trunked back from the TXK1 to the expedient exchange's penultimate selectors. The new exchange is, therefore, carrying traffic from 1000 lines more than originally planned. No congestion has been noted to date.

Coin-collecting boxes were converted to pay-on-answer type a fortnight before the change-over. Access to and from the manual board was provided via the temporary routes.

The local exchange was changed-over at 07.00 on 26 June, involving the manual board, the MNDXs, the composite racks, and the half of the 2000-multiple expedient exchange within the new exchange's numbering range. The wedging-out of the old exchange and the cutting-in of the new were carried out in the new TXK1.

The occasion was marked by a ceremony later that morning, held in the Abbey Hall of this historic and picturesque Thames-side town. Guests at the ceremony saw a film about the old exchange and a telerecording of the change-over.

A few subscribers remained connected to the old manual board until noon, to enable the Mayor of Abingdon, Councillor William Liversidge, to make the last call through England's last manual exchange. It was made to a local firm of solicitors, Morland and Son, who were connected to Abingdon's first exchange when it was opened by the National Telephone Company in 1896. The firm had had the same telephone number for 79 years—Abingdon 4.

Dr. Frank Garside, Chairman of Oxford Post Office Advisory Committee, made the official inaugural STD call to Lord Peddie, Chairman of the Post Office Users' National Council.

The new exchange is now providing automatic service for Abingdon and district and, with extensions 1 and 2 already in progress, it is planned that ISD will be available early next year.

The conversion was a sad event for many, particularly the operators and engineers who worked under trying conditions to keep the old exchange in service, but is another landmark in the progress towards a fully-automatic service. Only 6 manual exchanges now remain, all in Scotland, serving 1600 subscribers.

C. E. Ess
R. M. Wood

Associate Section Notes

Aberdeen Centre

On 23 April 1975, a party of members visited the National Engineering Laboratory, East Kilbride, and found it a most interesting and enjoyable visit.

The year's programme was concluded on 29 May with the annual general meeting and dinner, held in the Atholl Hotel, Aberdeen.

The elected office-bearers for 1975–76 are as follows.

President: Mr. J. H. W. Sharp.
Vice-President: Mr. G. Harvey.
Area Liaison Officer: Mr. W. Milne.
Chairman: Mr. J. Stephen.
Vice-Chairman: Mr. R. G. Strachan.
Secretary: Mr. I. Booth.
Assistant Secretary: Mr. J. H. McDonald.
Treasurer: Mr. R. Mathewson.
Librarian: Mr. B. G. Rae.

I. BOOTH

Bournemouth Centre

Our 1974 season closed with a visit to CS *Alert* at Southampton, which turned out to be a very interesting afternoon.

The new season started with a visit to the Royal Greenwich Observatory at Herstmonceux Castle. In April, 15 of our members set out at 05.00 hours for a visit to a working colliery at Treforgan in South Wales. We were very well received at the colliery and, after being equipped with helmet, headlamp, knee-pads and survival kit, we were taken down to the coal-face, 490 m below the surface. Here, the headroom was about 1 m, and we saw what it was really like to work in a coal mine. We were all very impressed and agreed it was an interesting and worth-while visit.

Our annual general meeting was held on 8 May, and the officers elected were as follows.

Chairman: Mr. R. H. Ough.
Secretary: Mr. G. H. Seagroatt.
Treasurer: Mr. J. Hancock.
Vice-Chairman: Mr. D. M. Woodley.
Assistant Secretary: Mr. M. Wigmore.

Eight members of the committee were re-elected, and Mr. B. Fielder was again elected as quiz organizer.

G. H. SEAGROATT

Dundee Centre

Our annual general meeting was held on 22 April 1975, following a dinner in a local hotel. The office-bearers and committee elected were as follows.

Chairman: Mr. D. Moore.
Vice-Chairman: Mr. I. J. McBean.
Treasurer: Mr. A. J. Vaughan.
Secretary: Mr. R. T. Lumsden.
Assistant Secretary: Mr. G. K. Duncan.
Committee: Messrs. J. Chisholm, J. Duncan, J. C. Howe, R. Maclachlan, A. W. Smart, R. C. Smith, and M. Williamson.

R. T. LUMSDEN

Guildford Centre

The centre held its annual general meeting (AGM) on Tuesday 8 April; it was quite a successful evening, in spite of a poor turn-out. The treasurer reported on the centre's monetary position, commenting upon the very large balance for the year ended 31 March 1975, which reflected the amount of work carried out by the centre.

The officers and committee members elected were as follows.

President: Mr. G. M. Blair, General Manager.
Vice-Presidents: Mr. A. Luck, Deputy General Manager; Messrs. N. Weedon, C. A. Jelliffe and C. Marsham, Heads of Division; Messrs. A. C. Anderson, E. J. Masters, H. M. Wells and R. C. Terry, Assistant Executive Engineers.
Chairman: Mr. W. G. D. Holt.
Vice-Chairman: Mr. B. G. Rogers.
Honorary Secretaries: Messrs. D. C. Heather and R. Stone.
Treasurer: Mr. G. E. Spickett.
Visits Secretary: Mr. B. Viner.
Quiz Secretary: Mr. K. Hannah.
Social Secretary: Mr. P. Williamson.
Film Secretary: Mr. S. Scantlebury.
Committee: Messrs. M. A. Luck, P. Moon, R. A. Foster, F. Piercy, J. Edwards, J. Sherwin and S. A. Cranstone.

Since the AGM, we have made a repeat visit to the Whitbread Brewery at Romsey, and have completed a very successful general-knowledge quiz competition. Twelve teams of 4 members having entered, the quiz was arranged on a knock-out basis and was conducted very informally on 3 separate evenings. Members' wives and friends were invited. The winning team came from Camberley telephone exchange and was presented with a trophy, donated by Guildford Telephone Area, by Mr. Blair, the General Manager.

One of our members, Mr. C. R. Mynott, a precision-testing officer from Aldershot, was successful in winning a prize in the 1974–75 IPOEE Essay Competition. This is only the second time that one of our members has been successful in this competition. He was presented with a cheque for £10 and an Institution certificate by Mr. Blair on 22 May. His paper, *The Rise and Fall of Pressurization*, makes very interesting reading and perhaps, one day, a winning essay may be published in this *Journal*.

