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The Post Office Electrical Engineers' Journal

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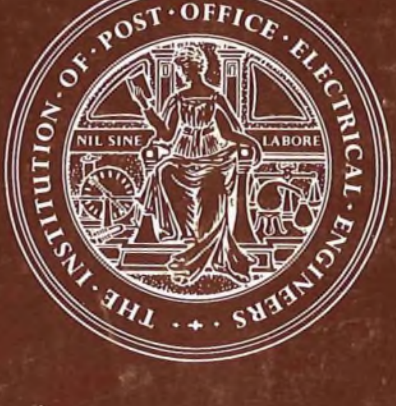

THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

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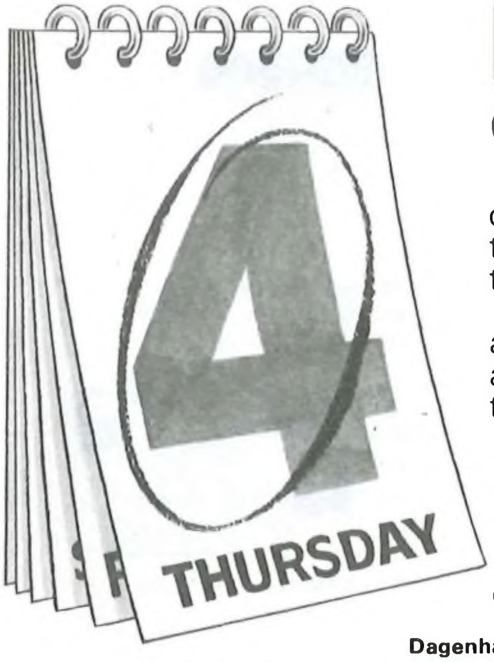
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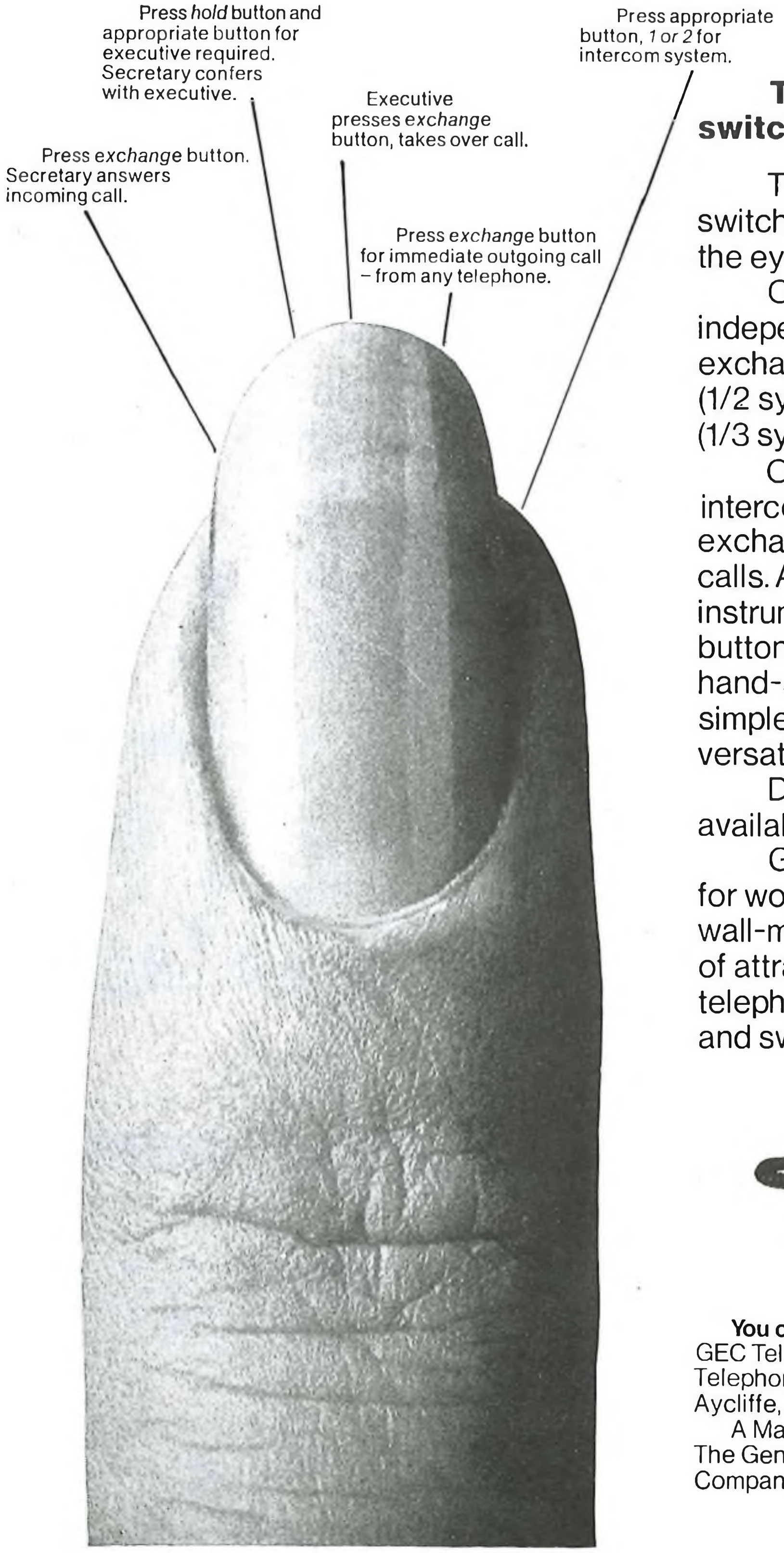
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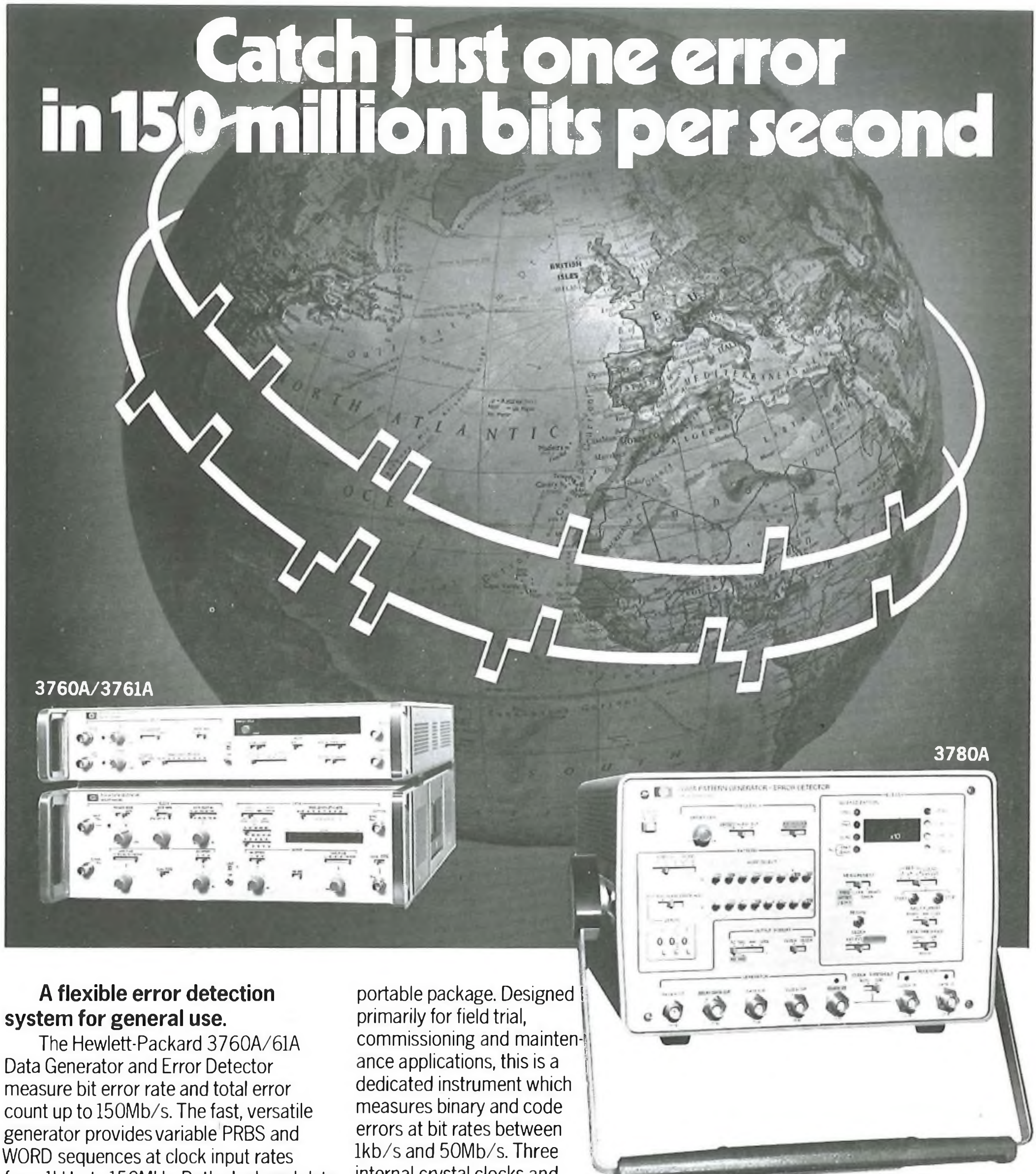

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The Post Office Electrical Engineers' Journal

EDITORIAL

Very soon, the transfer of the British Post Office (BPO) Research Department from its home of the past 50 years or so at Dollis Hill to its new residence at Martlesham will be completed. To mark this historic event, this issue of the *Journal* includes a very interesting account of the Dollis Hill story by Mr. F. E. Williams, who has spent his entire BPO career at Dollis Hill. Also included is the first part of a comprehensive description of the Martlesham Research Centre, written by Mr. C. F. Floyd, who headed the Division responsible for the development of the new research centre and for organizing the move from Dollis Hill to Martlesham.

Contracts have recently been placed by the BPO for seven 120 Mbit/s digital transmission systems, which are due to come into service by the end of 1977 in the Midlands Region. Further orders are expected to be placed later this year, and these will extend 120 Mbit/s digital transmission systems into northern England. A description of the multiplex equipment used in these systems was published in the July 1976 issue of the *Journal*, and this issue includes the first part of an article describing the 120 Mbit/s digital line system.

The view is often expressed that too many articles are published in the *Journal* on tomorrow's systems and equipment, and that there are not enough contributions on day-to-day topics of direct interest to the man in the field. This is not deliberate policy, but reflects the difficulty in commissioning articles of this type. Indeed, more articles on day-to-day subjects, particularly by authors in Areas and Regions, would be warmly welcomed by the Board of Editors. Three articles, written wholly or in part by authors from Telephone Areas, are included in this issue, and the editors hope that this will encourage Area staff to make similar interesting contributions.

The Story of Dollis Hill

F. E. WILLIAMS, M.SC.(ENG.), C.ENG., F.I.E.E.[†]

UDC 62.001:93

With the opening of the new British Post Office (BPO) Research Centre at Martlesham, the long era of BPO Research at Dollis Hill comes to an end.

FIG. 1—The main entrance of Dollis Hill in 1922 and 1971 from the same viewpoint

EARLY HISTORY OF BRITISH POST OFFICE RESEARCH

Dollis Hill in north-west London has been the home of British Post Office (BPO) research for more than 50 years, for, although the official opening of the Research Station did not take place until 1933, research had been going on in temporary accommodation on the site from as early as 1921. Fig. 1 shows the main entrance in 1922 and 1971 from the same viewpoint. However, the true history of research in the BPO goes back much further than this. The records show that early experimental work in connexion with telegraphy and telephony was carried out from 1878 onwards. But it was not until 1904 that a few members of the Engineering Department were relieved of their executive duties to pursue investigations of a purely experimental nature, in a room specially allocated to them in the Central Telegraph Office in London. It is recorded that the use of thermionic tubes for telephone amplifiers was being experimented with as early as 1908.

At about the same time, the National Telephone Company installed in Telephone House on the Victoria Embankment, London, a laboratory entirely devoted to telephonic research. Some of its early work on telephone transmission was described in 1907.[1] The length of life of the National Telephone Company had been fixed by Parliament in 1905, and so the 2 administrations were beginning to work together in anticipation of the eventual merger. Combined telephonic speaking tests were carried out and, in 1906, a telephone Standard of Reference was set up. An experimental laboratory in the south-east corner of GPO West, in London, was made generally available for such work.

In 1909, the BPO Research Section was given official recognition as a separate entity and, in 1912, when the BPO took over the National Telephone Company, the Section was augmented by amalgamation with the Company's Investigation Department. The laboratories of the National Telephone Company in Telephone House were transferred to the top floor of King Edward Building, London; the combined staffs were redistributed to deal with the various problems of telephone lines and apparatus, loading coils, and telegraph apparatus, involved in the rapid development of the communication services provided by the BPO. By the end of 1913, the total accommodation occupied by the Research Section in GPO West and King Edward Building amounted to more than 450 m^2 of floor area.

THE NEED FOR A PERMANENT RESEARCH STATION

In 1914, the then Postmaster General, Mr. Hobhouse, inspected the laboratories of the Research Section, and agreed that the BPO needed improved facilities for research, and that a permanent Engineering Research Station should be established. Even at that time, the high cost of land in cities made the purchase of a site in central London prohibitive, but it was felt that the proposed new Station should be within easy reach of BPO Headquarters. It was also desired that the site should be in a locality as free as possible from the noise and vibration of traffic and its consequent dirt, and from electrical interference from tramways and railways; these were important considerations in those days, when the

---

[†] Mr. Williams has spent his entire career, from 1933 until his recent retirement, in the Research Department

measurement of small electric currents depended upon sensitive mirror-type galvanometers.

Eventually, a site of 32 000 m^2, which appeared to fit the requirements, was found at Dollis Hill in north-west London, about 13 km from BPO Headquarters, in what was then farmland just north of Cricklewood and Willesden. The site consisted of fields and 2 small ponds, and occupied a commanding position on the summit of the hill, about 76 m above sea level. Away to the west lay the Neasden golf course and, beyond that, the small village of Neasden. On the other sides were fields, leading down on the north to the waters of the canal reservoir known as the *Welsh Harp*, and on the south to the slopes of Gladstone Park.

Authority to purchase the site and to erect on it a permanent building of 2600 m^2 floor area was sought from the Treasury in July 1914. The site purchase was sanctioned, but the Treasury demurred at the cost of the building scheme, and suggested that less ambitious proposals should be framed. Then came the outbreak of war, and the project was deferred.

During the 1914–18 War period, the greater part of the staff of the Research Section was allocated to research connected with the war effort, one example being the development of an apparatus by which the location of an enemy gun could be pin-pointed. During this period, the perfecting of the thermionic tube made the telephone repeater practicable, and thus opened up a boundless vista of possibilities in the development of long-distance telephonic communication. With demobilization, the arrears of work in the Engineering Department which had accumulated during the war years were taken in hand, and the development of telegraph and telephone services pushed forward. Underground schemes, both main and local distribution, were evolved, repeater stations were designed and installed, automatic switching made rapid headway, and telephone charges were revised and put on a paying basis.

By 1919, the Research Section had grown to such an extent that it was occupying parts of GPO West, King Edward Building, Newgate Street Building, Denman Street Building, Toll Exchange, New Barnet Exchange and Threadneedle Street Telegraph Office. The need for the new Research Station had become pressing.

THE MOVE TO DOLLIS HILL

In August 1919, the Treasury authorized the purchase of the Dollis Hill site—at a higher figure than the 1914 offer—and possession was taken in July 1920. The conveyance contains the information that Dollis Hill was formerly known as *Dolleys Hill.*

Experimental work on radio transmission had not, at that time, been considered to be proper to the Research Section, and was the province of the Wireless Laboratory at GPO West. Here also expansion was being considered, and authority had been obtained for 2 small experimental wireless stations to be set up, one at Dollis Hill and the other on the site of an ex-War Office wireless direction-finding station at Peterborough. In 1920, 2 small huts for the Dollis Hill wireless station were erected on the west side of the larger pond (see Fig. 2), and constituted the first use of the site by the BPO.

Meanwhile, the needs of the growing Research Section were becoming so pressing that it was decided not to wait for the construction of permanent buildings, but to accommodate the staff temporarily on the Dollis Hill site in ex-army wooden huts. The first huts erected thereon were occupied in December 1920, and the transfer of the whole of the research work involved was completed by October 1921; the total floor area of these huts was then 3300 m^2. In 1923, the Wireless Laboratory was also moved to Dollis Hill, into another hut of 110 m^2 area.

These wooden huts were heated by coke stoves in winter, and made unbearably hot by the sun in summer, but it does not appear that the staff were unduly dissatisfied with the working conditions. The remoteness of the site from tramways and railways also had its drawbacks, since car ownership was then a rarity and most of the staff had to face an uphill walk of 2 km every morning from the Metropolitan Railway station at Neasden. It is evident that the accepted standards of accommodation in the early 1920s were much lower than those of today.

FIG. 2—The beginning of Dollis Hill in 1920

RESEARCH IN THE 1920s

The nature of the experimental work being carried out in this complex of huts was described in detail in 1924[2]. The Research Station staff then totalled about 100, of whom 38 were qualified engineers. They were divided into 6 groups, covering the following fields.

(*a*) *Trunk Telephones* Research was carried out on underground and submarine cables and open-wire trunk lines, and repeater stations and loading coils.

(*b*) *Telephone Transmission* Studies were conducted in: standards of telephonic speech, and the production and maintenance of "standard" telephone transmitters and receivers; new methods of measuring transmission efficiency of telephone apparatus; new telephone apparatus.

(*c*) *Telephone Exchange Signalling* This group was concerned with the d.c. and a.c. measurements involved in exchange signalling, electromechanical tests of such items as relays, and special circuit problems.

(*d*) *Telegraphs* All research problems in telegraphy were dealt with by this group.

(*e*) *Physical and Chemical Group* This group handled all physical and chemical problems, and electrical problems not specially applicable to any other group; for example, studies of corrosion, primary and secondary batteries, insulating materials, materials used in thermionic tubes, carbon granules, alloys for electrical contacts and production of special magnetic alloys.

(*f*) *Construction* This group provided workshop and drawing office facilities; it was responsible for the design and construction of all apparatus required for research purposes by any group, and for the maintenance of laboratory services.

In the article in reference 2, the author, B. S. Cohen, notes that:

> "The main difficulty in the organization of technical research is to obtain researchers combining both the requisite technical experience and the necessary aptitude for research which is to a great extent inborn."

Capt. Cohen was subsequently to become Staff Engineer in charge of the Research Station, and to devote himself, in the

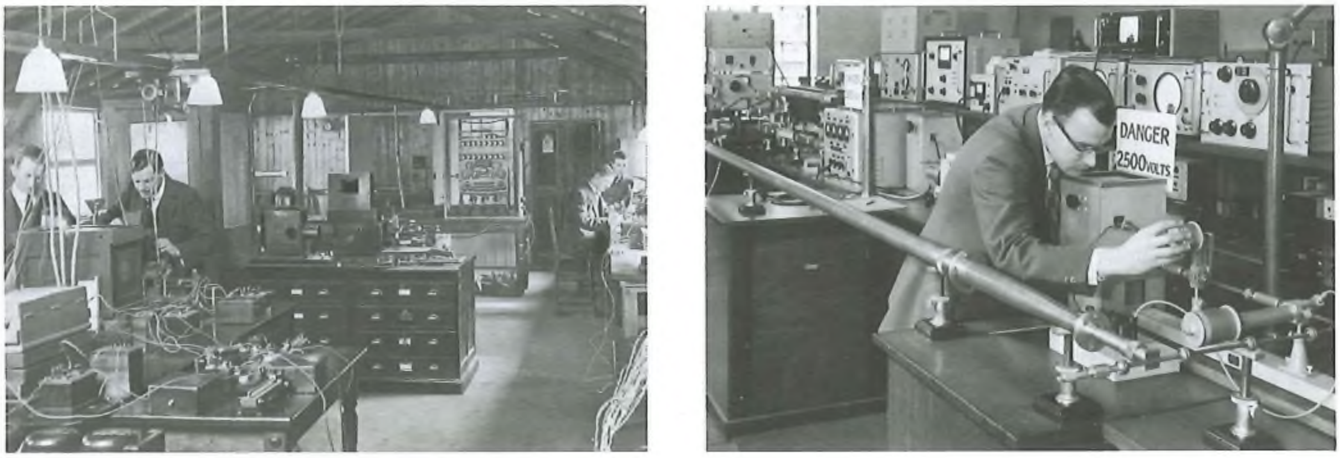

FIG. 3—The transmission laboratory in 1924 and the millimetric waveguide laboratory in 1960

1930s, to building up the Section with a well-chosen body of young graduate engineers and scientists.