R. STONE

London Centre

The twelfth annual conference of the London Centre was held at the Institution of Electrical Engineers, Savoy Place, on 14 May. The committee elected for the coming year is as follows.

Chairman: Mr. R. A. Gray, City Telephone Area.
Vice-Chairman: Mr. J. Dow, Purchasing and Supply Department.
Treasurer: Mr. N. V. Clark (telephone 01-205 1112).
Secretary: Mr. P. Harding (telephone 01-452 8456).
Assistant Secretary: Mr. C. J. Webb (telephone 01-462 1843).
Visits Secretary: Mr. D. Denchfield (telephone 01-229 7080).
Quiz Organizer: Mr. D. Thomas (telephone 01-579 8647).
Trainee Technician (Apprentice) (TT(A)) Quiz Organizer: Mr. P. Shaw (telephone 01-688 9772).
Registrar/Librarian: Mr. D. Randall (telephone 01-553 5599).
Editor: Mr. B. Gardner (telephone 01-462 1691).
Radio Secretary: Mr. L. Woods (telephone 01-205 4144).

The C. W. Brown Award was presented to Mr. C. J. Fry, our retiring Editor, and Mr. L. Archer, North-West Telephone Area. Both have given outstanding service to the Associate Section over the past years, and were deemed worthy of the award by the committee.

The office of radio secretary has been reintroduced because of the growing interest within the centre in amateur radio, with several areas already operating stations under the IPOEE call-sign.

The final of the Adult Technical Quiz Competition was held at Fleet Building on 21 May, when the South-East Telephone Area was narrowly beaten by the Centre Telephone Area, the score being 37 points to 36½ points. The final of the TT(A) Quiz Competition was played on 16 June at Camelford House, and the South-East Telephone Area was again beaten, this time by the North-Central Telephone Area. The score was 44½ points to 35½ points. The committee wishes to thank Mr. K. H. Ford, Director, London Telecommunications Region, the question-master of both quizzes, and the adjudicators, scorer and time-keeper.

At the time of writing, the programme of lectures for the forthcoming session has not been finalized, but details will be circulated in the near future. A great deal of enthusiasm is apparent amongst the membership, and I hope that, in the forthcoming session, new ideas will liven up the meetings and activities.

C. J. WEBB

Plymouth Centre

At the annual general meeting, in April 1975, the following office-bearers and members of committee were elected.

Chairman: Mr. K. Gorman.
Secretary: Mr. G. D. Scott.
Treasurer: Mr. R. Parker.
Committee: Messrs. M. Cholwell (publicity officer), P. Bertram (membership secretary), D. Pulling (minutes secretary), J. Trigger (librarian), and L. Andrews.

Proposed rules for the centre were approved, with subscriptions set at 1p/week for weekly-paid members and 5p/month for monthly-paid members.

Our early-1975 meetings included talks on Royal Naval diving clearance teams, Crypton car tuning, and war-time exploits, plus a film show and a visit to RAF St. Mawgan. Although attendances were low, our membership increases steadily.

It is of interest that the mention of this centre in the January 1975 issue of the *Journal* attracted the attention of a reader from the Central Electricity Generating Board who deals with private circuits. He asked if he could attend the centre's meetings to meet the people he speaks to by telephone.

At the time of writing, the 1975–76 programme is in the course of preparation and, by the time this appears in print, will already be circulated to members. The programme starts in September with a visit to the School of Navigation's planetarium.

G. D. SCOTT

The Associate Section National Committee Report

Annual Conference

The annual conference was held at the Technical Training College, Stone, on 31 May. The meeting brought an abundance of new ideas, and much useful discussion took place. It was the committee's pleasure to elect our second Vice-President—Peter Hewlett, who recently retired as secretary because of promotion. The President, Mr. K. Stotesbury, was thanked for all his work on our behalf during the year. A change of officers was approved, and the committee for 1975–76 is as follows.

Chairman: Mr. J. Hannah, Scottish Directorate.
Vice-Chairman: Mr. G. Rimmington, North East Region.
Secretary: Mr. C. J. Webb (telephone 01-462 1843).
Assistant Secretary: Mr. R. Calvert (telephone 0254 666259).
Treasurer: Mr. P. White (telephone 045 36 2943).
Editor: Mr. C. F. Newton (telephone 094 34 2361).
Quiz Organizer: Mr. K. Marden (telephone 0204 27560).
Visits Secretary: Mr. D. B. Hickie (telephone 035 281 3190).
Projects Organizer: Mr. E. W. H. Philcox (telephone 0234 61561).

Motor Spares

A national motor-spares discount scheme has recently been introduced and is available to all members. Full details are obtainable from the secretary.

National News

The committee is at present negotiating to alter the format of *National News* to enable a larger magazine to be printed, with a wider circulation. All articles and items for inclusion should be forwarded to the Editor, *National News*, Post Office Regional Engineering Training Centre, Kineholme, West Busk Lane, Otley, Yorkshire.

National Technical Quiz Competition

Most of the 10 teams that have entered this year are also holding regional quiz competitions on an annual basis. The preliminary rounds will be completed by 30 December, and the semi-finals by 14 February 1976, with the final to be held at the Institution of Electrical Engineers, Savoy Place, London, on 26 March 1976.

Timer and Scoreboard Project

The aim of this project is to produce an electronic timer and scoreboard for the use of regions during future national quiz competitions. The closing date for entries has been set for 31 March 1976. Centres, areas, regions or individual members of the Associate Section are invited to enter. A brief list of the basic requirements is obtainable from the projects organizer.

Cotswold Trophy

The Cotswold Trophy was awarded this year to the London Centre for the work done by Messrs. J. Dow and P. L. Hewlett in the furtherance of the aims of the IPOEE and the setting-up of the National Committee. The London Centre also won the membership-form competition held earlier this year.

C. J. WEBB
Secretary

Institution of Post Office Electrical Engineers

Essay Competition, 1975–76

To further interest in the performance of engineering duties, and to encourage the expression of thought given to day-to-day departmental activities, the Council of the Institution of Post Office Electrical Engineers offers cash prizes totalling £50, and 5 certificates of merit in each of the following sections, for

(*a*) the 5 most meritorious essays submitted by members of the Institution in all British Post Office (BPO) grades below the senior salary structure and above the grades in (*b*) below, and

(*b*) the 5 most meritorious essays submitted by BPO engineering staff below the rank of Inspector.

Awards of prizes and certificates by the Institution are recorded on the staff dockets of the recipients.

An essay submitted for consideration of an award in the essay competition, and also submitted in connexion with the Associate Section IPOEE prizes, will not be eligible to receive both awards.

In judging the merits of an essay, consideration will be given to clearness of expression, correct use of words, neatness and arrangement and, although technical accuracy is essential, a high technical standard is not absolutely necessary to qualify for an award. The Council hopes that this assurance will encourage a larger number to enter. Marks will be awarded for originality of essays submitted.

Copies of previous prize-winning essays have been bound and placed in the Institution's central library. Members of the Institution can borrow these copies from the Librarian, IPOEE, 2–12 Gresham Street, London EC2V 7AG.

Competitors may choose any subject relevant to engineering activities in the BPO. A4-size paper should be used, and the essay should contain between 2000–5000 words. A 25 mm margin should be left on each page. A certificate is required to be given by each competitor, at the end of the essay, in the following terms.

"In forwarding the foregoing essay of .... words, I certify that the work is my own unaided effort, both in regard to composition and drawing.

Name (in block capitals) ....

Grade ....

Signature..

Official Address ...."

The essays must reach

The Secretary,
The Institution of Post Office Electrical Engineers,
2–12 Gresham Street,
London EC2V 7AG

by 15 January 1976.

The Council reserves the right to refrain from awarding the full numbers of prizes and certificates if, in its opinion, the essays submitted do not attain a sufficiently high standard.

A. B. WHERRY
Secretary

East Midlands Centre Programme, 1975–76

Meetings will be held at Nottingham University unless otherwise stated, and will commence at 14.00 hours.

12 November:
Outline of the TXE4 System by A. M. Belenkin.

3 December:
An Integrated Telephone Network by W. T. Duerdoth.

21 January:
Radiophone by P. J. Linney, and
Radiopaging by N. W. Brown.

25 February:
Carbon Granules and Electrets by R. F. Yates, and
The Design of the new Residential Telephone by R. W. Stevens.

24 March (Peterborough Technical College):
Marketing Interface with Post Office Customers by F. G. Phillips.

London Centre Programme, 1975–76

Meetings will be held either at the Institution of Electrical Engineers (IEE), Savoy Place, London WC2, or at Fleet Building, Shoe Lane, London EC4, and will commence at 17.00 hours.

23 October (IEE):
Viewdata by S. Fedida.

9 December (Fleet):
Standardization of Exchange Switching Equipment—The Enigma by D. Kelson.

13 January (Fleet):
Carbon Granules and Electrets by R. F. Yates, and
The Design of the new Residential Telephone by R. W. Stevens.

26 January (IEE):
Some Reflections on Packet Switching by P. T. F. Kelly.

10 February (Fleet):
Motor Transport in the Post Office by P. E. Brownlow.

26 February (IEE):
Second-Generation Letter-Mail Code-Sorting Equipment by E. G. Hills.

1 March (IEE):
Development Plans for System X by L. R. F. Harris and J. Martin.

11 March (Fleet):
Auto-Manual Boards by P. Troughton.

24 March (Fleet):
Service Aspects of Pulse-Code-Modulation and Other Transmission Systems in the London Telecommunications Region by F. T. Booth.

5 April (IEE):
A Digital Local Network by J. Rhodes, Pye TMC Ltd.

22 April (Fleet):
Cable Television by F. Lawson.

28 April (IEE):
Annual General Meeting of the Institution, followed by *Marketing Interface with Post Office Customers* by F. G. Phillips.

North Eastern Centre Programme, 1975–76

Meetings will be held in the Bakery Hall of Tribute, Leeds Polytechnic, unless otherwise stated, and will commence at 14.15 hours.

5 November (Central Library Theatre, Bradford):
Ringing the Bell—First Time by T. A. Barker.

3 December:
Carbon Granules and Electrets by R. F. Yates and E. G. T. Johnson, and
The Design of the new Residential Telephone by R. W. Stevens.

7 January:
Progress Towards Digital Telephony by H. H. Fox.

4 February:
Viewdata by S. Fedida.

3 March:
Semiconductor Device Development by S. O'Hara.

7 April:
Accommodation for Modernization by K. J. Harvey.

Northern Ireland Centre Programme, 1975–76

Meetings will be held in the staff restaurant, Churchill House, commencing at 14.25 hours.

12 November:
Carbon Granules and Electrets by R. F. Yates and
The Design of the New Residential Telephone by R. W. Stevens.

10 December:
Local Distribution—A Time for Change? by A. G. Hare.

18 February:
Marketing Interface with Post Office Customers by F. G. Phillips.

24 March:
Time-Sharing Computing by A. Moon.

14 April:
Technology and Practices of the Evolving Telephone System by A. Kane.

12 May:
Outline of the TXE4 System by A. M. Belenkin.

Additions to the Library

The following books have been added to the IPOEE Library since the publication of the 1974 Library Catalogue. Any member who does not have a copy of the catalogue can obtain one from the Librarian, IPOEE, 2–12 Gresham Street, London EC2V 7AG. Library requisition forms are also available from the Librarian, from honorary local secretaries, and from Associate Section local centre secretaries and representatives.

Members are reminded that prize-winning essays, Associate Section prize-winning papers and various unpublished papers are held in the Library for loan, and that a list will be sent on request. Field Medal award-winning papers are also held for loan, and are listed in the Library Catalogue.

Printed Papers of the Institution are available on loan, or can be purchased from the Library. A list of papers will be sent on request.

5165 *Colour-Television Servicing Manual.* (Vol. 1.) G. J. King. (1973).

Essentially about the circuits of contemporary colour-television receivers designed to operate from PAL-encoded signals.

5166 *Communication and Effect.* T. Alloway (editor). (America, 1973).