Thus, in the 1920s, the work of the Research Section and the Wireless Laboratory centred mainly on the transmission of telephony and telegraphy by cable and by radio. Although by modern standards much of the laboratory equipment may seem primitive (see Fig. 3), many noteworthy contributions to the technology of communications were made during those years. Notable examples are the design of the radio transmitters for the long-wave radio station at Rugby and, in 1926, the historic measurements by W. West of the acoustical impedance of human ears[3]; this led to the design of the first artificial ear to provide a realistic acoustic load for measuring the performance of telephone receivers. Another urgent problem in those years was the protection of BPO cables from corrosion by the electrolytic action of stray currents (for example, from tramways), and much skilled effort was devoted to the development of accurate methods of measuring such currents.

In 1924, construction of the permanent buildings of the new Research Station in substantial red brick was commenced. Meanwhile, the hutments were proving inadequate to house the growing Research Section and, as a temporary measure, some groups were accommodated at Marshalsea Road, just over Southwark Bridge, and also in premises near the trunk exchange in Carter Lane. The first of the new blocks to be ready for occupation was that designed to serve as garage and life-testing laboratory. Other buildings followed one by one, and were occupied as they were completed: the chemistry laboratory in 1926, the carpenters' and millwrights' shops in 1928, the radio laboratory in 1929, the central block (containing power and battery rooms, canteen and lecture hall) in 1930, and training school blocks, workshops and radio assembly shop in 1932. Last to be completed was the imposing main administration block, commanding a fine view across London to the Surrey hills and visible from many miles around. Inscribed in the stone lintels over the front porch are the words *RESEARCH IS THE DOOR TO TOMORROW* and *TO STRIVE, TO SEEK, TO FIND*. The Research Station was formally opened on 23 October 1933 by the Prime Minister, the Rt. Hon. J. Ramsay MacDonald.

Meanwhile, suburban London had been spreading rapidly, and the Dollis Hill site was no longer surrounded by green fields (see Fig. 4). The golf course on the west side of the site had been sold in 1929, a plot of 36 000 m^2 immediately adjacent had been bought by Middlesex County Council for the eventual provision of a new secondary school (though this was not built until 1959), and the remainder, together with all the fields on the north side of the site leading down to the Welsh Harp, had been covered with rows of semi-detached houses and new roads. Gladstone Park, on the southern slope of Dollis Hill, had been preserved for all time as a public open space, but the surrounding woods and fields had gone for ever—and so too had any prospects of future large-scale expansion of the Research Station. The only available land remaining was a small plot of 10 000 m^2 on the south side of the site, all that was left of the old Dollis Hill Farm. This was purchased by the BPO in 1939, and used for additional laboratories after the war.

MONETARY RETURN FROM RESEARCH

There will always be argument about the proportion of its resources that an organization such as the BPO should invest in its research, and about the monetary return that can be expected from such investment. In 1930[4], Capt. Cohen, pursuing his aim of strengthening the research effort, claimed that:

> "An analysis in 1927 of the more important researches carried out (by the Research Section) during the preceding years indicated that they could be divided into two groups. In the first group, consisting of approximately one third, it was found fairly easy to allot a monetary value to the research, either by virtue of a definite saving in maintenance or by the introduction of a new service or channel and so forth. With respect to this group of researches, an estimated annual saving to the Department exceeding £150 000 was indicated. The remaining two-thirds researches, whilst more difficult to define in terms of pounds, shillings and pence, included many investigations the results of which it had been found necessary or advisable to incorporate into the Department's service, and also work which would have had to be done elsewhere if not done by Research staff. As the overall annual cost of the Research Station plant and staff does not exceed £75 000 per annum, it will be realized that the Research Section may be regarded as a highly successful business organization, paying a handsome profit."

Of the work done in 1929, Capt. Cohen claimed, on the same basis:

> "The work done showed a direct saving of £128 000 per annum, while important research and development work now in hand gives promise of very considerable reductions both in capital expenditure and in annual maintenance charges."

RESEARCH IN THE 1930s

The total staff of the Research Section (which at that time did not include those working on radio) had grown by the time of the official opening in 1933 to 290, of whom 110 were qualified engineers or scientists, under the direction of a Staff Engineer. Also housed on the Dollis Hill site were the Radio Experimental and Development Branch (under an Assistant Staff Engineer) and a section of the Engineering Training School.

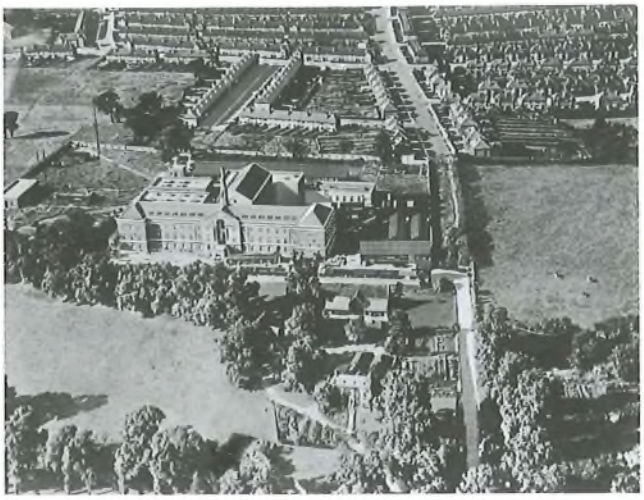

FIG. 4—The main block nearing completion, and suburban housing creeping up all around

FIG. 5—The first speaking clock in 1936 (with its principal designer, Dr. E. A. Speight)

This was a time of recession in industry, and qualified engineers and scientists could not find jobs easily. The BPO, with foresight, went ahead with the recruitment of a strong force of able young graduates, of whom many of the most highly qualified were posted to the Research Section. The wisdom of this policy of building up a strong research staff was to become evident in the years to come.

The 1930s were years of rapid development and expansion in the telecommunication field, and the research teams at Dollis Hill played a leading part in most of these advances. This was the era of innovations such as the first speaking clock[5], using photographic sound recordings on glass discs and controlled to a guaranteed accuracy of one-tenth of a second by a master pendulum (see Fig. 5), and the first loud-speaking telephone set for subscribers' use.[6] These were the years that saw the pioneering work on quartz crystals for the frequency control of oscillators and radio transmitters, the work on frequency standards, and the development of voice-frequency signalling for the telephone network. Wideband transmission systems for frequency-division-multiplex telephony and for television were developed using coaxial cables, and first installed between London and Birmingham.[7] In the development of television broadcasting, Dollis Hill engineers played a large part in providing the links for outside broadcasts, such as the first direct televising of the Cenotaph Remembrance-Day service in 1937.

Again on the subject of financial returns, Capt. Cohen wrote[8] in 1933 that:

> "It may be taken as axiomatic that it is generally impracticable to estimate the value of pure research in terms of pounds, shillings and pence; but in the case of a research station such as that of the Post Office, which deals mainly with *applied* research, this does not necessarily hold. Experience has shown that it is possible to produce an annual balance sheet showing expenditure and revenue accruing from a selected number of the cases dealt with.
>
> The number of investigations increased from 370 in 1927–28 to 511 in 1932–33. During the latter year, 14 of the more important cases dealt with were of the type for which the revenue accruing could be accurately assessed, and these 14 cases result in either increased annual revenues or savings to the Department, amounting to a sum more than double the total annual expenditure on research."

The 14 cases referred to above ranged from the introduction of a new voice-frequency signalling system[9] to methods of localizing submarine cable faults by means of electrodes towed from a cable ship.[10]

The financial aspects of research were continually being kept to the fore, and the Research Section was required to forecast annually its general expenditure on staff, plant and materials. Special authority had to be obtained for excess expenditure on any individual case, and schedules of running costs were maintained. In 1933, the overall value of the Research Station's plant (excluding consumable stores and materials) was put at £100 000.

In passing, it may be noted that in 1933 the American Telephone and Telegraph Company was spending on research about one dollar per annum per subscriber's station, equivalent then to about 5 shillings (25p), compared with the BPO figure of approximately 9½d (4p).

The system that evolved to ensure co-ordination at all stages of the work between the research group and the other sections of the Engineering Department concerned required regular progress reports on each case. In addition, overall supervision was exercised by a co-ordinating committee for Research and Development that had representatives of all the headquarters sections of the Engineering Department and met at approximately 3-weekly intervals. The Department as a whole was thus able to maintain close touch with any new developments within the functions of research.

Finally, a report (bearing the original case number) would normally be prepared on completion of an investigation, and copies circulated throughout the Department and also to various Service Departments and overseas administrations. Printing and publishing the reports in this form has ensured that they have remained permanently available and, to this day, it is still possible to request a copy of Research Report Number x, even though it may have been published 50 years or more ago.

Co-operation was always maintained with other research organizations, and it was never the practice to carry out research at Dollis Hill that might be better carried out elsewhere. For example, investigations into the acoustic properties of building materials were delegated to the National Physical Laboratory, and a purely chemical investigation which did not specifically involve electrical communication would be referred to the Government Chemical Laboratory. Use was also made of the work of organizations such as the British Non-Ferrous Metals Research Association, the British Electrical and Allied Industries Research Association, the Forestry Products Research Laboratory and the Building Research Station. Close touch was also maintained with the research laboratories of the large manufacturers of telecommunication apparatus.

In 1937, the first large-scale Open Day was held at Dollis Hill. The booklet issued for this event gives some idea of the wide-ranging activities of the Research Section, no less than 275 separate exhibits being listed from which the following examples are taken.

(*a*) Work was proceeding on the development of 12-channel carrier systems and group modulators, and the special measuring equipment being designed included a main-line transmission measuring set intended for use in repeater stations, a portable transmission measuring set, and an objective sound-level meter.

(*b*) Methods of measuring the transmission efficiency of telephone sets were being developed using articulation and other forms of speech tests, and standards were being laid down in co-operation with the telephone Administrations of other countries; in particular, with France, Germany and the USA.

(*c*) A conference amplifier had been designed which allowed up to 8 lines to be coupled together for a telephone conference.

(*d*) The external-plant group was studying methods of locating faults in submarine cables, and of measuring attenuation and crosstalk on land and sea cables; cable creepage inside ducts was also being investigated.

(*e*) Research had been commenced on mechanization of the postal services, and experimental devices had been made for removing parcels and small packets from mixed mail, and for the detection and recognition of the stamp by a photoelectric scanning system.

THE 1939–45 WAR

In 1939, came the Second World War, and the handsome red-brick facade disappeared under a camouflage network of wire mesh and painted hessian—as one wag put it, well and truly "tarred and feathered". The depleted staff soon found themselves involved in top-priority work for the fighting and defence services, and two 55 m lattice radio masts were erected on the site by the Admiralty; these were very useful in post-war years for radio propagation studies. Dollis Hill had already achieved international reputation as a communication research centre, and it was expected to be a wartime bombing target, but the Research Station escaped significant damage, whereas the surrounding residential areas all suffered some devastation.

In 1942, H.M. King George VI paid a surprise visit to Dollis Hill, and spent some time examining the work in the laboratories. Staff to whom he talked were impressed by the depth of his technical understanding of the projects.

As in all other establishments, able-bodied staff were required to undertake defence duties, either as firewatchers, firemen or Home Guards, on a rota of every ninth night. The firemen and the guards put in a good deal of practice, but fortunately none of them had to deal with any major incident.

POST-WAR DEVELOPMENTS

After the war, the Research Section reverted to its proper job of furthering the development of communication technology. The camouflage netting quickly came down, most of it through being accidentally set on fire; fortunately, during the daytime when the building was staffed and there were plenty of willing hands available to beat out the flames that entered the windows. The tempo of expansion increased, more staff were recruited, and new buildings erected to meet the specialized requirements of new techniques. The Training Branch had already moved away from Dollis Hill, and the next logical step was the integration of the Radio Experimental Branch and the Research Section under a Controller of Research. The Controller in those critically formative years was Dr. W. G. Radley—destined subsequently, as Sir Gordon Radley, to become Director-General of the BPO.

FIG. 6—Dollis Hill engineers (Messrs. V. G. Welsby, E. F. S. Clarke and R. A. Brockbank) on the deck of cable ship *Monarch* during submarine repeater laying trials in 1954

One important development which was to have far-reaching effects on world communications was the submerged repeater; an amplifier in a watertight case laid on the bed of the ocean. In 1943, the first such repeater ever to be installed in a working cable[11], designed and made at Dollis Hill, had been laid in a telephone cable crossing the Irish Sea. This was a vital step forward in the utilization of long under-sea coaxial cables; it opened up the possibility of installing repeaters at regular intervals along the sea bed and thus greatly widening the usable frequency bandwidth. A new BPO cable ship, *Monarch*[12], launched in 1945, was specially equipped to lay submerged repeaters, and research engineers from Dollis Hill sailed in her to see their precious repeaters lowered into the depths (see Fig. 6). Some of these laying trials, in rough weather, tried the Dollis Hill engineers, not all of whom were good sailors, more severely than did the repeaters.

With the ultimate target of a transatlantic telephone cable[13], a deep-sea repeater was developed. This required not only a construction that would remain watertight under pressures up to 100 MPa, but also, because of the difficulty of recovering such a repeater from the deep sea-bed, a high degree of reliability and long life expectancy from the components of the amplifiers. A high-pressure hydraulics laboratory was set up at Dollis Hill, and studies were undertaken of long-term component reliability. By his work on oxide-coated cathodes in thermionic tubes, Dr. G. H. Metson showed that it was possible, by the adoption of special techniques, to make tubes which had a working-life expectancy in excess of 20 years

Other major contributions made by Dollis Hill to submarine cable technology were the lightweight cable[14], having its tensile strength in a central steel core instead of in conventional outer armouring, and the linear cable engine, which speeded up the laying of cable with in-line repeaters.

Meanwhile, other teams were making progress in different

FIG. 7—Speech tests on a prototype 700-type telephone in 1958

fields. Working on the analysis of speech, E. W. Ayers produced an electronic speech machine known as *ESME.* New surveys were made of the acoustic characteristics of human ears and mouths, and greatly improved artificial ears and mouths were constructed for use in telephone measurements. Research on trunk signalling systems formed the basis of the national trunk-mechanization scheme, and electronic techniques were applied to the development of new switching systems. With the expansion of the telephone network, the need arose for a new telephone set of higher sensitivity than hitherto for use on longer local lines, and in 1958 the 700-type telephone was developed[15] (see Fig. 7). This incorporated F. A. Wilson's automatic regulator, an ingenious device that reduces the sensitivity of the telephone when connected to a short line.

INTO THE 1960s

The 1960s saw the field of research in telecommunications becoming even wider. In the radio field, great advances were made in microwave propagation, and Dollis Hill played a major part in the design and testing of the satellite earth station at Goonhilly. In the semiconductor field, studies were made of the utilization of transistors and the newer microelectronic circuits to improve communications. In the field of exchange switching, studies were concentrated on the switching of pulse-code-modulated telephone signals in digital form. Subjective studies were made of human visual requirements in broadcast and closed-circuit television, and related to transmission distortion. A human factors research group was set up to study the interface between the public and the telephone system. Work was proceeding on the evolution of new digital systems for the future, on new customer services like data transmission and Viewphone, and the development of Confravision, providing 2-way sound and vision links between distant conference rooms. New wideband transmission systems were being evolved, using microwaves in waveguides and using light beams in optical fibres.

In postal mechanization, extensive studies were being made of the possibilities of applying to postal sorting automatic recognition of typed and hand-printed characters on envelopes with the aim that one day all letter sorting would be possible by machine without the need for the addresses to be read by human sorters.

THE END OF THE LINE

With so much expansion in so many fields, the pressure for more laboratory space was ever increasing, and it was evident that the time was approaching when a move from Dollis Hill would be inevitable. By 1966, the total staff complement of the Research Branch had reached 1400, of whom 480 were qualified engineers or scientists, with about 700 engineering and scientific supporting staff, plus clerical, drawing office and other grades. The original site of 32 000 m^2 had been enlarged by the acquisition of the adjoining farm site of 10 000 m^2, and more laboratories erected thereon. But the local planning authorities had put a limit on the density of building they would permit on the site, this being now in a residential area, and there were no possibilities of further expansion. Already some research groups were housed in outlying stations, such as the radio laboratories at Backwell in Somerset and at Castleton in Monmouthshire.

After much deliberation, it was decided that the best plan would be to abandon Dollis Hill and to build an entirely new Research Centre well away from London, where there would be room to bring together all the scattered research groups on one large site, with ample room for field work and for further expansion. Thus, the Martlesham Heath site was chosen and now, in 1976, the final move from Dollis Hill is taking place. It is a sad day for Dollis Hill, so widely known for so long as the centre of BPO research, but the beginning of a great new era for the Martlesham Research Centre.

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The Design of Martlesham Research Centre

Part 1—Basic Design Requirements and Design of Buildings

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This first part of a 2-part article outlines the guiding principles adopted in the design of the Martlesham Research Centre, discusses the production of the Schedule of Requirements and describes the overall design of the buildings.

INTRODUCTION

The Director General of the British Post Office (BPO) had seriously considered moving the research activities of the Engineering Department from Dollis Hill, London, into the country as early as 1958, and a site was bought by the BPO for this purpose in the new town of Harlow in Essex. Discussions were held between the Engineer-in-Chief and the Ministry of Public Buildings and Works, and an architect was briefed to prepare a model. However, the staff at Dollis Hill showed little enthusiasm for moving to Harlow and, on the grounds of lack of consultation, appealed to the Director General against it. Harlow was eventually abandoned as a new site for research laboratories and, in 1963, the project was dropped.

The need for more space and better research facilities continued to grow, however, and the idea of moving Research Department out of London was revived in 1964. A new search for a suitable location was instituted and a joint working party, consisting of the official-side and staff representatives, visited areas where likely sites were available. The chief criteria were that

(*a*) the site should not be more than 2 h journey from the City of London, with good rail and road routes to London generally,

(*b*) the site should have good potential for the development of research laboratories without space or environmental restrictions,

(*c*) the site should be in an area attractive to the staff, offering a wide scope for leisure interests, and

(*d*) the local authorities should welcome the new arrivals as an asset to their area; naturally, it was hoped that the local population would also prove friendly.

The vacant airfield at Martlesham Heath, 9·6 km east of Ipswich in East Suffolk, was finally chosen. Ipswich is about 1¼ h from London by train, and there is now an excellent trunk road. The small East Suffolk towns offer many attractions in the Arts and in sport. The University of Cambridge, University of Essex at Colchester and University of East Anglia at Norwich are all within easy reach, and there is an excellent technical college, Ipswich Civic College. The local authority, Deben Rural Council, were pleased to be wholly helpful. A new small division of Research Department, R10, was set up to be responsible, in co-operation with the Department of the Environment (DE), for the planning of the new research establishment, and preparations for the move of Research Department from Dollis Hill and its out-stations to Martlesham were put in hand during early-1965.

The move of the BPO Research Department was part of the Government's plan to disperse some of the major elements of the Civil Service out of London. By moving this modern unit of high technology into East Anglia, the BPO has helped the area by providing a wide range of openings in a number of fields of technology that had not hitherto been available in Suffolk. Although the staff involved in the move had to come from London, graduate staff for further expansion has partly been drawn from East Anglia, and supporting staff almost entirely so.

It has taken 10 years to build the new Research Centre, shown in Fig. 1, move Research Department out of Dollis Hill and re-establish it at Martlesham.

THE SITE

The site of the Martlesham Research Centre originally belonged to a college of Cambridge University. The RAF acquired Martlesham in the early days of flying, and it became an important airfield for both the RAF and the USAF. When it was relinquished by the Services after the last war, a property company bought the whole airfield for small-scale industrial work and much of it was still derelict when the BPO became interested in 1964. At this time, there was Government pressure for new towns in East Anglia, and a new village and small industrial estate for light engineering was planned for the west side of the Martlesham Heath site with the BPO Research Laboratories on the east.

Owing to uncertainty over land values, the BPO took a long-term lease on 0·4 km^2, on which the new research centre has been built. More recently, a belt of the surrounding agricultural land has been acquired outright by the BPO and leased back for farming on a 7-year agreement. This will provide expansion space for future field experiments and should prevent the encroachment situation that eventually forced the closing of Dollis Hill.

The proposals for a new village have now become fact, some 12 years after the plans were drawn up. A housing estate with shops, banks, a public library and other essentials of village life is being built opposite the research centre.

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† Mr. Floyd was Head of the Division responsible for the planning of the Martlesham Research Centre, and for organizing the move from Dollis Hill, from the beginning in 1964 until his recent retirement

FIG. 1—Martlesham Research Centre

GUIDING PRINCIPLES FOR THE DESIGN OF THE NEW BUILDINGS

Before design work on site development and new buildings could be commenced, it was essential to state the broad aims that the designs should satisfy. Many recent buildings were visited by members of R10 Division, modern laboratories were inspected, some in great detail, and talks were held with architects and engineers who had been engaged in design work of a related nature elsewhere. As a result, the following guiding principles were drawn up for the design of the BPO Research Department laboratory buildings.

(*a*) The complex of buildings must be suitable for a self-contained research unit with its own administrative and support services.

(*b*) Air-conditioning should be installed from the outset to give the best environment for future equipment and staff; experience of adding air-conditioning to a completed building not originally designed for it had shown how expensive and unsatisfactory it can be.

(*c*) The building must have a high built-in resistance to mechanical vibration and be resistant to its transmission in the structure, whether the source is inside or outside.

(*d*) Flexibility should be provided in the way space can be used. The sizes of laboratories, including offices for research staff, must be determined by demountable partitions that can be moved readily without structural alterations to the building.

(*e*) Essential laboratory bench services (for example, electricity, telephone, gas, water, chilled cooling water, drains, chemical drains, compressed air, and special gases) must be easily made available, wherever needed, whatever the configuration of partitions. Service feeds must not be dropped from overhead; they can be dangerous with electric vehicles running about the laboratories.

(*f*) All floors of laboratories and corridors must be level and without steps. Goods lifts large enough to take small vehicles should give access for heavy equipment to all floors.

(*g*) A high standard of illumination should be provided from flush ceiling fittings so that a standard height of apparatus racks (3·2 m) can be used without obstruction.

(*h*) Substantial workshop services are needed with supporting drawing offices and stores. There must be space for future developments in mechanical technology. Preferably, workshop services should be provided in a building separate from the laboratories.

(*i*) All staffed accommodation must be in accordance with the standards defined by the report of the Working Party on Engineering Accommodation (WPEA) as agreed between the BPO and the Council of Post Office Unions. These agreements apply to all types of staffed rooms.

(*j*) Support services needed, preferably in a specialized administration building, are

(*i*) a technical library with ample reading-room facilities and book storage space for the future,

(*ii*) two lecture theatres, one large and one small, well appointed and suitably equipped for international telecommunication conferences,

(*iii*) a central conference room, with sufficient smaller conference rooms of various sizes dispersed around the building, some amongst the laboratories,

(*iv*) restaurant facilities able to provide 1000 lunches daily with sufficient amenities to cope with official occasions as well; rooms suitable for tea points are also needed, especially in accommodation far from the restaurant,

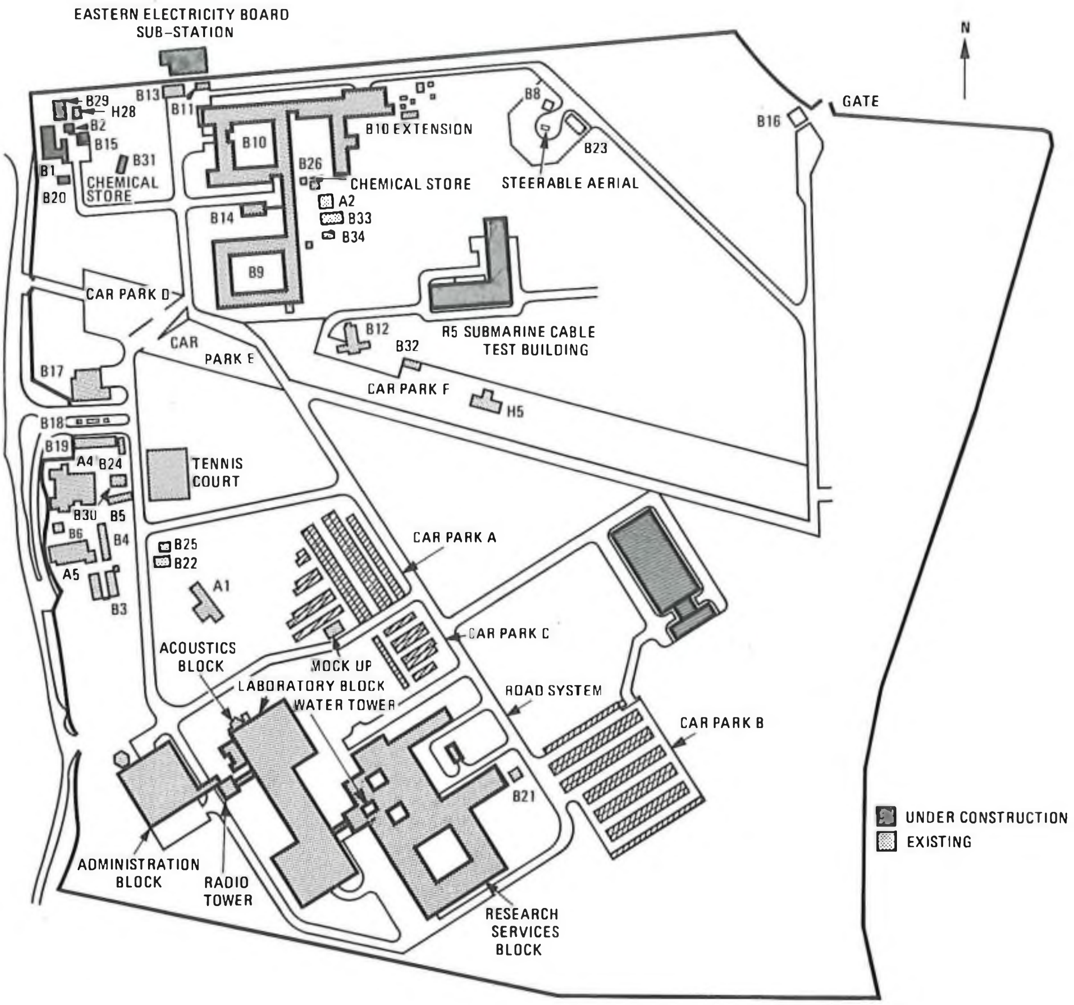
(*v*) welfare facilities suitable for social events, large and small, during evenings and weekends, and

(*vi*) a building layout such that social events are practicable without endangering security in laboratory areas.

(*k*) The buildings should help to create a friendly non-restrictive atmosphere that will encourage co-operation by discussion and exchange of ideas amongst staff.

SCHEDULE OF REQUIREMENTS FOR THE MAIN NEW BUILDINGS

The first duty of R10 Division was to draw up the Schedule of Requirements for the new building as a brief to the architects of the Ministry of Public Buildings and Works (now the DE), who were to act as agents to the BPO. All major capital buildings for Headquarters departments of the BPO were



A1—R10 administration offices
A4—Offices
B1—R7 laboratories and offices
B2—R7 workshop
B3—R1 plastics extrusion
B4—R2 laboratory
B6—Sub-station/store
B8—R6 aerial laboratory
B9 }—Laboratory and offices
B10 }
B10 Extension—Laboratory and offices and transistor factory
B11—R7 waveguide test building
B12—R5 cable test building
B13—Boiler house
B14—Computer building
B15—R7 waveguide laboratory
B16—R7 waveguide terminal
B17—Telephone exchange
B18—Gatehouse
B19—Sub-station
B20—R7 annex
B21—R1·4 annex
B22—R10 annex
B23—R6 field laboratory
B24—Security building
B25—Recreation building
B26—R3 laboratory
B29—R7 laboratory
B30—R1 building
B31—R3 laboratory
B32—Gas-cylinder store
B33—R3 laboratory
H5 —Cable-engine test block
H28—R1 store

FIG. 2—Site plan

then provided under the authority of the Buildings and Welfare Department of BPO Headquarters (this is now the responsibility of the Operational Programming Department of Telecommunications Headquarters).

Since no major laboratory buildings, especially those of the complexity and magnitude required by Research Department, had been built by the BPO for many years, there was no internal experience of modern laboratory design to help in drawing up the Schedule of Requirements. This massive document had to be prepared in accordance with strict BPO practice; it is designed to give the architect a clear expression of the detailed needs of the client, but it also exposes the client's statement of requirements to strict examination and defeats any attempts by clients to seek more area or facilities than the "authority to proceed" originally intended. The use of every room and the number and grade of staff using it must be stated, together with the function of the room relative to near-by rooms and lines of work flow. In the case of laboratories, it must detail the general function (chemical (wet), electrical (dry), or mechanical), the services needed (drains, fume-chamber outlets, chilled water, power socket outlets, internal cabling for coaxial links or computer connexions), the telephone connexions, and many other items related specifically to current research projects.

The magnitude and detail of the data needed in the Schedule of Requirements brought the first firm realization of the real size of the job Research Department had undertaken in agreeing to specify the new laboratory complex. The specifications had to satisfy the needs of Research Department at the date of opening, which was expected to be 5 years after the signing of the Schedule of Requirements; in fact, it was nearly 9 years. The needs of every division in Research Department had to be discussed and projected into the future; changes in grading and numbers of staff had to be estimated years in advance. The situation was further complicated by accommodation agreements drawn up nationally in the early-1960s between the BPO and the unions, embodied in the reports of the WPEA. The WPEA had laid down standards of accommodation to be met in new BPO engineering buildings throughout the country on a basis of "area-

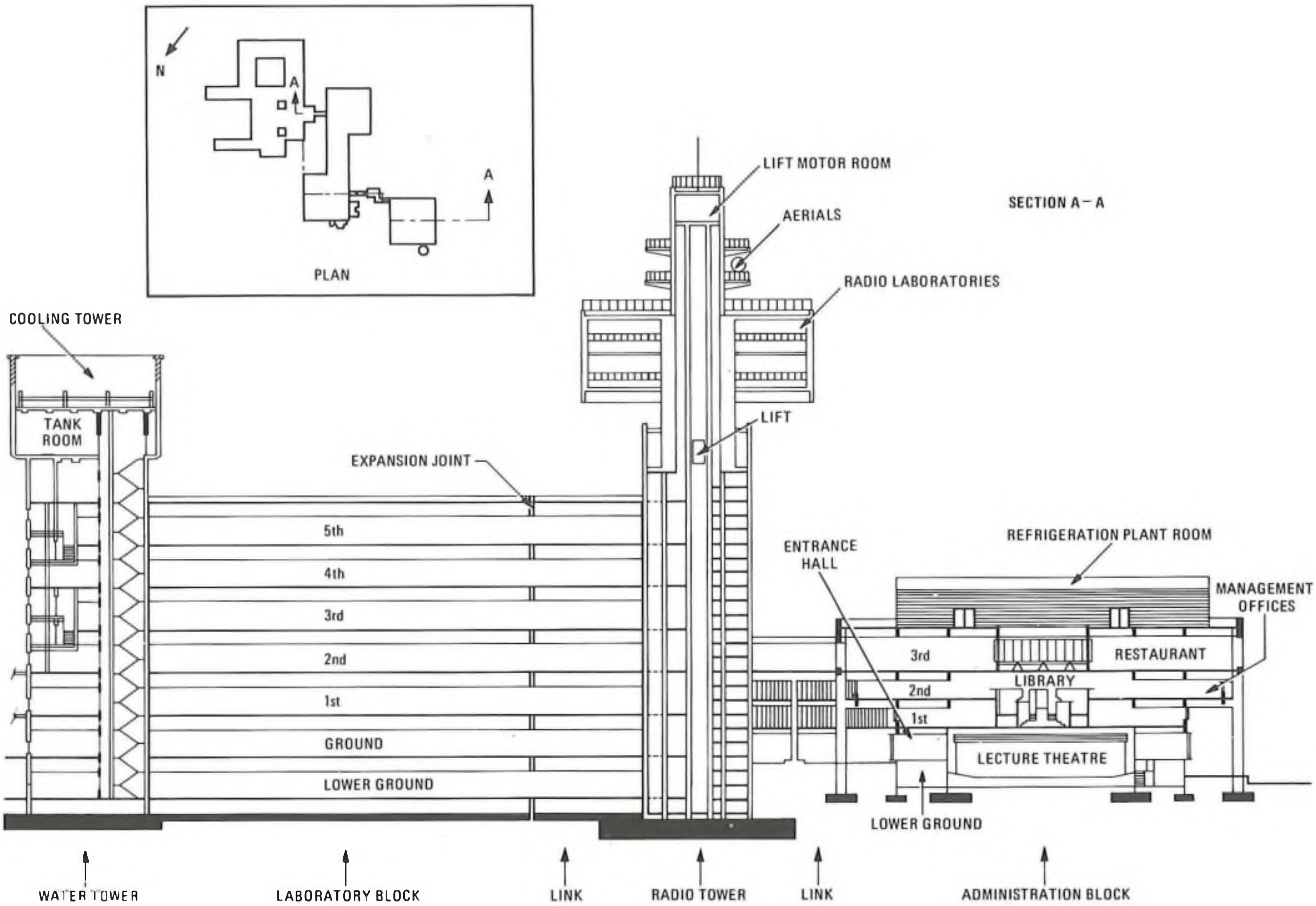


FIG. 3—Vertical sectional view of towers, administration and laboratory blocks

per-man plus additional functional allowances related to his duties". Some attempts had been made to include laboratory accommodation standards in WPEA, but these had never been properly tested in a major new building and, in any case, were conceived around chemical laboratories which are in a minority in BPO research and development buildings.

Early in the design stages, controversy arose over how some of the WPEA statements should be interpreted. The most difficult to resolve was that laboratory staff should all have their personal space allocation not more than 6·55 m from a window, which is 8·08 m from the outer edge of a balcony. This is difficult to justify in a building with high-intensity electric lighting, where a feeling of space is given by high ceilings and continuous windows running almost to ceiling height all round each floor.

A further problem, partly generated by the rapid advance of technology, was how to ensure that sufficient laboratory space was authorized to cover the almost certain future growth in research equipment, independently of staff numbers. This was resolved by dividing all the laboratory areas defined by the Schedule of Requirements into staffed and unstaffed categories. The staffed areas were related to numbers of staff and grades, and followed the WPEA agreements on area allowances. All this staffed area was contained in the 6·55 m belt alongside windows and, on this basis, the 7 floors of the laboratory building can comfortably accommodate the present (1976) staff numbers. The unstaffed area requirements are functional and are related only to work and equipment needs. The very wide laboratory floors have large central areas that fill these functional applications, with some space left for further growth.

For Research Department, an important outcome of the national WPEA agreements was that the local union representatives were in a position to contribute and to co-operate with management in drawing-up the basic requirements for the new Research Department buildings. Although the production of the Schedule of Requirements is a management responsibility, staff morale greatly benefitted from the close involvement of the unions which was organized through the machinery of the Martlesham Move Committee, to be described in a subsequent article.

THE OVERALL DESIGN OF THE BUILDINGS

Several basic designs for the Martlesham complex of buildings were prepared by the architect and R10 Division. The problem presented enormous design difficulties because the complicated engineering facilities needed, and the requirements for flexibility in use of space, were in conflict with the tight budget ceiling imposed by the BPO Board. A speedy completion was also demanded, but, eventually, contractual deficiencies outside DE and BPO control dictated the timing, and the building took nearly 7 years from contract to complete take-over.

The way in which the DE architect, Mr. Stanislaus Spielrein, met the requirements can be seen in the site plan (Fig. 2) and the photograph in Fig. 1. There are 3 main buildings of different character and heights: the main laboratory block, the administration block and the research services block. At every common floor level, the buildings are linked to 2 massive towers by lightweight steel-framed glass-panelled multi-storey bridges. These towers are primarily to house lifts, and they cater for all staff and goods transport between levels (see Fig. 3). The architects' term for this is *vertical circulation*.

The Towers

The need for batteries of lifts outside the laboratory building generated the idea of 2 separate towers, one on each side of the laboratory block. Other important uses for those towers developed as the design progressed and they became major features. They are similar in design, made of reinforced concrete, and are 12·2 m square and parallel sided with a cast rectangular-patterned surface to create an interesting appearance. Both have mezzanine floors in addition to those at the laboratory levels and emergency stairways, toilet facilities, and suites of offices for Heads of Divisions.

Water Tower

The tower on the east side, known as the *water tower*, has around its base a 2-storey cruciform-shaped building to provide drawing-office accommodation and, on the lower floor, a boiler room and various stores. At the top, the tower carries a 200 m^3 water tank, cooler batteries for the main refrigerators and smoke stacks for the boilers, all protected by a black louvred surround to an overall height of 53·3 m above the ground. Details of the useful floor area provided in the water tower, and the use to which it is put, are given in Table 1.

TABLE 1

Accommodation Provided by Water Tower

Section	Use	Useful Area (m^2)
Second to Fifth Floors	Divisional offices	368
Plant Room	Air-conditioning plant, electric light and power plant	1029
Cruciform	Boilers, a.c. plant, stores, drawing office	1658

The Radio Tower

The other tower, the *radio tower* (see Fig. 4), is extended upwards at reduced section to support a prominent 2-storey 18·3 m square radio laboratory set at 45° to the faces of the main tower. Above this, the tower continues in a 5·8 m diameter concrete column to carry 2 saucer-shaped aerial galleries. The overall height of the top slab of this column is 73·2 m above ground level. This massive tower is designed to provide a stable platform for microwave aerials in all weathers. Stability calculations were based on a 36 m/s steady wind, which allows for short gusts well beyond this. The calculated weight of the radio tower is 14 000 t, so that any swaying that does occur due to elasticity in the gravel bed beneath the foundations will be extremely slow. Each tower is founded on a 21·3 m square by 2 m thick concrete slab resting on undisturbed sandy gravel at 6·1 m below ground level. This ground is almost ideal for heavy buildings, having a loading capacity if undisturbed of 40 Mg/m^2. No piling was necessary on the site.

Optical measurements in the exceptionally severe gale of January 1976, when the wind velocity approached the design figure for a short time, showed a lateral movement of 200 mm at the top of the radio tower. This was about half the value expected for these extreme conditions. Differential movement between the towers and the adjacent main buildings is taken up by expansion joints at the appropiate places in the connecting bridges.

The accommodation provided by the radio tower is shown in Table 2.