A collection of original papers by eminent behavioural scientists on the communication of affective or emotional feelings.

5167 *Telecommunication by Speech: The Transmission Performance of Telephone Networks.* D. L. Richards. (1973).

Reviewed in the *POEEJ*, Vol. 66, p. 230, Jan. 1974.

5168 *Materials and Structures.* R. Whitlow. (1973).

Provides a coverage of those principles of strength of materials and elementary theory of structures that are usually included in courses followed by students of civil engineering, structural engineering and allied disciplines.

5169 *104 Easy Transistor Projects You Can Build.* R. M. Brown. (America, 1973).

The variety of the circuits described ensures that this book includes projects likely to interest a wide range of readers.

5170 *Illustrations in Applied Network Theory.* F. E. Rogers. (1973).

Primarily intended for the intermediate years of degree courses in electronic and communication engineering, but will also be of great value to students following similar courses, such as Higher National Certificate and Diploma, and Council of Engineering Institutions courses.

5171 *MOS Integrated Circuits and their Applications.* Mullard Ltd. (1973).

Describes the construction, manufacture and characteristics of metal-oxide-semiconductor integrated-circuits, and the ways in which they can be used.

5172 *Project Management Using Network Analysis.* H. R. Hoare. (1973).

The object of the book is to provide the reader with sufficient knowledge to enable him to question networks and provide constructive criticism of the development of project plans and control procedures.

5173 *Cryoelectronics.* W. P. Jolly. (1972).

The approach is such that the whole range of cryoelectronics can be understood and appreciated by those with the scientific background of a first-year or second-year college student.

5174 *Cybernetic Engineering.* J. E. Young. (1973).

This book is aimed towards the practical application of cybernetic engineering to the "brain" of robot devices.

5175 *Telecommunications Systems Design:* Vol. I—*Transmission Systems.* M. T. Hills and B. G. Evans. (1973).

Intended to provide an introduction to the design problems of transmission systems that are to be used as component parts of a large telecommunication system. An appreciable part of the book deals with the national and international telephone system.

5176 *Beginners Guide to Colour Television.* G. J. King. (1973).

The reader is guided through the principles of the NTSC and PAL systems.

5177 *FET Applications Handbook.* J. Eimbinder. (America, 1973).

This book explains how field-effect transistors can be used in a wide variety of common applications.

5178 *Training for Communication.* J. Adair. (1973).

Includes a wealth of practical guidance on the arts of speaking and writing. The author also explores the deeper nature of communication to show how the principles he derives can be applied to the situations of everyday working life.

5179 *Teleprinter Handbook.* D. J. Goacher and J. G. Denny. (1973).

Covers the theory and practice of modern European and American radio-teleprinter equipment.

5180 *Information and Communication Theory.* A. M. Rosie. (1973).

Intended to act both as an introductory text for the serious student of information theory and as background reading for those with a general interest in the subject.

E. Doherty
Librarian

Notes and Comments

Model Answers to City and Guilds of London Institute Examinations

Back numbers of the *POEEJ* are available, complete with model-answer Supplements containing model answers to past examinations of the City and Guilds of London Institute Telecommunication Technicians' Course. The following is a list of those available, showing the examinations covered in the respective model-answer Supplements.

The price of back numbers is 45p each (60p from January 1976), including the model-answer Supplement and postage and packaging. Supplements are not sold separately.

Oct.	1966	LT C 1965*, ES 1966, ED 1966, PM 1966, M A 1966, ETP 1966, TP A 1966*	☐
Apr.	1970	ES 1969*, M A 1969, C A 1969, LPP A 1969, TP B 1969, M B 1969, Tp B 1969*	☐
July	1970	Tp B 1969*, TT A 1969, C B 1969, LPP B 1969, Tg B 1969, M C 1969, TP C 1969*	☐
Oct.	1970	TP C 1969*, Tg C 1969, Tp C 1969, LT C 1969, LPP C 1969, BMC C 1969, CR C 1969*	☐
Jan.	1971	CR C 1969*, ETP 1970, ES 1970, PM 1970, RLT A 1970, C A 1970, TP A 1970*	☐
Jan.	1972	CR C 1970*, LPP C 1970, LT C 1970, ETP 1971, RLT A 1971, PM 1971, ES 1971*	☐
Apr.	1972	ES 1971*, Tg B 1971, Tp B 1971, M A 1971, C A 1971, C B 1971*	☐
July	1972	C B 1971*, TP C 1971, Tp C 1971, Tg C 1971, BMC C 1971, LPP A 1971, LPP B 1971*	☐
Oct.	1972	LPP B 1971*, TP A 1971, TP B 1971, TT A 1971, M B 1971, M C 1971*	☐
Jan.	1973	M C 1971*, CR C 1971, RLT B 1971, LPP C 1971, LT C 1971, RLT A 1972, PM 1972*	☐
Apr.	1973	PM 1972*, ETP 1972, ES 1972, TP A 1972, Tp B 1972, TP B 1972*	☐
July	1973	TP B 1972*, Tg B 1972, LPP A 1972, M A 1972, C A 1972, TP C 1972*	☐
Oct.	1973	TP C 1972*, CR C 1972, Tg C 1972, M B 1972, C B 1972, BMC C 1972, Tp C 1972*	☐
Jan.	1974	Tp C 1972*, M C 1972, LPP B 1972, RLT B 1972, TT A 1972, LT C 1972*	☐
Apr.	1974	LT C 1972*, LPP C 1972, ETP 1973, PM 1973, ES 1973, RLT A 1973, TP A 1973	☐
July	1974	M A 1973, TT A 1973, LPP A 1973, C A 1973, M B 1973, Tp B 1973, Tg B 1973*	☐
Oct.	1974	Tg B 1973*, LPP B 1973, C B 1973, M C 1973, CR C 1973, LT C 1973, Tp C 1973*	☐
Jan.	1975	Tp C 1973*, TP C 1973, Tg C 1973, LPP C 1973, BMC C 1973, PM 1974, ES 1974, M A 1974*	☐
Apr.	1975	M A 1974*, RLT A 1974, TP B 1973, RLT B 1973, ETP 1974, TP A 1974, TT A 1974, LPP A 1974, M B 1974, C A 1974	☐
July	1975	Tg B 1974, Tp B 1974, LPP B 1974, C B 1974*	☐

*Part of paper only
BMC C: Basic Microwave Communication C
C A, C B: Computers A, B
CR C: Communication Radio C
ED: Engineering Drawing
ES: Engineering Science
ETP: Elementary Telecommunication Practice
LPP A, LPP B, LPP C: Line Plant Practice A, B, C

LT C: Line Transmission C
M A, M B, M C: Mathematics A, B, C
PM: Practical Mathematics
RLT A, RLT B: Radio and Line Transmission A, B
Tg B, Tg C: Telegraphy B, C
Tp B, Tp C: Telephony B, C
TP A, TP B, TP C: Telecommunication Principles A, B, C
TT A: Telephony and Telegraphy A

A series of 6 model-answer books is also available, in which selected answers from past examinations have been collected together to cover the following subjects.

	Price (post paid)	
Elementary Telecommunication Practice	45p	☐
Telecommunication Principles A	45p	☐
Line Plant Practice A	45p	☐
Radio and Line Transmission A	80p	☐
Telephony and Telegraphy A	80p	☐
Telecommunication Principles B	80p	☐

Orders, by post only, should be addressed to *The Post Office Electrical Engineers' Journal* (Sales), 2–12 Gresham Street, London EC2V 7AG. This page may be used as an order form by marking the appropriate box or boxes against the required back numbers and model-answer books. Cheques and postal orders, payable to "*The POEE Journal*", should be crossed "& Co.", and enclosed with the order. Cash must not be sent through the post. If this page is used, please enter the total sum enclosed:

£ ____________

Subscriptions

Those wishing to subscribe to *The Post Office Electrical Engineers' Journal* can obtain an order form from the Managing Editor, *The POEE Journal*, NP 9.3.4, Room S 08, River Plate House, Finsbury Circus, London EC2M 7LY. Please state whether or not you are employed by the British Post Office.

Publication of Correspondence

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

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 be possible to consider letters for publication in the January issue only if they are received before 7 November 1975.

Letters intended for publication should be sent to the Managing Editor, *The POEE Journal*, NP 9.3.4, Room S 08, River Plate House, Finsbury Circus, London EC2M 7LY.

Regional Notes and Short Articles

The Board of Editors would like to publish more short articles dealing with current topics related to engineering, or of general interest to engineers in the Post Office.

Also, brief reports of events of engineering interest will be published under "Regional Notes". Authors should obtain approval for publication of their contributions at General Manager or Regional Controller level.

As a guide, there are about 750 words to a page, allowing for diagrams. Articles and Regional Notes should preferably be illustrated, where possible, by photographs or sketches. Contributions should be sent to the Managing Editor, *The POEE Journal*, NP 9.3.4, Room S 08, River Plate House, Finsbury Circus, London EC2M 7LY.

Notes for Authors

Some notes are available to authors to help them prepare manuscripts of *Journal* articles in a way that will assist in securing uniformity of presentation, simplify the work of the *Journal*'s printer and illustrators, 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. Articles, and contributions for Regional Notes, must be approved for publication at General Manager/Head of Division (Controller) level.

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. Good colour prints can be accepted for black-and-white reproduction. Negatives or plates are not needed and should not be supplied.

Complete Set of POEEJ

Mr. J. C. Flemons, Midland Telecommunications Region, is offering for sale a complete set of *The Post Office Electrical Engineers' Journal* from Vol. 1–67. Volumes 1–38 (1908–1946) are bound, the rest are loose. Included in the offer is *History of the Telephone in the United Kingdom* by F. G. C. Baldwin, first published in 1925, the classic description of early Post Office and pre-Post Office practice. Those interested should contact Mr. Flemons, telephone 021 262 4069. Individual volumes will not be sold separately.

Correction

In the article *The Anechoic Chamber in the London Test Section of the British Post Office*, published in the July 1975 issue, it is regretted that Fig. 8 on page 94 is shown upside-down, it being inverted prior to printing.

Selling Price of the Journal

The Board of Editors regrets that, from January 1976, the price of the *Journal* will be increased to 35p per copy (60p including postage and packaging); annual subscription £2·40 (Canada and the USA $6·00).

The price to British Post Office staff remains unchanged.

Post Office Press Notices

Inflation and the Post Office

The British Post Office's (BPO's) forecast loss of about £290M in 1975–76, made up of £150M for telecommunications, £134M for posts and £6M for Giro, led to its proposals for price increases this autumn.

Despite internal economies which will save £60M, and the price increases earlier this year, the high level of inflation leaves no alternative to the increases in the prices of postal and Giro services, and telephone calls. The previous increases were made when the forecast annual inflation rate was 20%. It is now over 25%. As the biggest employer in the UK, with a heavy investment programme, the BPO is more vulnerable to the effects of inflation than most organizations, because of the cost of labour and of borrowed money. Also, the economic climate has depressed business activity in general, causing a reduction in the rate of growth of demand for telecommunication services.

The Government has indicated that it is not prepared to continue to pay compensation to offset losses after 1975–76. Consequently, besides the price increase, a searching enquiry is in progress within the BPO for more economies, including higher productivity and reduced expenditure.

A significant element of the financial situation is the necessity to find £90M out of the 1975–76 revenue to make good the pension-fund deficiency attributable to commitments related to the period before the BPO became a corporation in 1969. The deficiency stems from inflation and the way the Treasury funded the pension scheme, and leaves the BPO with heavy annual commitments to clear the deficiency. When the BPO ceased to be part of the Civil Service, the Government credited to the pension fund a notional stock of 2·5% Consols to meet liabilities up to October 1969. Because of inflation, the liabilities have increased and the cash value of the Consols has gone down. The funding arrangements proved to be inadequate and, in 1972, the BPO began trying to clear a deficiency of £1100M over a 20-year period, charging the annual payments to its profit-and-loss account.