FIG. 4—The radio tower

TABLE 2

Accommodation Provided by Radio Tower

Section	Use	Useful Area (m^2)
Lower-Ground, Mezzanine, and First to Fifth Floors	Divisional Offices	503
Cabin Laboratories (2 floors)	Microwave laboratories and link equipment to Mendlesham	654
Basement	Store	50
Plant Room (near top of tower)	Air-conditioning plant, electric light and power plant	190

The Laboratory Block

The laboratory building has 7 floor levels at 5 m spacing, comprising a lower-ground level that contains all heavy air-conditioning plant, ground level and 5 upper storeys. The accommodation provided is shown in Table 3, and a typical floor layout plan is shown in Fig. 5. All the laboratory floors have a uniform clear room height of 3·35 m, with hanging ceilings and a services void above. The overall height of the building to the parapet is 35·4 m above lower-ground level. The overall length is 142·6 m and the overall width is 50 m; these dimensions include 1·8 m wide balconies that run completely round the building at each of the 6 above-ground floors, to provide some shade to reduce the solar heat entering the windows below. They also give good emergency exit routes via emergency exit doors that replace windows at

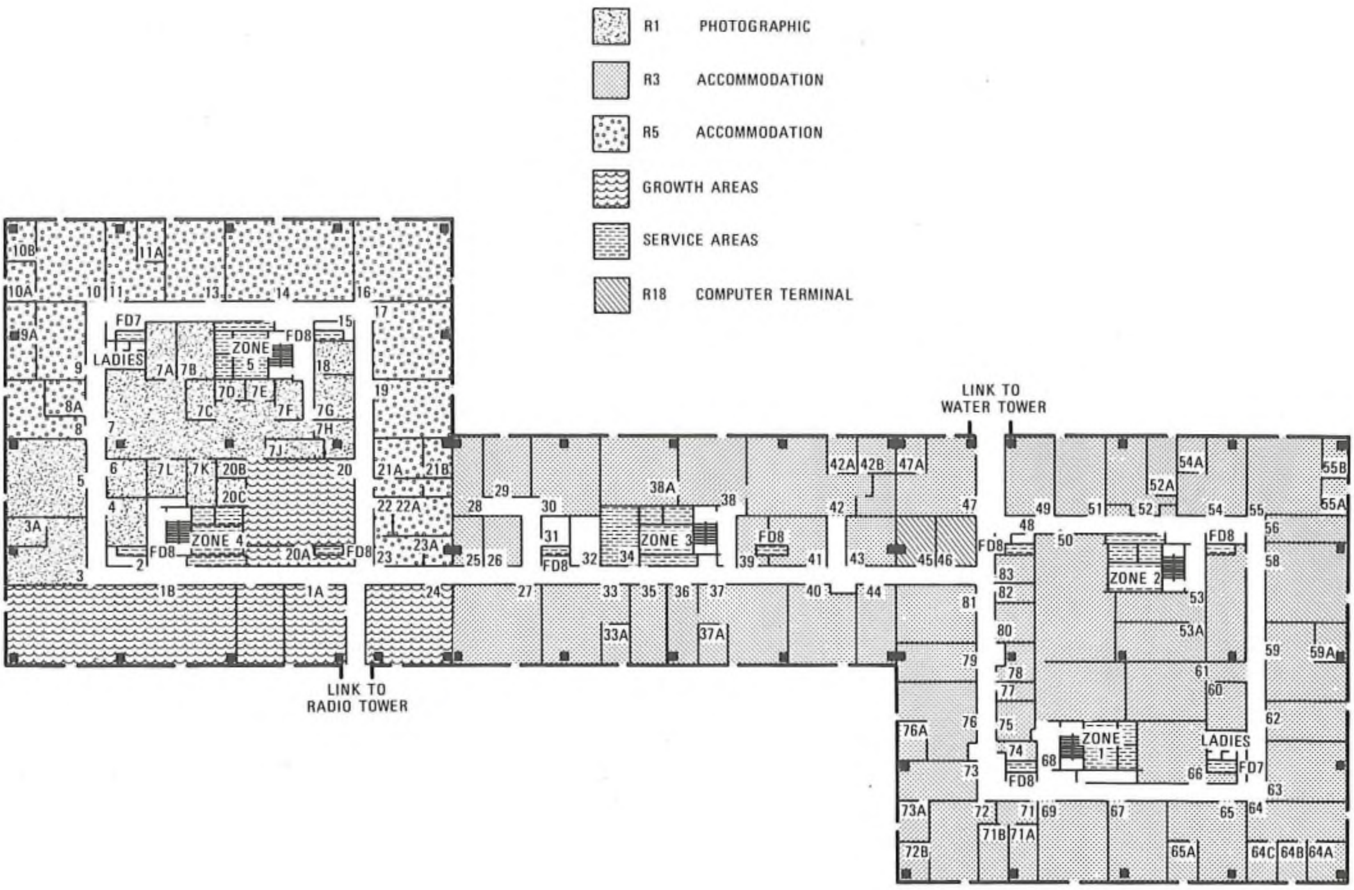


FIG. 5—Typical laboratory floor plan

TABLE 3

Accommodation Provided by Laboratory Building

Floor	Useful Area (m²)		
	With Windows (for staff)	Without Windows (for special equipment)	Air-Conditioning and Services Plant Circulation Area
Lower-Ground	790	108	4250
Ground	2900	1231	1214
First	2900	1300	1050
Second	2900	1140	1214
Third	2900	1064	1295
Fourth	2900	1269	1140
Fifth	2700	480	1180

10 m intervals. Supporting frames beneath the balconies are enclosed by anodized corrugated-aluminium panelling to give a distinctive horizontal pattern to each floor when viewed from the ground.

In plan, the laboratory building consists of 2 squares having 45·72 m sides, linked at all 7 levels by a rectangular building 45·72 m long by 22·86 m wide. This shape was considered the best practical compromise to meet the following 3 major design parameters:

(*a*) efficient air-conditioning, which demands minimum outer area for maximum internal volume to achieve the maximum fuel economy,

(*b*) large open floors with a minimum of fixed obstructions, and

(*c*) freedom from building vibration and from transmitted noise within the structure.

The 2 squares and the rectangular link are constructed as 3 separate steel frames on individual reinforced-concrete pad footings. The heavy services plant is carried on separate foundation rafts cast in gaps left between footings.

The designs were prepared before metrication in the building industry, but to simplify future work the nearest standard imperial size to 1 m, namely 3 ft 4 in, was chosen for the sub-module on which all dimensions are based. All windows are at 1-sub-module spacing continuous around every floor and, in the laboratory block, are 1·52 m high with double glazing.

The basic structural module between steel pillars is 11 sub-modules long, and there are 4 structural modules to each side of a square. This configuration is shown in Fig. 6, the dimensions being in imperial units for the reason given above. The windows and wall-cladding panels are spaced outside the steel pillars, which leaves a clean exterior appearance, but gives considerable obstruction in those rooms containing the pillars.

The laboratory floors are all designed for a maximum loading of 880 kg/m². The floors consist of 150 mm thick poured concrete slabs, carried on neoprene cushions that sit on the secondary steel joists. The slabs are separated by ducts that are closed by heavy-duty duct covers, and sealed at the edges with neoprene gaskets. This form of construction prevents transmission of vibrations from a floor slab into the steel framework (that is, it gives acoustic insulation down to a low frequency), but with the penalty that the floors contribute nothing to the stability of the building.

Stability of the building framework is, however, obtained from 5 vertical reinforced-concrete shafts, 2 in each square end and one in the centre link. These shafts are 8·1 m × 5·2 m in

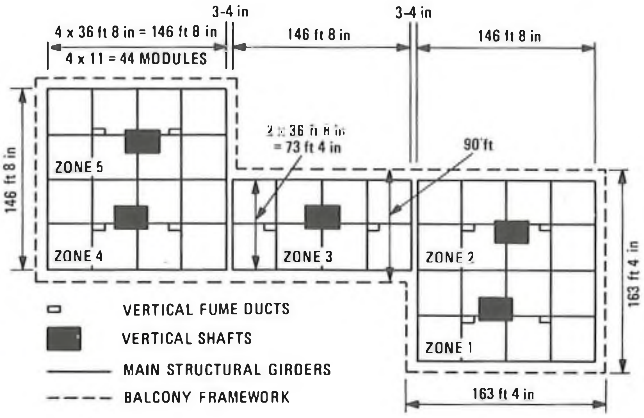


FIG. 6—Arrangement of main structural modules of laboratory block

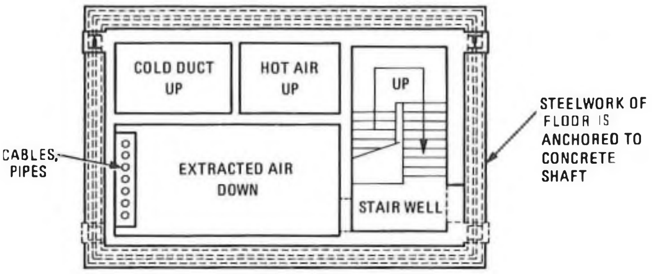


FIG. 7—Cross-section through a shaft

outside dimensions with walls 305 mm thick, they rise to the full height of the laboratory block and rest on independent concrete foundations. A collar of steelwork at each floor level surrounds and grips each vertical shaft, so ensuring the lateral rigidity of the whole steel framework. Fig. 6 shows the location of the 5 vertical shafts in relation to the building as a whole, and Fig. 7 shows a cross-section through a shaft.

Internal diaphragms divide the shafts into 4 vertical ducts. Three are vertical air-conditioning ducts: 2 riser ducts, one of 3·72 m^2 section for hot air and one of 4·18 m^2 for cold damp air, and a third of 13·38 m^2 for a downflow return air duct. This return air duct also contains pipes and power cables. The fourth duct in the shaft contains an emergency stairway to all floors.

For service purposes, the laboratory block is divided into 5 vertical zones each being based on one vertical shaft, as shown in Fig. 6. Structurally, in plan, zones 1 and 2 are built as one square, zones 4 and 5 as another and zone 3 is the link block. Expansion joints link the 2 ends of zone 3 with the squares at all floor levels, to give insulation from sound transmission within the steelwork and allow for differential movement during the settlement period, most of which will occur during the first 5 years. An air-conditioned building should stay at a constant temperature and, once this is achieved, there should be negligible differential movement from expansion.

There are no permanent partition walls on the laboratory floors. The rooms are all made from demountable steel partitions that slot into ceiling grids already in position on a 2-sub-module pattern. The partitions rest on 76·2 mm wide metal strips that in turn rest on the floor covering held from slipping by an adhesive layer. Vertical side columns support the panels (610 mm wide by 3·35 m high by 88·9 mm thick) formed of 2 sheets of plastics-covered steel, separated by a layer of glass-wool insulation. The panels, although heavy, can be fitted into place by 2 men. A completed wall is firm, but can be demounted without damage to the floor or panels. A 2-sub-module wide corridor, also made of demountable partitions, is at present used to divide the outer belt illuminated by windows from the special equipment areas illuminated only by artificial light.

Electrical connexions of all types are taken from wall ducts in the outer wall, with leads under the 3·05 m long benches which butt up to the window. Pipework, including chemical drains for sinks, rises via up-stands through the floor ducts to the laboratory benches. All floors have a distribution network of pipes for chilled water, compressed air, natural gas, and drainage, with hot water from local electric heaters fitted under the benches where needed. External pipework for oxygen and nitrogen runs along balconies to connect gas cylinders by lateral spurs through walls to benches as required. Other gases are provided from cylinders mounted in fire-resistant cubicles in alcoves in corridors outside the laboratories using them.

The Administration Block

The administration block (see Fig. 3) is the administrative centre for the whole of Research Department; it contains a large technical library and reading room, large and small lecture theatres, 2 conference rooms, a Confravision studio, restaurants and kitchen, the Director's suite of offices, Deputy Directors' and secretarial offices and the general management units for the Department. A large glass-fronted entrance hall, with an exhibition gallery projecting into it from above, helps to make this building distinctive and architecturally interesting. It is an attractive place in which to hold technical conferences. The useful floor area provided is given in Table 4.

TABLE 4

Accommodation Provided by Administration Building

Section	Useful Area (m^2)
Restaurant and Kitchen	1700
Welfare and Club Room	150
Lecture Theatres, Exhibition Gallery, Conference Rooms, Entrance Hall, and Confravision Studio	1100
Library	457
Directorate Offices and Administration	1056
Plant Rooms	515

The administration building is a monolithic structure in reinforced concrete, with the general shape of an inverted truncated square pyramid. There are 3 levels, the largest floor is at the top, containing a restaurant to seat over 300, a cafeteria with waitress service and a centrally-placed kitchen, a large coffee lounge, a snack counter, a well-furnished bar and a large games room for use by the various clubs.

Below the restaurant on the second floor is the library which is large and of an unconventional square design having a gallery at mezzanine-floor level surmounted by a large reading area in the form of a square. The library has glass pyramid roof lights in the central part of its ceiling to give some natural light over the lending area which is on the lowest level at the centre of the well of the library. Two book storage rooms with motorized book shelves on rails occupy the space beneath the reading area on 2 sides. Microfiche facilities are provided, and also offices for librarians and translators.

The large 450-seat lecture theatre is vertically beneath the library. It has a raked floor, a good stage, 3 translation boxes for simultaneous translation at conferences, and sound and projection equipment adequate for all occasions and purposes. A small 50-seat lecture theatre, in octagonal form and also well equipped, opens off the outer side of the entrance hall beneath the main staircase.

The whole of the administration block is air-conditioned, each level being served by a separate plant situated on the ground floor. The restaurant is served by an air-handling plant on the roof above. The kitchens are ventilated by fans exhausting straight out through the roof. Cooking uses gas heating.

The administration building is designed to be suitable for social as well as official occasions. It is structurally separate from the other blocks and access to it is independent of the laboratories. There is capacity in the restaurant for up to 1000 lunches using 3 sittings. Experience shows that about half the staff will lunch in the restaurant, so the restaurant should be able to cope adequately with a site population of 2000.

No enlargement of the administration building is likely to be practicable. It was designed for a maximum site population of 2000, and further building will be needed if the population increases beyond this.

The Research Services Block

The third major building unit, concerned with mechanical engineering and workshops, mostly of single-storey factory-type steel-frame construction, extends from the cruciform at the base of the water tower towards the north and north-east. Extensive workshops are essential to Research Department because improved mechanical technology is often needed to further new electronic ideas. The accommodation provided is given in Table 5.

The single-storey workshops and ancillary rooms are grouped around a small courtyard, which gives the advantage of natural light on the inner side. The drawing offices and part of the research services areas are air-conditioned to ensure a suitable environment for numerically-controlled machines and similar precision devices. These rooms occupy the cruciform structure around the base of the water tower and the wing over the lower loading bay. The air-conditioning here operates from the a.c. system for the water tower.

Two loading bays have been provided for heavy transport. These are located at different levels, one on each side of the services block. The lower loading bay, the larger of the two, is at lower-ground level and underneath the printed-circuit board production area on the south side. It is close to the heavy stores area with easy access to the goods lift in the water tower. The upper loading bay, at ground level, is a continuation of the workshop-floor level, and is also given wide corridor access to the tower lifts.

TABLE 5

Accommodation Provided by Research Services Building

Section	Use	Useful Area (m^2)
Lower-Ground Floor	Storage	1454
Ground Floor	Workshops, ancillary services, R1 Divisional offices	3339
Stand-by Engine Room	0·5 MW diesel alternator emergency set	92

Two features of the workshops, as originally specified, have proved unsatisfactory: the mercury-vapour lighting which gives an unpleasant stroboscopic effect with rotating machinery, and the workshop floor surface where the screed tends to crack and lift from the concrete substrate. The floor surface also seems to have some oil-absorbing property, giving a fire risk. The installation of new lighting is in hand and an additional floor-covering overlay is being tried on sample areas.

A motor-transport workshop and fuelling station, which was included in the original schedule of requirements but later deleted as an economy measure, will shortly be built on the east side of the services area road. This motor transport workshop will be under the control of the Eastern Region of the BPO, because the Research Department vehicle fleet is maintained by the Motor Transport Officer, Ipswich.

CONCLUSION

This first part has described the design principles, the requirements, and the overall design of the main buildings forming the Martlesham Research Centre. Part 2 will describe the services provided and a separate article will describe the organization of the move from Dollis Hill.

Book Review

Mathematics for Electronic Technology. D. P. Howson, B.SC., M.SC., D.SC., C.ENG., F.I.E.E., F.I.E.R.E. Pergamon Press Ltd. x + 270 pp. 93 ills. £5·85 (hard cover); £3·95 (flexible cover).

It is well known that engineers sometimes find mathematics difficult, and this may, to some extent, be due not to the difficulty of the subject, but to the standard of mathematical teaching and text books. It is essential to present the basic notions and techniques in a clear and consistent way, and to show that the mathematical formalism does give a concise description of the physical phenomena that are being studied.

This book is unlikely to remedy any deficiencies in the literature. It is an expanded version of a book reviewed unfavourably in this *Journal* in October 1967. The changes that have been made remove none of the defects of the previous version. The text is as confusing as before and, worst of all, there are now many obvious errors.

The first occurs on p. 2, where it is stated that, if a function is continuous, it has a derivative. Now, the derivative of a function is the slope of its graph, and so, if the graph has a corner, then obviously there is no well-defined slope at that corner. An intelligent student is almost sure to spot this, and his reaction may be to dismiss mathematics as some sort of Mumbo Jumbo, rather than to blame the presentation. There are many other errors in the book. Readers may be amused by pp. 126 and 127, where it is "demonstrated" that the nth roots of unity are $e^{jk\pi/n}$, where $k = 1, 2, \ldots n$. All other authorities prefer the formula $e^{2jk\pi/n}$, since it gives the correct results.

There is a great need for good text books on engineering mathematics, and many students may be tempted to try this book since it is written by an engineer, However, it may serve only to create difficulties in learning and using mathematics. In fact, no one who wishes to learn mathematics, or use it in electronic technology, is advised to read this book.

D. J. B.

Development of a 120 Mbit/s Digital Line System

Part 1—System Principles, Equipment Engineering and Maintenance

M. J. SCHICKNER, C.ENG., M.I.E.E., and L. C. ZICK, B.SC.†

UDC 621.394.4

This first part of a 2-part article describes the system principles, the equipment engineering and maintenance facilities of the 120 Mbit/s digital line system, 2 designs of which have been installed and successfully tested in an experimental field trial. Part 2 will describe the equipment.

INTRODUCTION

As part of the general plan for the introduction of time-division-multiplex (TDM) systems into the British Post Office (BPO) transmission network,[1] it was considered necessary to develop a digital line transmission system that was suitable for use on coaxial cable and compatible with the current designs of frequency-division-multiplex (FDM) systems, such as the 12 MHz Coaxial Equipment Line No. 4000 (CEL 4000) system. Compatibility was required so that the TDM system could work in existing cables and repeater cases with FDM systems, without mutual interference, using the same spacing for repeaters (2·1 km for 1·2/4·4 mm coaxial pairs) and power-feeding stations (30 km), and the same power-feeding system (49 mA constant current). System performance must be in accordance with the currently-proposed *international hypothetical reference circuit*, suggesting a design error rate of 1 in 10^{10}/km. The ability to transmit any sequence of bits in the 120 Mbit/s input signal, termed *bit-sequence independence*, was also required.

Feasibility studies showed that, with existing technology, a maximum transmission rate of 120 Mbit/s should be achievable, and that one of the main design limitations was the maximum power (1·6 W) available from the line power-feeding system for each dependent regenerator. Tenders were invited for the design, manufacture and installation of an experimental field-trial system and, because of the alternative designs offered, resulted in the BPO placing 3 contracts to enable the alternatives to be practically evaluated. Fig. 1 shows the field-trial route.

One contract was placed with Standard Telephones and Cables Ltd. (STC) for a system to be installed between Guildford and Portsmouth. This company proposed that the regenerator design would use conventional technology, with mainly discrete components. Due to the power restriction imposed on regenerators, a supervisory system was designed that required few components in each regenerator.

Contracts were placed also with The General Electric Co. Ltd. (GEC) and Plessey Co. Ltd. (PCL), these 2 companies

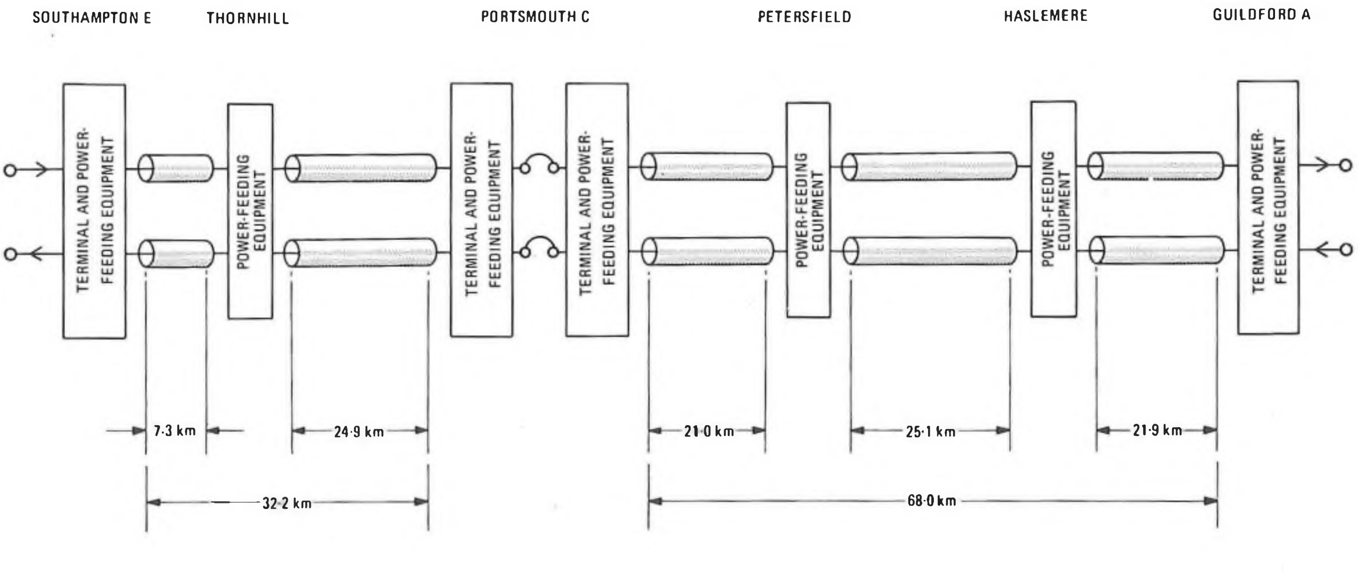


FIG. 1—Experimental field-trial systems

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† Telecommunications Development Department, Telecommunications Headquarters

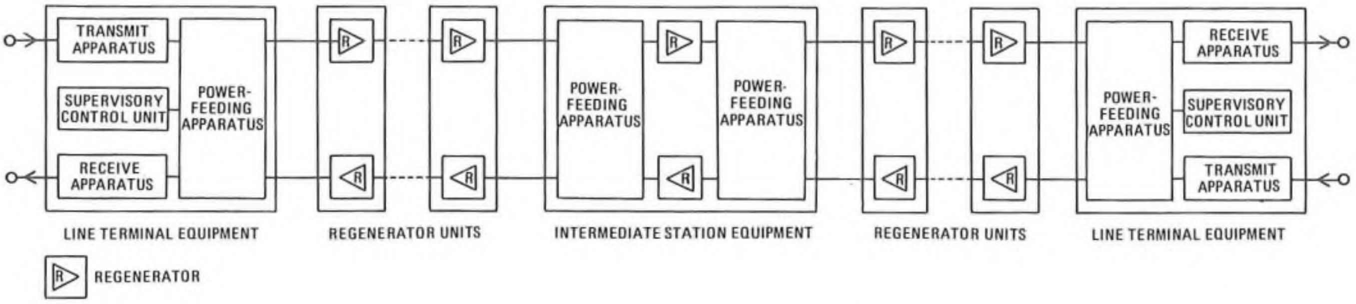

FIG. 2—System organization

to collaborate in providing a second system between Portsmouth and Southampton. GEC were to design, manufacture and install the surface station equipments, and PCL the regenerator units which would use some custom-built integrated circuits and thick-film hybrid circuits to enable a more advanced type of supervisory system to be provided, while still meeting the power restrictions.