Had the pre-corporation liability been properly funded, the deficiency would have been only about £300M. The BPO feels very strongly that the deficiency should not have to be made good at the expense of the customer, but by the Government, over a defined period. Sir William Ryland, Chairman of the BPO Board, said, "These commitments are an obligation of the Government, but they have not been prepared to meet them. For this reason alone, the customer is having to pay 0·5p more a letter and 0·3p on a telephone call." So far, the Government has declined to accept this argument, and the customer must go on footing the bill while negotiations continue. If the Government were now meeting the pre-corporation deficiency, the 1975–76 revenue requirement could have been reduced by £55M for telecommunications and £35M for posts.

The increase in inland postal charges is expected to yield £54M in 1975–76. Together with the yield from increases on the overseas service, plus savings accrueing from service changes, this would reduce the loss to £70M, which is the maximum amount by which the Government is prepared to compensate the BPO in the current financial year.

The increases in telephone-call charges will raise a total of £230M, and this is expected to provide a profit on turnover on inland services within the 2% permitted by the Government's price code.

The effect of the increases will be about 0·25% on the retail-price index, although telecommunications price increases will still be below the general level for retail prices.

Bringing Information into the Home

"Developing techniques will be used more and more to take information into people's offices and, perhaps, into their homes as well," said Sir William Ryland, Chairman of the British Post Office, at the International Press Telecommunications Council's conference in May. Developments, such as Viewdata, Oracle and Ceefax, would make it possible for anyone to seek information from central banks. The television screen, or a display unit, in the home or office might be used to display a wide range of information that, today, was looked for in a newspaper.

"These developments might be seen by some," commented Sir William, "as threats to the press, but you cannot stop the tide. Canute couldn't do it; you can't do it. You have to adjust to it and join those who want to harness it for good, with the confidence that the authority of the written word will surely hold its place."

Looking at the world-wide scene, Sir William said, "At the moment, we all seem to be afflicted by an obsession with power. We must see that the bad does not drive out the good. Of those with muscle, most use it for the good of all; not selfishly and to the disadvantage of the weak. It is vital to preserve tolerance, to promote understanding, to maintain and expand freedoms."

Telecommunications in Business

Businessmen casting around for economies in the current financial situations should think twice before pruning their communications. "Telecommunications are a vital part of businesses, and operational efficiency could be impaired if economy was carried too far," said Mr. F. G. Phillips, Director of the British Post Office's (BPO's) Telecommunications Marketing Department. Mr. Phillips was one of 6 BPO speakers at "Telecommunications 1975", an international conference and exhibition for business users of telecommunications systems and equipment, held during June 1975.

Many business customers were unaware of the poor image created for the companies by inadequate telecommunications facilities. "The possible loss of business through degrading your incoming service," he told his audience, "could greatly outweigh the annual saving of £40 achieved by giving up an exchange line."

The communication needs of business extended well beyond the simple telephone instrument; a wide range of ancillary apparatus was now available. To help companies improve the efficiencies of their telecommunication systems, the BPO operated a telecommunications consultancy service, with technical support from transmission and development specialists. A fee was charged for the service but, in addition, telephone-area staff gave free advice on smaller jobs. The customer needed only to contact the area sales office. Training was also provided for customers' staff, if required.

Mr. M. L. Ford, Head of the Marketing and Service Development Department of the BPO's External Telecommunications Executive, described the BPO's plans for improving Britain's international links, and to keep pace with the 20% per year growth in telephone calls. He also mentioned the BPO's comprehensive business services for overseas communication, including ISD and a public telegraph service. The latter is shortly to be enhanced by a computer-controlled system for automatically sending telegrams to their overseas destinations.

With a future likely to be dominated by a world-wide energy shortage, telecommunications made it possible for people to communicate without unnecessary and expensive travel, Mr. Ford said. Communications and meetings by telecommunications were likely to form an expanding market. As an indication of what could be done, the BPO, in co-operation with its partners in Europe, was already operating an international Confravision service with the Netherlands and Sweden.

Other BPO speakers described the use of international leased circuits and the future digital transmission systems.

Decade of Space Communication

Space communication celebrated its tenth anniversary this year. Ten years ago, on June 28 1965, the British Post Office's satellite-communications earth-station on Goonhilly Down, Cornwall, began commercial operations, transmitting telephone calls across the Atlantic through the satellite *Early Bird*.

In its first year of commercial operation, Goonhilly earth-station, with one aerial carrying 24 telephone circuits, handled 40 000 calls: fewer than a tenth of all intercontinental calls made to and from Britain. Now, its 3 aerials, carrying 1300 circuits, handle about 8·5-million calls a year—well over half the total intercontinental calls into and out of the UK.

Early Bird, the first satellite owned by the International Telecommunications Satellite Organization (INTELSAT), was also the first commercial geographically-stationary satellite. It had a capacity of 240 circuits, and calls were made between America and Europe through 5 earth-stations. More dramatically, it made possible the transoceanic transmission of uninterrupted live television broadcasts.

Now, the Earth is girdled by 7 INTELSAT satellites, all of them the giant series-IV type, capable of relaying over 4000 telephone calls simultaneously, as well as high-quality colour television signals. Goonhilly is part of a global network of 88 earth-stations in 64 countries, operating a total of 111 aerials.

National Data Processing Service wins Commonwealth Accounting Contract

A new computing contract for calculating the international telecommunications accounts of 25 Commonwealth countries has been won by the British Post Office (BPO). Under the contract, the BPO's National Data Processing Service (NDPS) will operate the cost-sharing scheme known as the Commonwealth Telecommunications Financial Arrangements (CTFA). This is a batch-process scheme which the NDPS will run on the BPO's IBM 370/168 computer—the first major commercial use of this processor since it came into service last year. The NDPS has also secured the contract to convert the existing CTFA scheme to enable it to be run on the IBM machine.

In the CTFA system, 25 Commonwealth countries have formed a partnership to share the cost of their international telecommunication facilities. Settlement is based on the use of the international links owned by each partner, and is a complicated accounting exercise. Both provisional and final settlements are derived quickly and easily by using a computing system.

The CTFA system has, in fact, been operated by the NDPS since 1 April 1973, using a Burroughs B5500. The software consists of 4 suites of 42 programmes written in Burroughs COBOL 61. Following its purchase of the IBM 370/168, however, the BPO is phasing-out the Burroughs processors, as the in-house work on them is transferred to the IBM machine. Consequently, the Commonwealth Telecommunications Bureau (CTB) invited tenders from selected organizations for providing services for the CTFA after its removal from the Burroughs B5500.