The experimental field-trial systems have now been installed and tested. The viability of such systems has been proved, and a specification for a production 120 Mbit/s digital line system issued with a planned ready-for-service date of 1978 for the first systems.

This first part of a 2-part article describes the system principles adopted in the design of the 120 Mbit/s digital line system. It also describes the equipment engineering aspects and the maintenance facilities. Part 2 will give a description of the equipment.

SYSTEM ORGANIZATION

The systems described in this article use fully regenerative repeaters (regenerators), and the general organization of a system, shown in Fig. 2, is similar to that of the FDM, CEL 4000 system. One digital line section (DLS) consists of 2 line terminal equipments, a number of intermediate station equipments and the regenerator sections between them. A regenerator section comprises a regenerator and the preceding section of coaxial pair.

The line terminal equipment consists of a transmit apparatus, which processes the traffic signal for transmission to line, and a complementary receive apparatus. A supervisory control unit is provided in each line terminal equipment for system supervision; this uses a low-digit-rate telemetry system working over the same coaxial pairs as the main traffic signal, but in a lower band of the frequency spectrum. Line terminal and intermediate station equipments also contain power-feeding apparatus for energizing the intermediate dependent regenerators.

Dependent regenerators are normally housed in pressurized repeater cases which are placed in footway boxes or manholes at intervals along the cable route. Two dependent regenerators, one serving each direction of transmission, are engineered as one regenerator unit. The size and shape of the regenerator unit is such that 2 will fit into the standard BPO Case Repeater Equipment No. 1[2]; alternatively, one regenerator unit and one FDM bothway repeater can be accommodated.

The production DLS is designed for a nominal maximum route length of 280 km although, under favourable conditions, it could be longer. The absolute limit is fixed by the engineering of the supervisory control unit which can cater for a maximum of 14 intermediate station equipments and 198 regenerator units between the 2 line terminal equipments.

SYSTEM PRINCIPLES

Early studies showed that the maximum transmission information rate that could reasonably be expected to be achieved, using fully regenerative repeaters with the type of coaxial cable and the regenerator spacing specified, was in the region of 120 Mbit/s. Although there has subsequently been an increased interest in hybrid systems, in which a proportion of repeaters are linear amplifiers, the techniques required are generally more sophisticated. In the event, it was felt that the best solution was a fully regenerative system, with regenerators deriving a timing signal to retime accurately the restored pulses.

An ideal regenerator should reproduce at its output a perfect replica of the original signal, thereby realizing the main advantage of digital transmission—the virtual elimination of cumulative distortion. As high-speed systems use coaxial cables having very high crosstalk attenuation, the fundamental limit to regenerator performance is thermal noise. The amplitude of the noise has a normal distribution, and so there always exists a certain probability of errors being made in the decision circuit of the regenerator. This probability can be made arbitrarily small by providing regenerators before signal distortion becomes excessive; the system error rate is then the sum of the error probabilities of all regenerators.

A practical regenerator usually comprises equalization and amplification stages, incorporating shaped automatic gain control (AGC) to compensate for a range of cable attenuation. A timing signal is recovered which is used to control the sampling of the line signal at the threshold detector. This determines the type of pulse present at that instant; reconstituted pulses are then produced by an output power amplifier.

Cable Attenuation

Considerable effort was expended on deriving the worst-case characteristics of the cable. Existing sections are specified up to only 12 MHz, while for 120 Mbit/s systems, control of the characteristics to frequencies of the order of 100 MHz is required. Fortunately, measurements on sample drum-lengths and a number of laid sections showed the cable to be reasonably uniform to frequencies in excess of 100 MHz.

Doubt was cast over 3 areas: the spread of manufacturing tolerances, inaccuracies in length measurements and records, and the temperature variation experienced by cable. In the absence of any further reliable data, the last of these was dealt with by retaining the 0–20°C range previously specified for coaxial systems; the first 2 topics were dealt with by allocating tolerances based on a sample of measurements. In a regenerative system, section length, or more specifically section attenuation, is of critical importance; excessive loss causes severe reduction of operating margin leading to a practically unusable system. For example, the temperature of a cable in a steel duct on the side of a bridge exposed to direct sunlight could exceed the normal design maximum of 20°C, causing excessive attenuation and, hence, an unacceptable error rate at the following regenerator. In the case of analogue systems, excessive attenuation is compensated for at following repeaters and results in only a slight worsening of the signal-to-noise ratio. Abnormal temperature conditions are covered by planning rules and are overcome, where necessary, by restricting the length of the regenerator section; very occasionally, on short sections, non-standard line-building-out networks are fitted.

In specifying 78 dB at 45 MHz and 20°C as the worst-case loss for sections of nominally 2·1 km, it is confidently believed that any section of that length, or less, can be safely used for 120 Mbit/s DLSs. The reason for specifying the loss at 45 MHz will become apparent later.

Line Signal Coding

To make the signal more suitable for transmission, it is encoded in the line terminal equipment transmit apparatus into a line code having bit-sequence independence and also the following properties:

(*a*) limited power at low frequencies,
(*b*) limited power at high frequencies,
(*c*) a suitable pulse sequence for the derivation of a timing signal,
(*d*) a suitable pulse sequence for maintaining AGC circuits at the correct level,
(*e*) ease of translation between the line code and binary signal, and
(*f*) some means of providing in-service monitoring.

Low-Frequency Signal Power

In common with analogue line systems, dependent regenerators are power fed along the coaxial inner conductors, using low-pass power-separating filters to isolate the signal and power paths. Thus, the signal should preferably have no d.c. component and limited low-frequency content. This also has the advantage that transformer coupling can conveniently be used at regenerator inputs and outputs if required. A d.c. component is avoided by making the signal balanced about zero, but to restrict low-frequency components, the extent of slow, or long-period, excursions from this level must be limited. Consideration of these factors is simplified by the concept known as *disparity*, or *digital sum*. Pulses are assigned weights related to their amplitude; a 3-level signal can have levels weighted $+1$, 0, -1, representing a positive pulse, no pulse (middle level), and a negative pulse. For no d.c. component, the signal must have zero average disparity, and the low-frequency content is related to the maximum variation in cumulative disparity, termed the *digital sum variation*.

High-Frequency Signal Power

As the loss of air-spaced coaxial cables is proportional to the square root of frequency, the noise power at the decision point in the regenerator increases rapidly with increasing bandwidth. To reduce the bandwidth required for transmission, the line code is designed to give a reduction in symbol rate sent to line. This can be achieved only by generating a code with more than 2 levels.

The binary signal to be encoded has, by definition, one bit of information per unit time interval, or time-slot. A random event of probability, p, conveys information, I, given by $I = \log_2(1/p)$ bit. If a line code generates m levels, which are independent and equally likely, the probability of each level is $1/m$, and the information transmitted in each time-slot is $\log_2 m$ bit. Thus, for a random ternary (3-level) signal, there are 1·58 bit/time-slot, for quaternary (4-level) signals, 2 bit/time-slot, and so on. These figures represent the maximum information capacity of the codes; any restrictions imposed by the encoder reduce this capacity.

Nevertheless, it would be possible to encode 2 binary digits into one quaternary signal, thereby reducing the symbol rate to one half the information rate, while using the maximum capacity of the quaternary line signal. The proportion of the available capacity not used is referred to as the *redundancy* of the code. The quaternary code described would, therefore, be non-redundant.

In principle, the symbol rate can be reduced to any value by providing a suitable number of levels: in practice, the difficulties of making regenerators for such codes has meant that codes with more than 3 levels have seldom been used.

Timing Signal Content

Many types of code give a line signal having no power at the symbol frequency, so that, to derive a timing signal at this frequency, some non-linear operation must be performed on the signal. Typically, this process is rectification and slicing, the resulting signal being used to excite a tank circuit. To maintain a constant output from the tank circuit, the line signal must contain a certain minimum density of transitions; long strings of zeros or symbols of the same polarity are particularly disadvantageous.

Automatic Gain Control Stability

To compensate for different cable-section lengths, and cable-temperature variations, AGC is provided in the regenerator. As no pilot is present, the control signal for the AGC circuit must be derived from the line signal, and this can conveniently be achieved by sensing the peak pulse amplitude. The AGC circuit has a time constant associated with it, so that a minimum density of pulses must be ensured.

Ease of Translation

Certain types of code rely on translation between binary and line-code words, or groups of symbols. In this case, word alignment must be acquired at the decoder for the correct output to result. This process should be automatic; thus, the code must have some property that allows alignment to be achieved, ideally independently of the binary signal being transmitted. As relatively few complex logic functions are available in high-speed logic, code words should be kept short to avoid unmanageable coder complexity.

In-Service Monitoring

By using the redundancy inherent in the encoding process, the line signal can be monitored for the occurrence of errors. This allows in-service monitoring of traffic and, potentially, provides an in-service means of locating faulty regenerators.

Line Code Adopted

The line codes adopted for the 120 Mbit/s DLSs are of the type known as *4B3T*; that is, the symbol rate is reduced by translating 4 bit binary words into 3-symbol ternary words (see Fig. 3). This gives a reduction factor of 3/4, thus reducing the 120 Mbit/s input signal to a 90 Mbaud line signal. This ratio is chosen because it allows the selection of ternary words that fulfil the requirements described previously and gives a bounded digital sum.

Consideration of the 27 possible 3-symbol ternary words shows that one is the word 000 which is discarded because it contains no timing information, 6 are balanced (that is, have

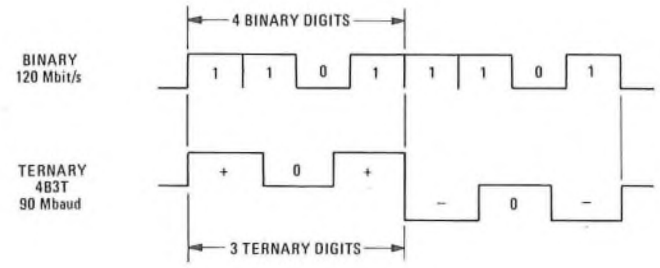

FIG. 3—4B3T code word alignment

TABLE 1

Basic 4B3T Binary to Ternary Code Conversion Table

Binary Input	Ternary Output Signal		
	Running digital sum at end of preceding word equal to		
	−2, −1 or 0	1, 2, or 3	
0000	+ 0 −	+ 0 −	Balanced
0001	− + 0	− + 0	
0010	0 − +	0 − +	
0011	+ − 0	+ − 0	
0100	0 + −	0 + −	
0101	− 0 +	− 0 +	
0110	0 0 +	0 0 −	Inverse Pairs
0111	0 + 0	0 − 0	
1000	+ 0 0	− 0 0	
1001	+ + −	− − +	
1010	+ − +	− + −	
1011	− + +	+ − −	
1100	0 + +	0 − −	
1101	+ 0 +	− 0 −	
1110	+ + 0	− − 0	
1111	+ + +	− − −	

+, 0, and − represent the 3 states of the ternary symbol

TABLE 2

MS43 Binary to Ternary Code Conversion Table

Binary Input	Ternary Output Signal		
	Running digital sum at end of preceding word equal to		
	−1	0 or 1	2
0000	+ + +	− + −	− + −
0001	+ + 0	0 0 −	0 0 −
0010	+ 0 +	0 − 0	0 − 0
0011	0 + +	− 0 0	− 0 0
0100	+ − +	+ − +	− − −
0101	0 − +	0 − +	0 − +
0110	− 0 +	− 0 +	− 0 +
0111	0 0 +	0 0 +	− − 0
1000	0 + 0	0 + 0	− 0 −
1001	+ 0 0	+ 0 0	0 − −
1010	− + 0	− + 0	− + 0
1011	+ − 0	+ − 0	+ − 0
1100	+ 0 −	+ 0 −	+ 0 −
1101	0 + −	0 + −	0 + −
1110	− + +	− + +	− − +
1111	+ + −	+ − −	+ − −

+, 0, and − represent the 3 states of the ternary symbol

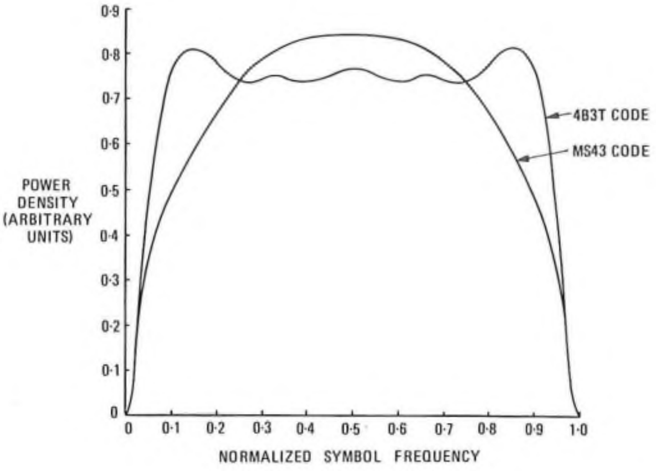

FIG. 4—4B3T and MS43 power spectra

zero disparity of the form + 0 −, − + 0, etc.), and 20 can be arranged to form 10 inverse pairs. Of the 16 possible 4 bit binary words, 6 can be uniquely allocated to the balanced words, and the remaining 10 to the inverse pairs of ternary words, as shown in a typical 4B3T code book (Table 1). When one of the latter group of 10 binary words is received, the encoder chooses the ternary word of opposite sense to the running digital sum; a running digital sum of zero must be arbitrarily assigned as being positive or negative.

Provided that the rule for the selection of words is maintained, the pairs of words need not necessarily be inverse pairs. Further, the selection of the words can be based on the actual value of the running digital sum, rather than just its polarity. Thus, codes can be created that retain the basic property of the 4 binary to 3 ternary translation, but have differences of detail. One such code, termed *MS43*, is shown in Table 2. Here, 3 sets of ternary words are used, the selection being made according to the value of the running digital sum at the end of the last word transmitted.

Many other possibilities exist; for example, codes with 4 sets have received some attention. However, MS43 achieves 2 principal advantages over the basic 4B3T type, which are reduction of digital sum variation from 7 to 5, and reduction of the maximum number of consecutive like symbols from 6 to 5, though at some increase in complexity. The maximum number of consecutive zeros remains constant at 4.

The power spectra for these 2 codes, when transmitting a random binary signal, have been calculated and are shown in Fig. 4. Both have a null at d.c., as required, but MS43 has greater power towards the half-symbol rate and less at low and high frequencies. The spectra given are for sequences of impulses† only and must be modified by a suitable expression, dependent on the output pulse shape, to give the spectra sent to line.

Interface Coding

The requirements for an interface code are much less demanding than those for a line code. An interface code is used for interconnecting equipments within one station to avoid the need for separate data and clock connexions and for adjusting the delay in each to be the same. The binary signal is, therefore, encoded into an interface signal, which is chosen to ensure that a timing signal can be recovered for all bit sequences. As the insertion loss of station cabling between

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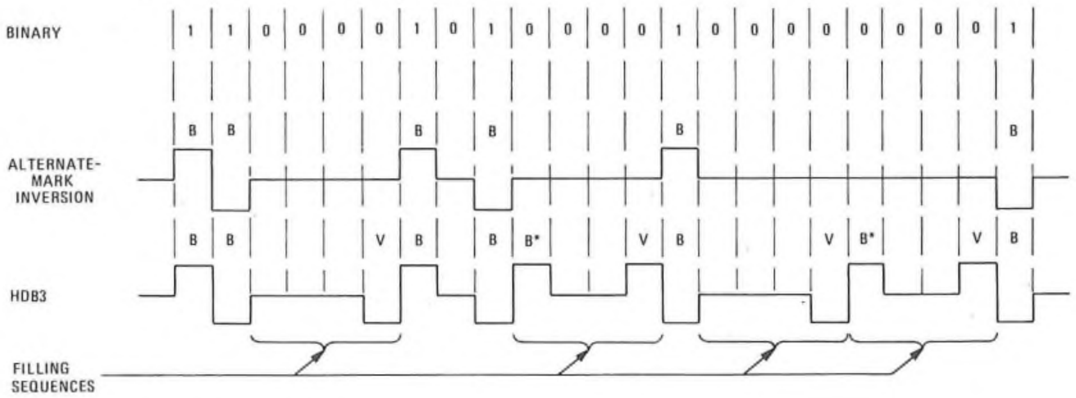
† Impulses are zero-width pulses used to simplify calculations



B = NORMAL BIPOLAR PULSE
V = VIOLATION PULSE OF THE FILLING SEQUENCE
* PULSE ADDED FOR CONTROL OF VIOLATION POLARITY

FIG. 5—Example of HDB3 interface code

equipments is comparatively low, symbol-rate-reducing codes need not be considered, and it is generally assumed that the margin against noise is such that errors have an extremely low probability and can be neglected. The same is assumed to be true of all the line terminal equipment, except the terminal receive regenerator.

The interface code used for the 120 Mbit/s digit rate is of the type known as *high-density bipolar*. Bipolar code is more commonly known in the UK as *alternate-mark inversion* (AMI), and the high density is achieved by replacing a sequence of zeros by a filling sequence (see Fig. 5). This sequence is recognized at the decoder by always making the last symbol a *mark* with a polarity that violates the AMI rule; that is, the same polarity as the previous *mark*. The filling sequence can then be recognized and removed by the decoder. For a code HDB*n*, blocks of ($n + 1$) zeros are replaced. The code used, HDB3, replaces 4 zeros by 3 zeros followed by the violation, so that the maximum number of zeros in the encoded stream is 3. However, to maintain the d.c. balance, violations must alternate in polarity and, to do this, the filling sequence has a *mark* in the first time-slot, when required, which conforms to the AMI rule. HDB3 is also used as the interface code and line signal at the 2 Mbit/s and 8 Mbit/s digit rates, but with a different pulse amplitude.

EQUIPMENT ENGINEERING

The development of equipment operating at a rate of 120 Mbit/s will introduce no new engineering practices to BPO repeater stations, as the line terminal and intermediate station equipments are constructed in, and conform to, the rules of BPO 62-type construction. Fig. 6 shows an experimental line terminal equipment. Production equipments are expected to occupy five 152 mm shelves, or less.

Components

Logic devices for the signal paths are chosen from the compatible emitter-coupled-logic families ECL 10 000 and ECL III. These give gate delays of 2 ns and 1 ns, with pulse-edge durations of 1 ns and 3·5 ns respectively. Some medium-scale-integration functions are also becoming available. Regenerators use mainly discrete components, though some thick-film hybrid circuits have been used.

Due to their low power consumption, metal-oxide-silicon integrated circuits have been used in the relatively low-speed regenerator supervisory unit. These devices have such a high input (gate) impedance that they can be damaged by static charges when being handled. Despite protective devices being built into the integrated circuits, it is still prudent to deal with these devices in a specially-equipped repair environment.

Impedance of Circuit Interconnexions

With analogue systems, it is common practice to match the impedances of transmission lines to their terminating equipments to achieve maximum power transference; for digital systems, matching is necessary to minimize pulse reflections. This is particularly important where the length of the path is an appreciable fraction of a wavelength of the signal. As frequencies increase, the critical length reduces such that, with 120 Mbit/s digital equipment, care must be taken to match the impedance of connexions between integrated-circuit devices that are greater than a few centimetres apart on the same printed-circuit board. Microstrip transmission line techniques are therefore used, the track width being adjusted so that its inductance, and capacitance through the board to a copper earth plane on the other side, give the required impedance. This requires extra care in the manufacture of the printed-circuit boards, but is still considered economic and practical. Typically, 50 Ω and 100 Ω transmission lines are used, the lower impedance giving faster operation at the expense of increased power consumption. The use of longer pulse-edge durations, where possible, results in less stringent requirements for control of impedance irregularities.

Interconnexions between integrated circuits on separate printed-circuit boards are made either by using coaxial cable with the required impedance, or by a mother–daughter board technique in which small (daughter) printed-circuit boards are mounted parallel to one another on, and perpendicular to, a larger (mother) board; this normally carries no components except connectors, and provides the matched interconnexions.

Data–Timing-Signal Relationship

The data and timing signal relationship must be tightly controlled. This presents a problem in the line terminal equipment, in which data and timing signals have to be passed through several stages of processing, and each process introduces an appreciable delay. Two solutions acceptable to the BPO have been developed.

GEC and PCL use separate 62-type cards for the various processes, and 2 coaxial pairs, where necessary, to interconnect the data and timing signals. The relative delay and,

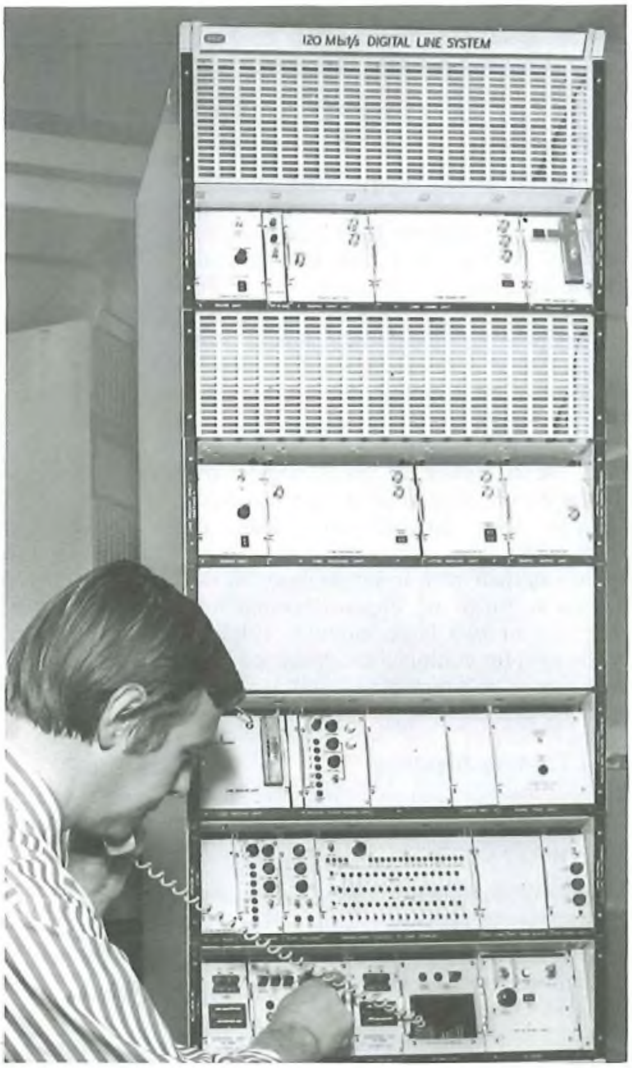


FIG. 6—Line terminal equipment

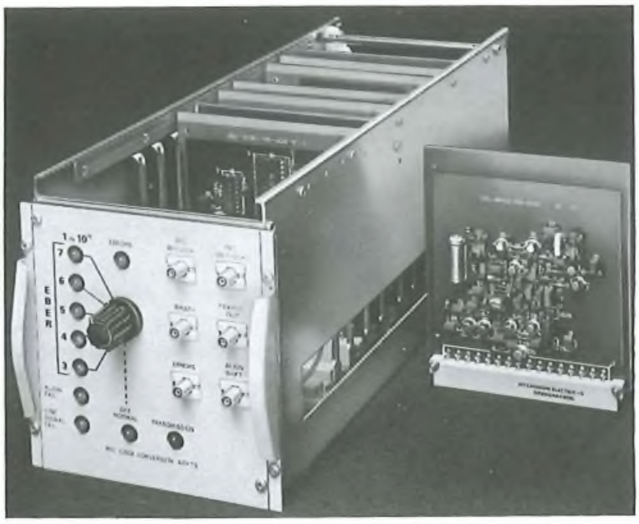


FIG. 7—Cassette

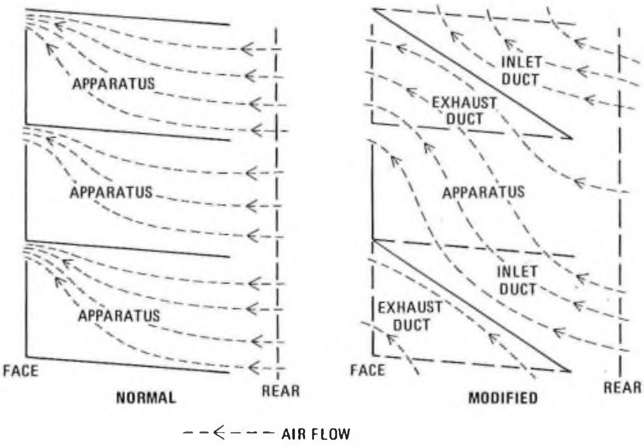


FIG. 8—Cooling of 62-type equipment shelves

hence, the relative lengths of these coaxial pairs is critical to within about 10 mm. To simplify maintenance, the use of these interconnecting cables has been restricted to a few standard lengths that are treated as replaceable components which must not be shortened by retermination.

STC have used a different approach, which is to mount the various processes on daughter boards, and the complete mother–daughter board assembly formed into a 62-type chassis unit, or *cassette* (Fig. 7). The mother board provides tight control of the relative data–timing-signal delays.

Heat Dissipation

Circuits using emitter-coupled-logic devices require very careful layout and tend to give a high packing density. This conflicts with the need for the equipment to cool by natural convection, instead of forced-air as normally used with devices of this type. High packing densities lead to high local ambient temperatures and "hot-spots". Investigations into this problem have led to the development of convection cooling methods that improve the normal 62-type practice of air flow from the rear to the front of 15° inclined shelves. One method developed uses special ducting to promote air flow vertically through the apparatus cards (Fig. 8).

Crosstalk

Due to the high attenuation of the cable to a 90 Mbaud line signal, the input amplifier of a regenerator requires a peak gain of the order of 80 dB, compared with the 37 dB of a 12 MHz analogue repeater. This, together with the short wavelength of the very high frequencies involved, presents a considerable problem in ensuring that the various sections of a regenerator are adequately screened to prevent unacceptable feedback. Once achieved, however, this goes a long way to ensuring that a regenerator works satisfactorily in close proximity to another regenerator, or an analogue repeater. Field tests, using equipment from both of the experimental DLSs, have shown that 120 Mbit/s digital and 12 MHz analogue systems can be used in the same cable with their repeaters/regenerators in the same repeater cases, without mutual interference. Fig. 9 shows a typical regenerator unit.

MAINTENANCE REQUIREMENTS

From the outset, it was decided that a DLS should be at least as reliable as the modern 12 MHz FDM system, and that advantage should be taken of digital techniques to

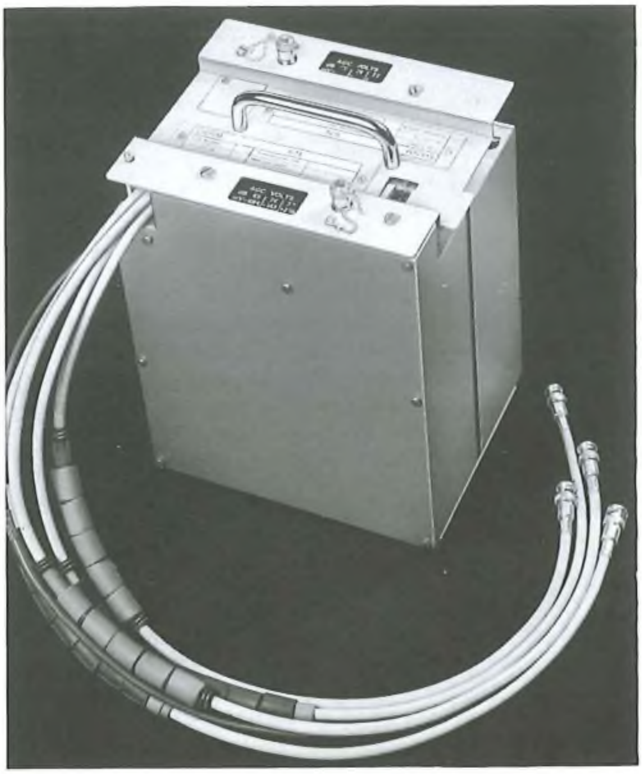


FIG. 9—Regenerator unit

improve fault location methods and, hence, reduce out-of-service time.

Reliability

The reliability, in terms of mean time between failure (MTBF), of each experimental DLS was calculated using component failure rates from various sources, and was found to be comparable with modern transistorized 12 MHz FDM coaxial cable systems; the production specification calls for a 4-year MTBF design objective for a nominal 100 km bothway digital system. As failures of dependent regenerators are more expensive to correct, in time and manpower, than faults in surface station equipment, it was decided to break down further the MTBF design objective to 8 years for underground plant (50 regenerator units), and 8 years for surface-station equipment (2 line terminal plus 3 intermediate station equipments).

Rack Power Supplies

A practice has developed over the last 2 decades for each rack, or part of a rack, of FDM transistorized transmission equipment to work off a common 20 V d.c. supply. This supply is provided by a number of power converters having their outputs connected in parallel via isolating diodes, with an extra unit provided to ensure continuity of supply in case any one unit fails. These units work off the station supply, are all mounted at the top of the rack and each supplies 2·5 A.

The advent of highly-concentrated digital integrated circuits introduced various problems which necessitated a change from the above practice for the following reasons.

(*a*) The main derived supplies required are of the order of ±5 V and individual equipments may require up to, say 20 A, though some types of logic or circuitry require other supply voltages.

(*b*) The voltage tolerances required on these supplies are quite stringent and, hence, a tight control is required on the voltage dropped across the distribution wiring used.

(*c*) The provision of adequate decoupling to prevent crosstalk presents a particular problem with high-speed digital circuitry.

It was therefore decided that power converters should form an integral part of each equipment; this avoids the need to specify a standard BPO range of converters and the necessary interface, and gives the equipment designer a free hand to optimize the location as well as the size of his power units. This policy is also being applied to BPO digital multiplex equipments.[3] One disadvantage of using dedicated power units is that it is not economic to provide extra power units for security of supplies. However, reliability calculations have shown that modern power units, using silicon semiconductor devices and approved types of electrolytic capacitors, are as reliable as the equipment they feed and hence make it unnecessary to have stand-by units.

Rather than provide tailor-made, high-output-current power units for each equipment, most contractors are developing their own in-house modular designs for use over the whole range of digital transmission equipments. By using one or two basic modules, either individual modules can be used for equipments requiring a low-rated or medium-rated supply, or a number of modules can be used on a high-rated equipment.

Fault-Finding Strategy

The fault-finding strategy adopted in the design of the DLS is that terminal monitors are provided in the line terminal equipment to detect

(*a*) transmit apparatus: loss of input signal, and
(*b*) receive apparatus:
  (*i*) excess error rate, above a manually-set threshold,
  (*ii*) loss of word alignment, and
  (*iii*) loss of line signal.

Any one of these conditions will raise a station alarm.

Maintenance staff will then use a self-checking supervisory system, which has a telemetry path over the whole length of the DLS, to locate the source of the defect. The terminal monitors and the supervisory system have lamp-lock facilities, so that many types of intermittent faults can be located on the first occurrence. The supervisory system does not originate transmission alarms and, in surface stations, is built into units physically separate from the main transmission path, so that a faulty supervisory unit can be changed without affecting traffic. The terminal monitors are built into the main transmission path units, so as to maintain a traffic check facility while the supervisory unit is being changed.

Alarm-Indication Signal

A previous article[3] described the principle of using an alarm-indication signal (AIS), this being an all-ones binary sequence that can be used to suppress station alarms at points in a transmission system subsequent to the point at which an alarm is raised. This is of great advantage where demultiplexing would otherwise cause a multitude of alarms.

In the development of a DLS, 3 conditions have to be considered in respect of the AIS.

(*a*) For a failure detected at an equipment preceding the DLS, such that the preceding equipment transmits an AIS, the DLS transmits the AIS as a valid signal and takes no further action.

(*b*) A failure of the output stage of a preceding equipment, the interconnecting cable or the input stage of the DLS is detected as a *traffic-input failure* by the DLS, which raises a local station alarm, and generates a stand-by timing signal and an AIS which is transmitted through the DLS. The *traffic-input-failure* condition could be conveyed over the supervisory telemetry path and the AIS generated at the distant terminal, but, where the input signal may be absent for a long time, as with a stand-by or spare system, it is desirable to have an alternative signal injected at the transmit terminal so that the normal DLS monitoring can take place.

(*c*) Excessive error rate, loss of word alignment or loss of line signal within the DLS would be detected at the receiving line terminal equipment, and an alarm raised. As a precision clock would have to be provided purely to generate the AIS, it has been decided that, for this class of failure, the DLS output will be disconnected. The DLS will be connected to one other equipment in the same station, and this will detect an *input-fail* condition and inject an AIS; thus, only one additional alarm, in the same station, will be originated when the DLS fails.

Terminal Monitors

Loss of Input Signal to the Transmit Apparatus

This detector monitors only the output of the preceding equipment, the interconnecting cable and the input stage to the DLS. It was not, therefore, considered economic to provide an expensive error detector, but rather a simple signal-fail detector. One way to do this is to connect a limit alarm to the input AGC voltage. The speed of operation of the alarm is then dependent upon the time constant of the AGC circuit.

Excessive Error Rate

Error monitors are provided in the receive apparatus to detect, and give a visual display, when the error rate exceeds each of the following levels: 1 in 10^7, 1 in 10^6, 1 in 10^5, 1 in 10^4 and 1 in 10^3. A threshold switch is provided which can be set to raise a station alarm at any one of these error rates. In addition, strapping is provided to enable the traffic path to be disconnected, if required, when the error rate exceeds 1 in 10^5, 1 in 10^4 or 1 in 10^3.

Two basic methods of determining the error rate are used: these are either to count the time for a predetermined number of errors to occur, or to count the number of errors occurring in a predetermined time. In designing error-rate counters, a minimum count number has to be fixed to set the confidence limit of the measurement; consideration is also given to whether hysteresis should be built into the detector to give a more stable indication. This design work is based on an assumed random distribution of errors. Because of the minimum count requirement, it is considered unpractical to extend the system error monitors below the 1 in 10^7 rate; 1 in 10^8 would require several minutes to respond.

A lamp is provided, which is operated from the error detector by a pulse, lengthened to light the lamp for about 1 s, to give an indication of a single error or burst of errors. This facility has proved to be very useful for locating bad connexions by vibration techniques. Further study is required of the effects of, and action needed for, non-random or burst errors.

Loss of Word Alignment

Detection of loss of word alignment is also used to operate a display lamp and raise the station alarm. To minimize confusing multiple-lamp displays, subordinate displays are suppressed; in this case, error-rate displays.

Loss of Line Signal

Loss of line signal can be monitored by detecting the loss of the timing signal derived by the terminal regenerator.

Chart-Recorder Facility

Single errors, the monitored error rates, loss of alignment and loss of signal conditions are combined to provide a graduated current to drive a chart recorder. This provides a useful historic record facility for performing reliability runs and locating intermittent faults. As field experience with analogue coaxial cable systems has shown how reliable such systems normally are, recorders will not be supplied as a permanent part of the line terminal equipment, but as an external device to be patched in when required.

Restoration of Service and Test Equipment

Due to the high cost and complexity of test equipment suitable for high-speed digital systems, it is expected that, once the supervisory system has located a fault, service will be restored by changing individual units and the faulty item sent away for repair.

Nevertheless, it is prudent to provide some field test equipment for location of faults in the transmission network down to the specific DLS or digital multiplex. Such items are pattern generators and error detectors for connexion at in-station interface points, and frequency counters for checking clocks and timing signals. A long-term development is planned for certain network and jitter testing equipments that may be required for more extensive networks and may have to take into account international standards. A wider range of test equipment is expected to be used for commissioning purposes.

A range of test points and TRAFFIC IN and TRAFFIC OUT U-links are provided on the DLS equipments, some for use on the initial systems and some for use with test equipment yet to be developed.

CONCLUSION

This first part has described the system principles, the equipment engineering and the maintenance facilities of the 120 Mbit/s digital line system. Part 2 will give a description of the equipment.

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A Review of the British Post Office Microwave Radio-Relay Network

Part 1—History and Planning

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This first part of a 3-part article outlines the history of the development of microwave radio-relay systems in the UK, and describes the size and use of the present network. The planning principles adopted for the network are then discussed and problems of interference are described.

INTRODUCTION

The British Post Office (BPO) has completed over 25 years operational service with microwave radio-relay links, and it is opportune to take stock of the overall position, look back over the first 25 years and take a tentative look forward. Some of the problems that have been met during the rapid expansion of the microwave radio-relay network to its present stage are discussed, together with some aspects of the introduction, in the near future, of digital radio systems. Over the years, there have been a number of articles in this and other *Journals*,[1,2,3] describing various aspects of microwave systems, and this article is not intended to be a comprehensive guide to all aspects of the design, planning and equipping of microwave links. Part 1 deals with some of the aspects of history and planning, Part 2 will deal with reliability and performance and Part 3 will review the evolution of the equipment.

HISTORY

The multichannel radio link was no new thing even 25 years ago. Much development work was carried out before the war in the very-high-frequency band, and valuable contributions to the technique were made on both sides of the Atlantic. From 1930 onwards, commercial interest in the band of frequencies above 300 MHz began to grow, and one of the first microwave links was set up on an experimental basis in 1931 between Dover and Calais. An aerial of that time is shown in Fig. 1. Operating at what was then regarded as the extremely high frequency of 1700 MHz, with a radiated power of about 0·5 W, it was regarded as an enormous advance on the techniques of the day, and it demonstrated that the little used band of frequencies from 300–3000 MHz was ripe for exploitation. The first operational microwave link is claimed to be that established by Marconi between the Vatican City and Castel Gandolfo in 1932. Nearer home, it is certain that, in 1934, a microwave link operated on a commercial basis between the airports of Lympne in Kent and St. Inglevert in France, a distance of some 56 km.

A halt to further progress in the development of BPO microwave communication systems was caused by the outbreak of war, but advances in technology still continued for radar. Such devices as magnetrons, klystrons, mixer diodes, waveguides, parabolic aerials and broadband amplifiers were the outcome, and these were to make an important contribution to the development of microwave radio links after the war.

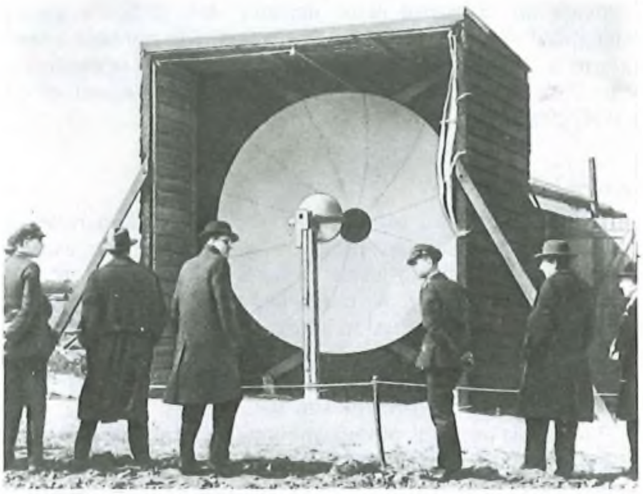

FIG. 1—The St. Margaret's Bay, Dover, terminal of the experimental link in April 1931
(Photograph by courtesy of STC Ltd.)

During the 1930s, carrier cable systems and frequency-division-multiplex (FDM) techniques were developed rapidly, and showed the pattern of future national and international trunk telephone networks. These networks indicated that, if microwave radio was to have a role for the transmission of trunk telephony, it would have to integrate with a rapidly expanding FDM network. After the war-time radar work involving pulse-modulation techniques, the most likely natural progression for communication links would have been with pulse modulation. In the event, much work was devoted to the development of analogue FDM telephony and television microwave systems to ensure compatibility with the FDM line transmission network.

In 1946, the BPO set up its own experimental link between London and Castleton, near Cardiff, initially operating at a frequency of 200 MHz and later converted to 4 GHz. It was one of the first links to use frequency modulation (FM) for the transmission of television. Valuable information was gained about the problems involved in the use of this form of modulation.