The NDPS submitted proposals for converting the existing programme suite to enable it to be run on the IBM 370/168. The CTB supplied 3 programmes for a test conversion which was carried out last summer by the NDPS, with support from IBM staff employed under a sub-contract. As a result, the NDPS has been given responsibility for completing the conversion of the programme suite. The CTB may also call upon the NDPS to modify the programmes as needed in the future; for example, to cater for expansion in the partnership.

Because no current production computer has COBOL-61 compilers, the programmes have to be rewritten in another version of COBOL that can be read by the IBM machine. ANSI COBOL was specified by the CTB, and the NDPS will use an existing software package developed by IBM to convert the programmes from Burroughs COBOL 61 to IBM ANSI COBOL. Conversion software developed by IBM is also being used to transfer magnetic-tape files from the B5500 to the 370/168.

The programmes contain shorthand descriptions for some COBOL commands peculiar to Burroughs COBOL 61, and these must be fully interpreted during the conversion process. The Burroughs machine uses service or utility routines differing in extent and detail from comparable routines on other machines. As a result, the NDPS will check each converted programme to ensure that the results obtained from using utility or service routines on the IBM computer are compatible with those that would have been achieved on the B5500. Under the present system, data are presented in correct order using the Burroughs collating sequence of characters. To preserve the correct presentation order, the NDPS is modifying the programmes during conversion to take account of the different IBM collating sequence.

New UK-Spain Cable

Britain's second submarine cable to Spain was inaugurated in June, raising the number of direct telephone circuits to 1860. The new cable runs 880 km from the Lizard peninsular, Cornwall, to Sopelana, near Bilbao, and can carry 1380 simultaneous telephone calls. The cable is jointly owned by the British Post Office and the Compania Telefonica Nacional de Espana, and was supplied by Standard Telephones and Cables Ltd., who also installed the associated terminal equipment. CS *Mercury*, flagship of the Cable and Wireless Company's fleet, laid the cable.

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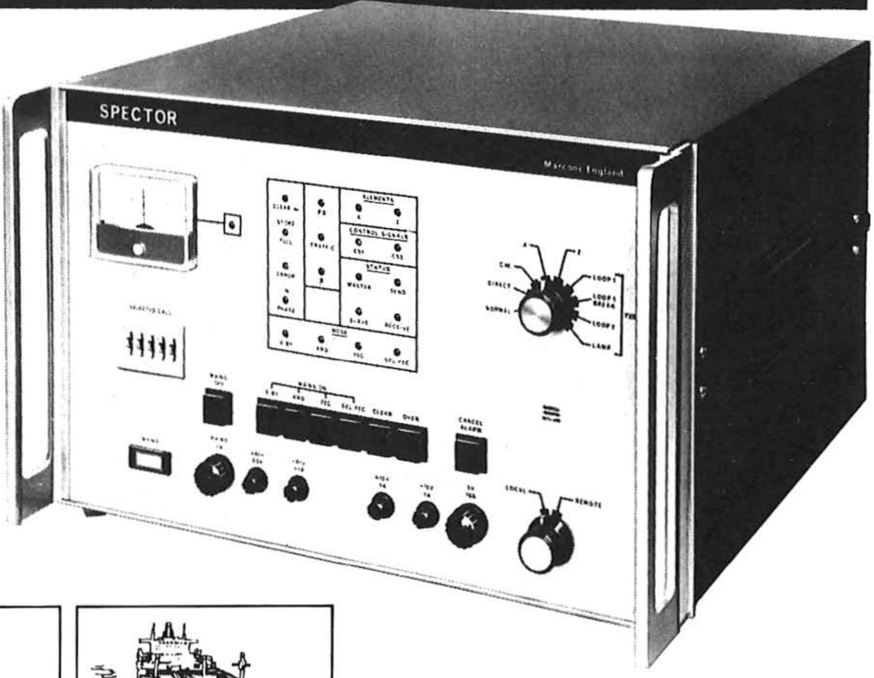

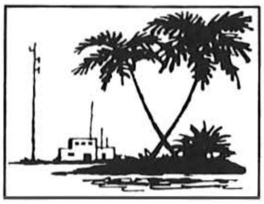

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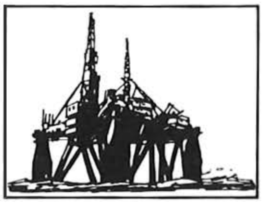

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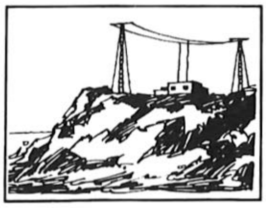

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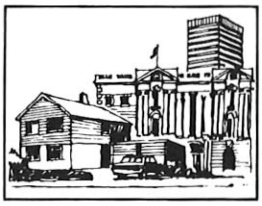

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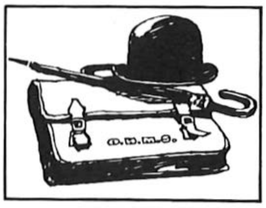