The first truly microwave radio link used in the BPO network came about because of the Government's decision to extend domestic television coverage from the London area

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† Network Planning Department, Telecommunications Headquarters

progressively to include the rest of the country by the early 1950s. The BPO placed a contract for the development and installation of a 900 MHz radio link to carry the signals between London and the first regional transmitter at Sutton Coldfield, near Birmingham, using 4 repeaters to cover a distance of some 185 km.[4] Initially, the equipment was developed to use amplitude modulation (AM), but it was not found possible to obtain the required linearity to achieve the performance standards necessary. So, with an element of pioneering spirit, the engineers on the route changed the system design to FM operation only 8 months prior to the in-service date of December 1949. FM has become the universally established modulation method for reasons that are well documented.[2,3] In addition to the easement of linearity problems, it offers improvements in the signal-to-noise ratio achieved compared with double-sideband AM.

It is interesting to note that a revival of AM is taking place in the USA, where single-sideband AM is being investigated to give an even greater concentration of circuits for a given unit bandwidth than is obtained using FM. Non-linearity problems are now overcome by using feed-forward techniques.[5]

The London–Sutton Coldfield link was followed in 1952 by the Manchester–Kirk O'Shotts link operating at 4 GHz and using the travelling-wave amplifier for the first time. This link was required for further extension of the 405-line monochrome television service and provided many years of excellent service. Part of this equipment can still be seen at the Science Museum, where its historic role is commemorated. From then on, the 405-line monochrome television distribution network was extended throughout the UK by microwave links. Coupled with this expansion, microwave links were increasingly being adopted for telephony transmission.

Continued development during the 1950s extended the capability of microwave circuit design so that, progressively, microwave links could carry on each radio carrier 600, then 960, then 1800 (and in some countries 2700) FDM telephony channels, or a 625-line PAL standard colour television signal.

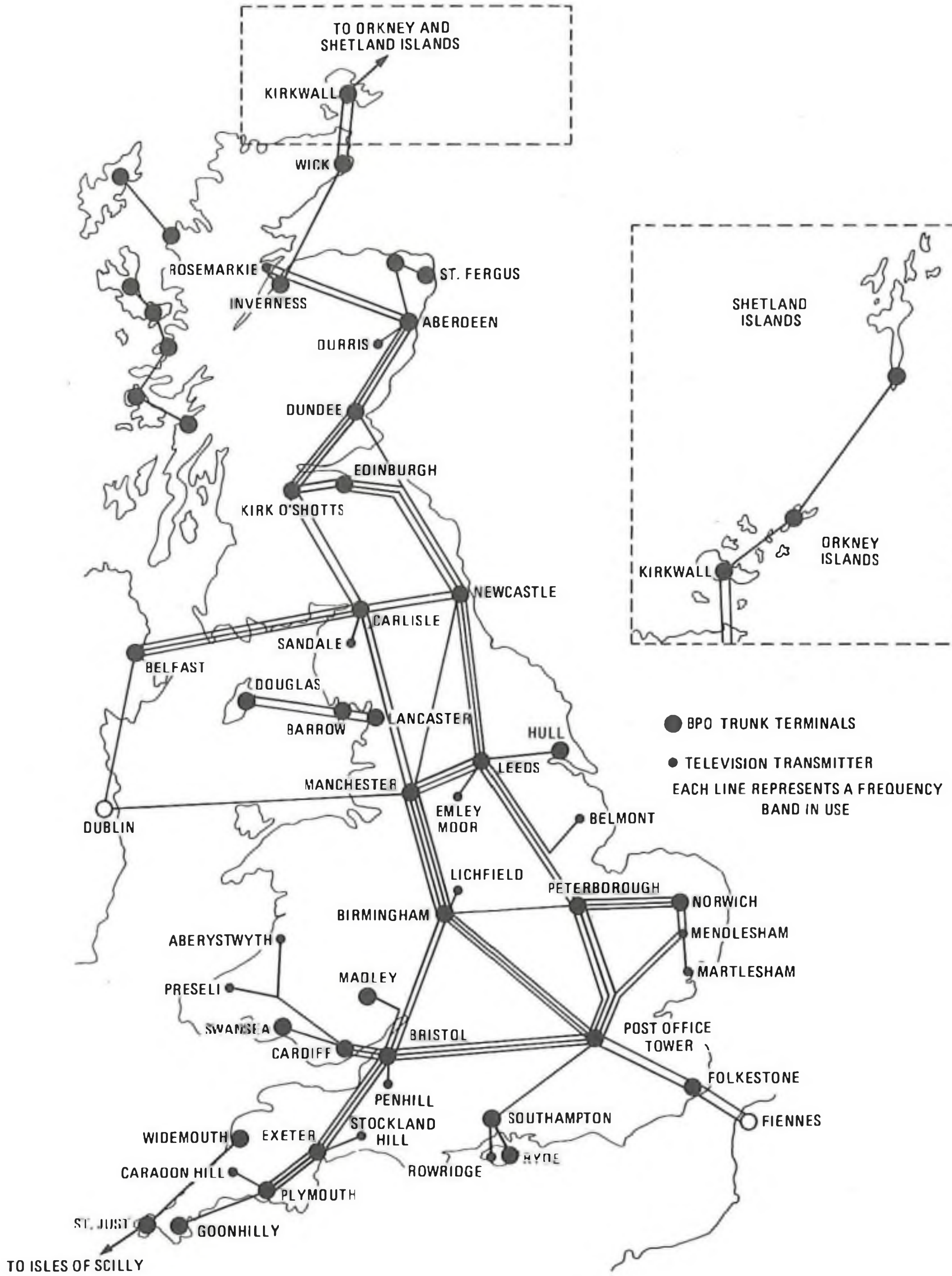


FIG. 2—BPO microwave radio-relay network at 1980

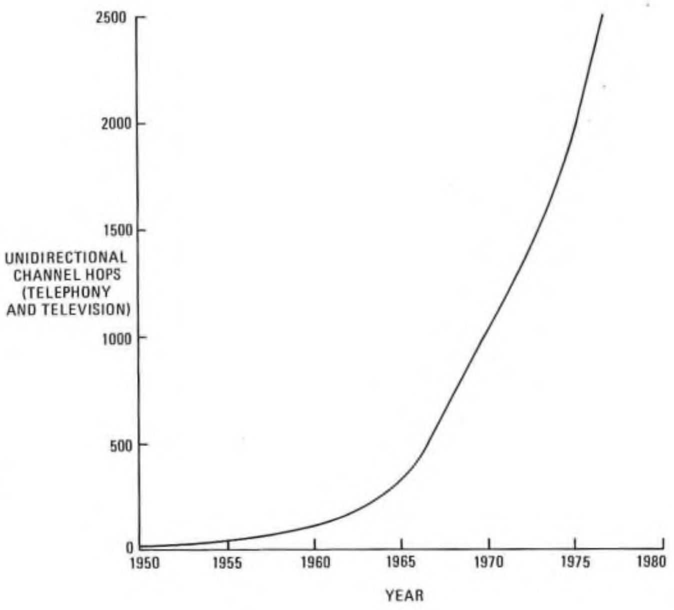


FIG. 3—Growth of microwave radio network

By the late-1960s, the television network had been upgraded so that all distribution could be to full 625-line colour standards.

As well as extending the transmission capacity of systems, other frequency bands were brought into use in quick succession. In equipment technology, the remarkable feature was the extremely rapid change-over from the all electronic tube system to solid-state techniques by the mid-1960s. With the move in the UK towards an integrated digital network,[6] the BPO is giving much attention to the transmission of digital signals over microwave links.[7,8,9] Microwave engineering therefore has been, and continues to be, a dynamic and challenging field for the transmission engineer.

SIZE AND USE OF THE NETWORK

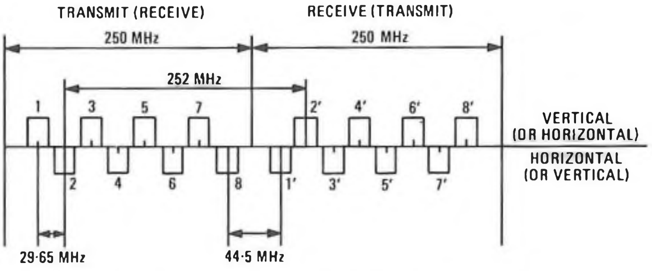
The main BPO microwave radio-relay network is shown in Fig. 2. There are 166 stations in service in the network (17 of which are on non-BPO sites), and a further 25 are being brought into use during the next few years. The average distance between adjacent stations is 40 km, the longest path between adjacent stations being 103 km. The average system length between terminals is 120 km, the longest being 280 km. This is short in comparison with systems found in the larger countries; for example, Australia and the USA. However, the BPO network is as concentrated as any in the world; the Japanese network is probably the nearest equivalent in this respect. The existing and planned capacity of the BPO network amounts to approximately 35-million bothway telephone-circuit-kilometres, representing about one fifth of the total telephony requirement, the remainder being provided by cable; the television network comprises some 16 000 channel-kilometres. Microwave radio has become an established complementary transmission medium to cable systems, offering truly alternative routing with significant economic advantages in many cases. Fig. 3 illustrates the rapid growth of microwave radio in the BPO network.

A key factor in expanding the network is the availability of frequencies. The radio frequency spectrum is a limited resource on which many demands are made by the various radio services. Its use is carefully controlled and the maximum amount of sharing is encouraged. By agreement between members of the International Telecommunications Union (ITU), bands of frequencies are allocated to the various services or groups of services, as given in the *International Radio Regulations*. These regulations were last completely revised in 1959. However, considerable changes were made to the frequency allocation table at an ITU conference in 1971,[10] to allow the then new space services using satellites to operate in the 4–40 GHz part of the spectrum. A complete revision of the regulations is scheduled for 1979.

TABLE 1

Frequency Bands in Use and Planned for the BPO Network

Frequency (GHz)	Title	Use
1·7–1·9	2 GHz Spur	Television and 960-channel telephony systems; low-capacity links in remote areas; local sea links in North Sea
1·9–2·3	2 GHz Main	960-channel telephony systems; shared with tropo-spheric-scatter systems in North Sea
3·7–4·2	4 GHz	1800-channel telephony systems; shared with satellite services (down links)
5·85–6·425	Lower 6 GHz	1800-channel telephony systems; shared with satellite services (up links)
6·425–7·11	Upper 6 GHz	960-channel telephony and television systems; part of band used for temporary radio links
10·7–11·7	11 GHz	960-channel telephony and television systems on periphery of network; will be used for 140 Mbit/s digital radio links on main network; part shared with satellite service
17·7–19·7	19 GHz	Multiples of 140 Mbit/s digital systems, used with short repeater sections, system in development



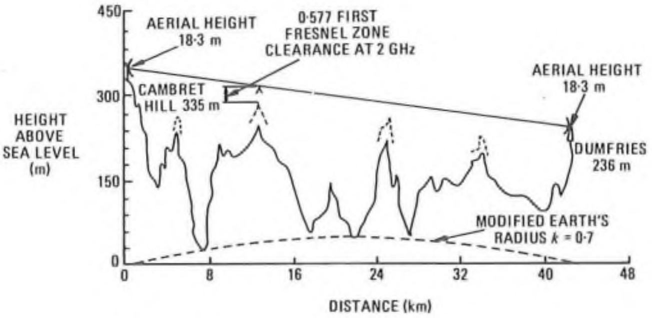
Note: Alternate channels are on opposite polarizations

FIG. 4—Typical radio-frequency channel arrangement

At a national level, the BPO is allocated the bands shown in Table 1 in which to operate microwave radio-relay systems. Each frequency band is sub-divided to allow a number of radio channels to be operated simultaneously on a route; the exact number is dependent on the bandwidth requirements for the channels (for example, 960, 1800 or 2700) and on the state of the art when the channelling plan is drawn up. The International Radio Consultative Committee (CCIR) recommends channelling plans for each band (see Fig. 4 for a typical example). These are agreed internationally to reduce the problems in operating radio systems near to, or across, frontiers; radio signals are no respectors of such artificial boundaries. It also assists manufacturers to produce systems with a wide potential market.

PLANNING

Planning radio links is as much an art as a science. The performance objectives are known, and so is the capability of the available equipment and aerials. The art is to balance



Note: Dotted lines show heights of principal hills modified to allow for curved earth ($k = 0 \cdot 7$)

FIG. 5—Overland path profile drawn on flat-earth basis

the economic, environmental and technical aspects to give the best solution in the particular circumstances. This is relatively easy when planning the first route in a country, but the problems multiply as the network grows in complexity; particularly when certain of the early plans, which seemed correct at the time, later impose unwelcome constraints.

Route planning involves the selection of stations having a line-of-sight path between them, even under adverse propagation conditions. The further apart the stations are placed, the fewer repeaters there will be in a particular link and, consequently, the lower will be the radio equipment costs. These longer repeater sections (hops) usually involve taller and more expensive towers, greater attenuation between repeaters and abnormal propagation is more likely. Conversely, shorter repeater sections mean more towers and repeaters. Also, because all equipment produces some distortion and has an inherent failure rate, greater difficulty will be found in meeting the performance objectives of the route. However, the towers will generally be shorter and less expensive, attenuation between stations lower, and propagation conditions more stable.

The stations must be planned not to interfere with, and be protected against interference from, other links in the network and space satellite systems. Finally, the stations must be reasonably accessible, and in a position where they can be accepted environmentally.

The mechanics of route planning have been fully described in this *Journal*.[3] To ensure a line-of-sight path between stations, clearance must be allowed above the earth's curved surface, taking account of any hills or other obstacles. Fig. 5 shows the principle. The radio beam has a finite cross-sectional area and, from optics, can be considered as comprising a number of Fresnel zones.† To ensure free-space signal strength, about 0·6 of the first Fresnel zone must be clear of all obstacles. The refractive index of the atmosphere causes the beam to bend as it traverses the path between stations. To allow for this, the curvature of the earth is considered as having an effective radius k times that of the true earth radius. Under normal refraction conditions, the value of this k-factor is taken as 4/3, but abnormal propagation can arise which requires the value of k to be reduced to 0·7; this has the effect of increasing the height of obstacles. In practice, k will reduce to 0·7 for only small percentages of the time, and some administrations do not take into account such small k values. It is a matter of planning judgement.

There now follows a discussion of some of the aspects that feature in the planning process when working in a highly concentrated radio network such as that in the UK.

Expanding Capacity on Existing Routes

The early links were designed for the transmission of 405-line monochrome television. The noise objectives for such links allowed the planner to use longer repeater sections and/or feeder lengths than are now generally acceptable for the transmission of 960-channel or 1800-channel telephony. As the network evolved and telephony became the predominant traffic, the long section lengths caused problems when introducing new systems using 1800 channels, mainly because they coincided with tall aerial supporting structures which resulted in high feeder losses.

Section lengths, and hence tower heights, could have been reduced by introducing additional stations, but apart from cost and planning-consent problems, this solution causes frequency-allocation difficulties among the existing stations. To reduce long feeder runs, and hence losses, equipment could be mounted at the tops of towers. This technique is used in a number of countries, but where massive growth is likely, as in the BPO network, the size of accommodation required results in prohibitively expensive structures; the arrangement is not favoured by the maintenance staff due to access and other operational problems. The special towers in London and Birmingham are exceptions to this rule, but these serve to highlight the enormous cost of adopting this approach.

The problem of long feeder runs and repeater sections could be reduced by using extra-low-noise receivers with cooling techniques, but to do so would increase the cost of not only the radio equipment but also accommodation.

The problem, therefore, had to be resolved by other methods adjusted to suit the individual situation. Consequently, planning the expansion of the network entailed making judgements such as when to use extra-low-loss feeders (for example, circular waveguide) and extra-high-gain aerials; all of this resulted in engineering problems for the installation engineer, and it was essential that the right balance was struck between performance demands and engineering reality. It is to the credit of the engineers concerned that these problems were solved with a very high measure of success.

Planning New Radio Routes

Despite early fears that extensive topographical surveys and propagation testing would be necessary for every radio path, experience has shown that new routes can be planned in the office using Ordnance Survey 1 : 50 000 or 1 : 25 000 scale maps. Brief site surveys only are required to confirm the map information and to add new building data. More elegant methods of surveying, such as aerial photography, have been tried, but discarded as unnecessary. It is now normal to restrict propagation testing to over-water, or otherwise unusual, paths.

During the last decade, a new public awareness of environmental pollution in all its aspects has become evident. This awareness has had a significant effect upon site acquisition and planning procedures. Prior to the establishment of the BPO Corporation, it was not necessary to apply for formal planning consent under the terms of the Town and Country Planning Act to establish a microwave station. However, in practice, the BPO discussed microwave radio station proposals with the planning authorities as a matter of course. Today, each proposal has to be advertised locally and submitted for planning approval in the normal manner. This stage of planning is both difficult and time-consuming. Compulsory purchase, although possible, has never been used to obtain land for a microwave station.

Site-Sharing with other Organizations

When planning a new route, all existing radio-station sites are explored, both technically and practically, to ascertain their usefulness as BPO radio-relay stations. Should such sites prove to be acceptable, approaches are made to the

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† Fresnel zones arise in the theoretical approach to the diffraction of light waves; a Fresnel zone is defined as a zone on a specified surface such that the sum of the distances from the transmitting source and from the receiving point to any point in the zone does not vary by more than half a wavelength throughout the zone

owners with a view to either sharing or co-siting. In the last few years, sharing and co-siting with other organizations have been taken up on several occasions; for example, with the Home Office, local authorities and broadcasting authorities.

The BPO has a good record of compliance with the Government requirement to make maximum use of existing radio-station sites and, hence, avoid proliferation of aerial support structures throughout the land. Indeed, such a policy was in operation long before the relevant Government directive was issued in 1968. At present, of the BPO-owned microwave-station sites, 52 are being shared by at least one other organization. To safeguard BPO services, strict rules are maintained regarding access to the sites; no unsupervised access is allowed to the BPO building or tower and, in most cases, the BPO provides and maintains the sharer's aerials and feeders. The sharer's equipment is positioned in a separate building, fenced-off from the remainder of the site and served by a separate access road.

Frequency Planning

The number of frequency bands available to the microwave planning engineer is limited. It is, therefore, essential that maximum use is made of them. The CCIR-recommended plans rely on

(*a*) high-grade filtering, and operating adjacent channels on opposite polarizations (cross-polar working) to accommodate as many channels in the frequency band as possible, and

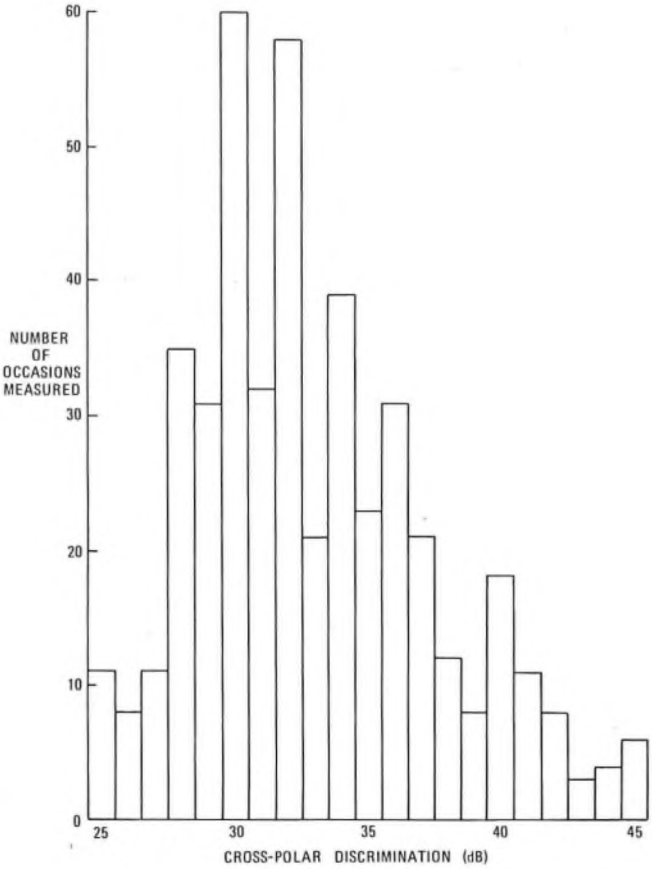
(*b*) good route planning and the use of highly-directive aerials, to allow the same frequencies to be used on alternate radio paths.