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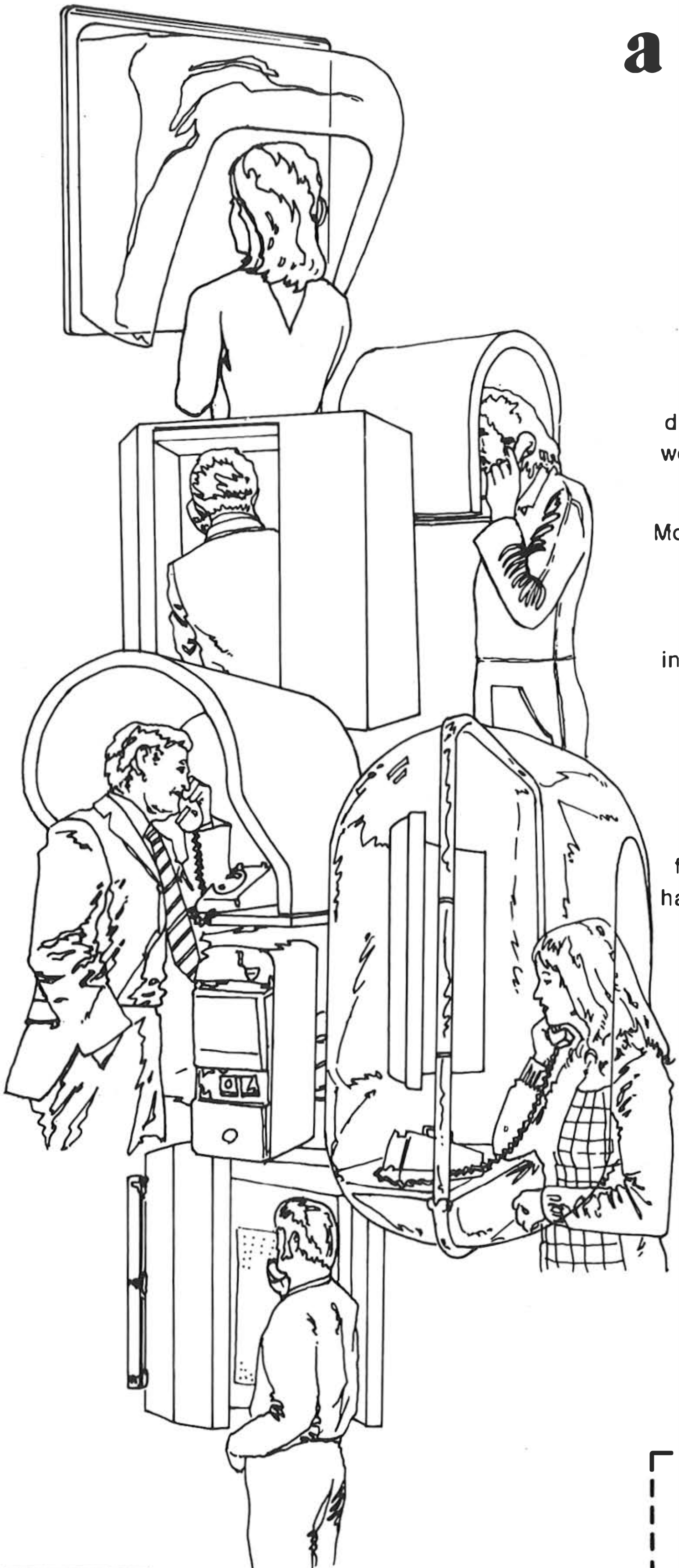

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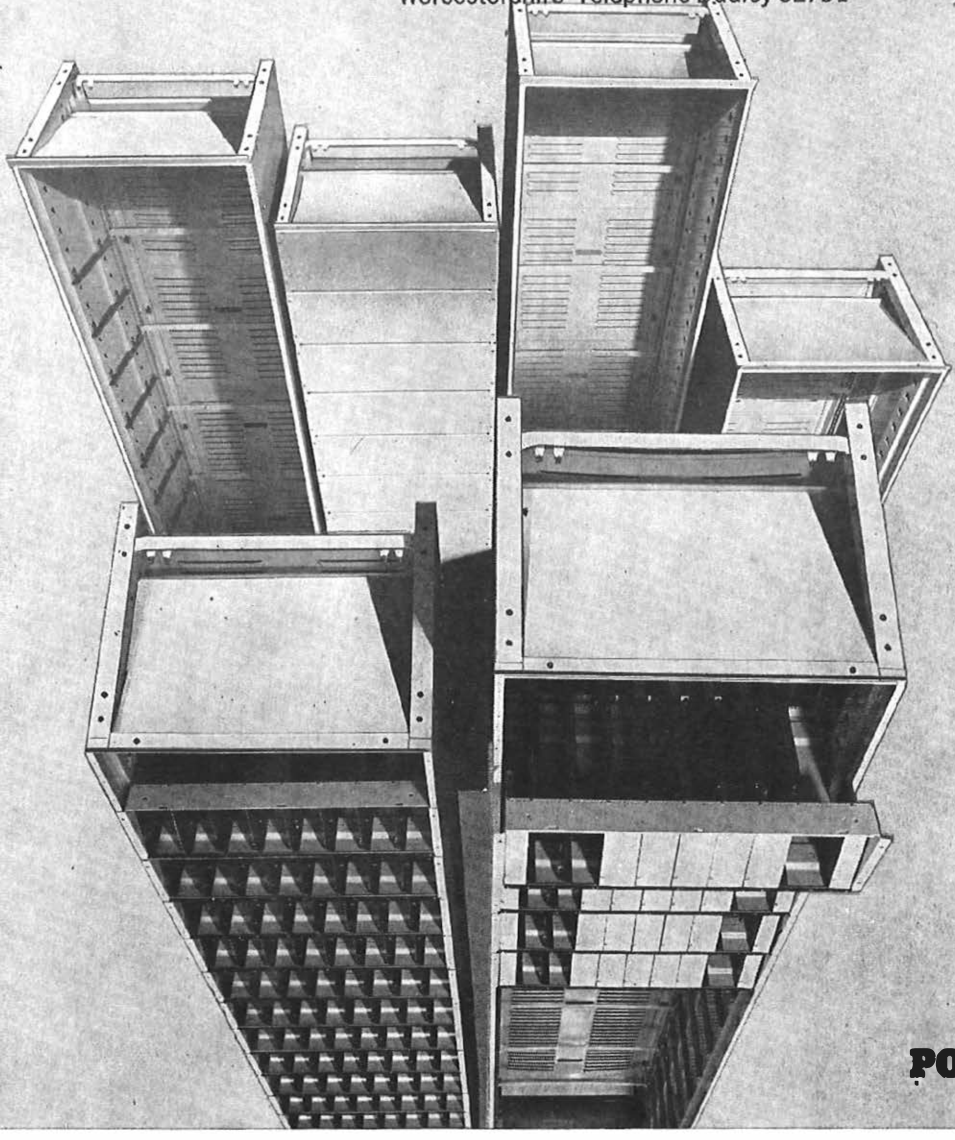

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