For effective working on opposite polarizations, an adequate value of cross-polar discrimination must be maintained. Although it is possible to produce aerials with 40 dB, or more, of cross-polar discrimination within the main beam, it is difficult to adjust them adequately over a repeater section to give a complete aerial-system cross-polar discrimination of better than 30 dB at all frequencies in the band. Fig. 6 shows the results obtained over some single repeater sections in the network.

To use the same frequencies on alternate radio paths, the CCIR recommendations divide the frequency band into 2 halves (Fig. 4); frequencies in one half-band are used to transmit in both directions from one station, while frequencies in the other half-band are transmitted from the next station. By this means, even in the concentrated network of the UK, each frequency can be used time and time again. Currently, some frequencies in the upper 6 GHz band are used over 70 times, and it is confidently expected that this number will increase. It is inevitable that the reuse of frequencies requires very careful planning; some of the main factors to consider are described later.

Diversity and Fading

Where the signal path traverses very flat terrain, or more particularly water, a reflected ray can arrive at the receive aerial in addition to the direct ray. For water, the reflection coefficient is close to unity and the reflected ray is of similar strength to the direct ray. Taking the case of constant refractive index and the direct and reflected ray differing in effective path length by an even or odd multiple of half wavelengths, the sum of the 2 signals results in either enhancement or near complete cancellation respectively. Raising or lowering the aerial alters the difference between the direct and reflected path lengths which varies the resultant signal level. Alternatively, for a given aerial height, variations in the refractive index cause the direct and reflected signals to travel different path lengths, resulting in variations in the cancellation and enhancement. The refractive index varies with time and, hence, so does the received signal.



Note: Measurements taken at 5 spot frequencies in each band. Results for 4 GHz, lower 6 GHz and upper 6 GHz, horizontal to vertical and vertical to horizontal

FIG. 6—Results of cross-polar-discrimination measurements

The effect on a system can be minimized by using 2 receive aerials at different, but selected, heights; this is known as *height diversity*. As the refractive index varies, one of the aerials will have an acceptable signal level, even when the other is unusable. The 2 aerials can be fed to separate receivers and the best output selected by a switch, or the signals from the 2 aerials can be phased, combined and fed to a single receiver. This latter method is the one preferred by the BPO since the continuous combining process introduces no breaks in transmission. This is of particular benefit in the proposed digital system where breaks could cause errors.

The 2-path fading mechanism described arises from a specular reflection and is a frequency-conscious effect. If 2 frequencies with sufficient separation are used, improvement can be obtained with only one aerial. This *frequency-diversity* method, however, requires 2 frequencies for every working channel and is not suitable for use in the UK network because of its wasteful use of the spectrum.

Variations in signal strength can also arise from multipath propagation. Because the air is not a homogeneous stable medium, the radio beam can be considered to separate into several rays which arrive at the receive aerial by slightly different routes. Cancellations and enhancements thus occur, and the resultant effect can be deep and rapid fades that follow a Rayleigh probability distribution. Height diversity tends to combat the effect, which becomes more marked on longer paths. Despite early fears, experience in the UK is that, below 11 GHz, multipath propagation is not a serious problem. Height diversity may have to be used more extensively to combat multipath fading on 11 GHz digital systems.

Another form of fading, known as *ducting*, can cause complete loss of signal, but the effect is rare in the UK and normally occurs only at intervals of many years over long paths over water.

Digital Planning

Many of the techniques outlined above are also applicable to planning digital systems. The main difference in planning these systems is in the technical parameters, which tend to help rather than constrain the radio planner. The performance of digital equipment will be described in Part 2.

Initially, the contribution of microwave radio to the digital transmission network will be in the higher frequency bands. The first systems are planned to be operational during 1980, using the 11 GHz band. This is the highest frequency band that can use the UK microwave network fully, without modification, because repeater section lengths of approximately 40 km are still suitable, even though precipitation begins to be the major propagational effect at, and above, these frequencies.[11] Therefore, for the next frequency band available, 17·7–19·7 GHz, repeater section lengths will need to be very much shorter at approximately 10 km. Such a system is being investigated using aerials mounted on poles or buildings.

Investigations are being carried out into the possible use, in a digital mode, of the frequency bands currently used for analogue systems.

Two advantages of digital transmission to the microwave engineer are as follows.

(*a*) The frequency usage per degree azimuth is greater; for example, at one station, separate routes at 11 GHz using the same polarization can be spaced every 27° for digital systems, as opposed to every 90° for analogue systems. Cross-polar working allows closer angular spacing to be used in both cases.

(*b*) Digital systems have a greater immunity from interference.

Above 11 GHz, where short repeater sections will be used, aerial support structures will be restricted to 30 m poles[12] and, as such, can be considered as plant under the Telegraph Act. This being the case, no formal planning permission is required and only a notification procedure will be used. This, together with the strong possibility of stock-piling the all solid-state radio equipment, should enable routes to be established in a short period. In urban situations, tall buildings, previously a problem, may be turned to advantage by using them as intermediate stations.

INTERFERENCE

As a network grows in complexity, the problem of interference becomes one requiring more careful attention by the system planner. Indeed, so important is this problem that an international conference was held in 1968 to discuss it.[13] The causes of interference in the microwave radio-relay network are numerous, but can be sub-divided into interference between

(*a*) channels on the same radio-relay route,
(*b*) different radio-relay routes,
(*c*) radio-relay systems and satellite microwave systems, and
(*d*) radio-relay systems and any other systems; for example, radar.

Interference in categories (*a*) and (*b*) are closely linked, and can give rise to adjacent and/or co-channel effects.

Adjacent-Channel Interference

Adjacent-channel interference occurs mainly on very heavily loaded routes where all the available radio frequencies are being used. The sideband spectrum of the adjacent channels can cause interference to the wanted channel, and this type of interference must be controlled by careful design of filters in the equipment and of the frequency plan itself.

One mechanism, which has been the subject of much study, is that known as *direct adjacent-channel interference.* Travelling-wave amplifiers, transistor circuits, limiters and other circuits display the unfortunate ability of changing any amplitude variations at their input to phase variations at their output; an effect known as *amplitude-modulation–phase-modulation conversion.* Such effects are now well known, but can be minimized only at the circuit-design stage. Direct adjacent-channel interference arises from the close spacing between channels; the FM signal on the interfering channel sees the skirt of the filter of the adjacent channel as a linear amplitude slope similar to a demodulator characteristic. The affected channel, therefore, demodulates the FM signal from the interfering channel and transmits it forward in an amplitude-varying form. If this signal is then applied to a device having significant amplitude-modulation–phase-modulation conversion, it is converted to a phase-modulated interference signal that will be demodulated at the terminal. Two features of direct adjacent-channel interference are that

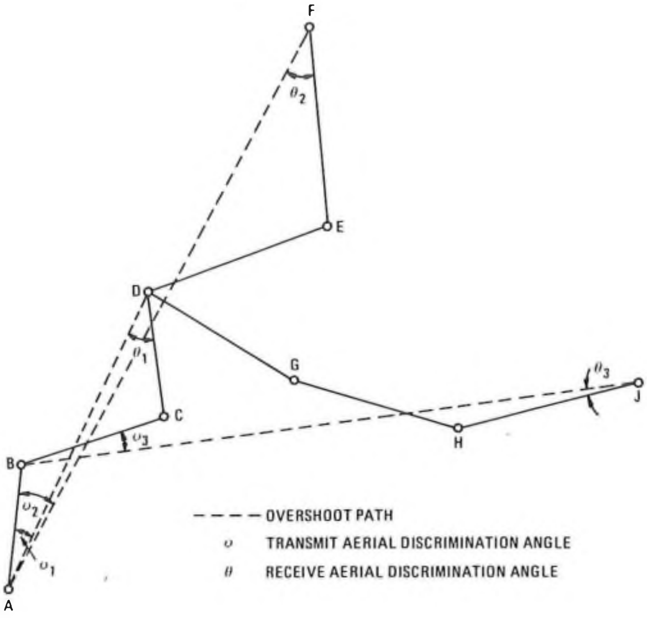


FIG. 7—Examples of co-channel interference due to overshoot

(*a*) for every 1 dB increase in the interfering carrier level, the baseband interference level increases by some 2 dB, and

(*b*) the interference can be intelligible.

Co-Channel Interference

Co-channel interference is very important when planning microwave radio-relay systems and generally arises because of the problems of overshoot. With the frequency plan discussed previously, alternate stations on a route receive the same frequencies. At first sight, it would seem sufficient to ensure that the route zig-zagged such that the aerial discriminations between the direct and the overshoot ray exceeds the BPO's objective wanted-to-unwanted signal ratio of 65 dB (equivalent to an interference power of 2 pW at a 1 mW point in a telephone channel). Thus, in Fig. 7, the aerial discrimination at station A (transmit) and station D (receive), plus the difference in path loss (C to D − A to D) must exceed 65 dB. It is, however, more difficult to achieve because the stations are located on high ground and therefore, for small percentages of time, propagation conditions can allow the signal to overshoot not just from station A to station D, but on to station F, some 200 km away. Therefore, when planning a new radio route, careful consideration must be given to overshoot sources within a radius of some 200 km; this includes stations on adjacent routes.

Overshoot is one of the main reasons why it is important

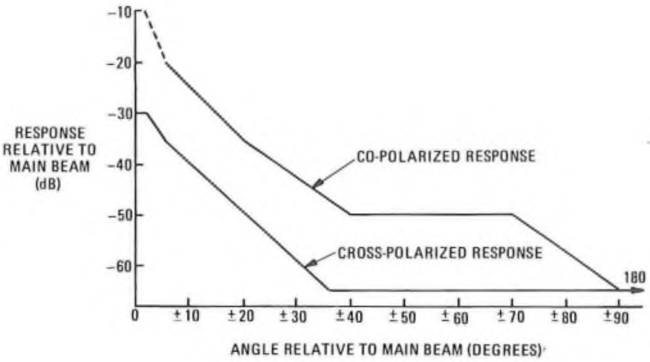


FIG. 8—Aerial directivity characteristic

to use an aerial design that gives a high degree of discrimination against off-beam signals. The required aerial characteristics are given in Fig. 8; modern aerials are consistently better than this. It may not be possible to rely on cross-polar discrimination when considering overshoot problems because, although the aerials on each radio path are commissioned one with another, it is not practicable to optimize the alignment of all aerials in the network against each other.

When the radio stations in the city centres were planned in the early-1960s (for example, London and Birmingham), care was taken to ensure that the aerials were provided at heights greater than the surrounding buildings. Since then, improved building techniques have allowed taller buildings to be erected. To the microwave planning engineer, this adds another dimension to his job. The obvious case is where a tall building could block a line of sight, but, in addition, every building illuminated by the transmit aerial can produce diffuse (omnidirectional) reradiation.[13, 14] If these same buildings are within the beam of the receive aerial, the reradiated signal contributes noise to the telephony baseband. The strength of the unwanted signal depends upon the receive aerial discrimination, and the type, size and position of the building. An even worse situation occurs when an off-beam building is oriented so that it acts as a perfect reflector to an unwanted signal. If this type of situation were allowed to arise, the aerial discrimination alone may be insufficient and the interference could be high enough in level to render the wanted signal unusable.

To avoid this type of interference, an early-warning system of notification of possible building development is in operation with the co-operation of the local planning authorities. Appropriate action can then be taken.

Satellite Services

As shown in Table 1, 3 of the frequency bands used for terrestrial microwave links are shared with satellite services. To avoid interference to or from these services, co-ordination procedures must be carried out whenever these bands are planned to be introduced into the network. For the terrestrial microwave engineer, the following main points should be observed.

(*a*) When providing terrestrial links in shared bands, calculations must be carried out in accordance with CCIR recommendations to ensure that levels of interference from the terrestrial network to known earth stations and vice versa are within acceptable limits. This reduces the number of frequencies that can be used for terrestrial services and presents particular difficulties when serving earth stations.

(*b*) The geographically-stationary satellite orbits must be protected against terrestrial transmissions.

For every terrestrial station, each transmit aerial must be examined to see whether it points at any part of a geographically-stationary satellite orbit. Cases require critical study when their direction in azimuth falls within the sectors 95–112° and 248–265° east of north for the UK. For these cases, any plans for using shared frequency bands must be specially investigated to ascertain the exact angular discrimination to the geographically-stationary satellite orbit and, hence, ascertain the maximum effective isotropic radiated power allowed at the terrestrial station.

Other Forms of Interference

Interference can arise from unwanted aerial couplings or be generated within the equipment itself, such as spurious signals from oscillators. This latter type is within the control of the equipment designer and system planning can have little impact. Outside the system, the other form worthy of mention is interference from high-power radar installations, which has been fully discussed in this *Journal*.[15]

Dispersal

The effects of interference in telephony circuits can be reduced by baseband-dispersal techniques, in which the carrier is deviated using a sub-baseband tone, typically in the 6 kHz region. The effect is to sweep the interfering tone through a number of telephone channels, thereby reducing the mean interfering power falling in any one channel by up to 14 dB.

CONCLUSION

This part of the article has discussed the history and planning aspects of the BPO microwave radio-relay network. Subsequent parts will describe performance and equipment aspects.

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A Review of Cable Pressurization in the British Post Office Network

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UDC 621.315.2.001.4: 621.395.74

This article is based on an IPOEE prize-winning essay by Mr. Mynott. It considers the progress made and the difficulties encountered in implementing cable pressurization. The advantages and disadvantages of pressurization, and the techniques used for locating leakages, are reviewed, as seen by a member of the underground-plant maintenance staff of a telephone area. Assistance in the production of this article has been given by Mr. Harcourt, who supplied additional information concerning national implications and performance.

INTRODUCTION

The idea of pressurizing cables is not new; the principle was applied to the first dry-core cable laid for railway-signalling purposes in 1834.[1] Attempts were also made, between 1900–10, to pressurize cables in London's junction network, but the scheme was abandoned. In 1930, however, the British Post Office (BPO) considered the apparent advantages of pressurization sufficient to justify a field trial on 47 km of the main-underground network. The results of this trial did not, however, justify an extension of the scheme.

In the late-1940s, the BPO again showed interest in pressurizing telecommunications cables, and this led to a field trial, in 1950, in which the main-underground and junction cables radiating from Leatherhead exchange were pressurized to a static pressure of 69 kPa (690 mbar).[2] The success of this, and of a further series of trials commencing in 1957 in the local network in 7 telephone-exchange areas,[3] led to the decision to pressurize all new and most existing main-underground, junction and local main cables with dry air. This decision was implemented during the 1960s.

REASONS FOR PRESSURIZATION

The first and most important reason for pressurizing cables is to prevent loss of service due to the ingress of moisture. It is necessary, therefore, to maintain the air within a cable at a pressure greater than normal atmospheric pressure. Ideally, the pressure differential should be sufficient to prevent water entering the cable irrespective of the depth of water in which the cable is submerged. However, the hoop strengths of the cable-sheathing material and joint closure impose a limit on the permissible pressure differential and, for this reason, a maximum applied pressure of 62 kPa (620 mbar) has been adopted by the BPO. Provided the leak is not too large, this pressure differential will withstand a 5·5 m head of water, which is sufficient to provide protection for most cables. Cables in very deep situations may still be at risk.

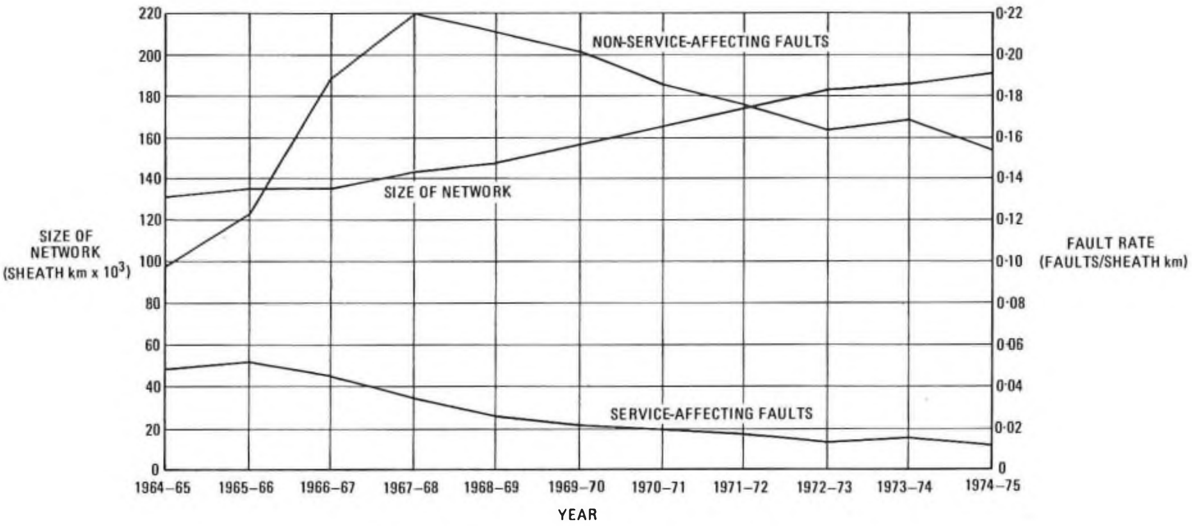

FIG. 1—Size of the main-underground and junction-cable network, and variation in fault rates for the period 1964–75

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The second reason for pressurization is that the pressure differential monitors the condition of the cable sheath throughout its length. Thus, by means of pressure-monitoring devices, it is possible to obtain an early warning of a sheath or joint-closure defect.

Finally, leaks on pressurized cables can be located and cleared without the immediate urgency necessary when an out-of-service cable has to be dealt with. Many sheath or joint-closure failures which, prior to pressurization, would have needed a length renewing or the prolonged piecing-out of a joint, can now be rapidly repaired *in situ*. This enables a systematic approach to be taken towards cable maintenance and makes it easier to deploy staff efficiently. Against this, however, is the disadvantage that an air leak normally takes longer to locate than an electrical fault.

ADVANTAGES OF PRESSURIZATION

The long-term advantages of cable pressurization are illustrated by Fig. 1, which shows the size of the BPO's main-underground and junction-cable network and the variations in the non-service-affecting and service-affecting fault rates for the period 1964–75. The number of non-service-affecting faults rose markedly during the early years while pressurization was being implemented, but the number of service-affecting faults has steadily decreased.

The cost per sheath-kilometre of upkeeping the main-underground and junction-cable network is shown, for the same period, by the 2 graphs in Fig. 2. The maintenance-cost graph represents the cost of locating faults, *in-situ* repairs, and all other operations concerned with maintenance of the cables, with the exception of cable-renewal work, the cost of which is shown by the renewal-cost graph.

Both maintenance and renewal costs rose during the initial period as long-outstanding defects were located, cleared, and the standard of the network progressively improved. Having passed the peak in 1966–68, the costs are now steadily decreasing.

PRESSURIZATION SYSTEMS

Two types of pressurization system have been introduced: the *static system* for main-network and junction cables, and the *flow system* for local main cables, which interconnect exchanges and primary cross-connexion points.

Static System

The static system consists of pressurizing cables to 62 kPa (620 mbar), shutting off all the air supplies, and monitoring the pressure by means of gauges at each exchange or repeater station, and by contactors fitted at intervals along the cable. The gauges and contactors are set to give an alarm if the pressure falls to 48 kPa (480 mbar), and alarms are extended over a common alarm circuit to a staffed building.

This system has the advantage that, provided leaks are located and cleared on an individual basis as they arise, leak-locating procedures are more reliable. However, the reservoir of air contained in a cable must be sufficient to keep the cable in service until any leaks have been located and cleared, or until alternative supplies of air have been connected to the cable.

Flow System

Because of the nature of the local main network, with its many spurs and joints, it was considered that a static system would be unpractical and uneconomic. Also, the quantity of air contained in each cable might not be sufficient to maintain service until repair was completed. The flow system has therefore been introduced. Dry air is continuously pumped into the cables at the exchanges at a pressure of 62 kPa (620 mbar). Flowmeters at the exchange measure the rate of air flow into each cable, and this should not normally exceed $1{\cdot}028 \times 10^{-6}$ kg/s.

A minimum pressure of 21 kPa (210 mbar) is considered essential at the far end of any local main cable. Pressure gauges, set to operate when the pressure falls to 14 kPa (140 mbar), are installed in the most remote cross-connexion point on each cable. Pressure gauges, set to operate at higher values, are installed in intermediate cross-connexion points along the route of each cable.

EXTERNAL CONSTRUCTION PRACTICES

The most essential operation, when pressurizing any cable, is to fit air-blocks at each end of the cable, and at the end of every spur cable. An early type of air-block used a molten-wax compound inserted under pressure. Later air-blocks consist of an epoxy resin and hardener.

Tubing is required to connect air supplies and pressure gauges to cables and, in audio main-underground and junction cables, for bypassing the loading pots.

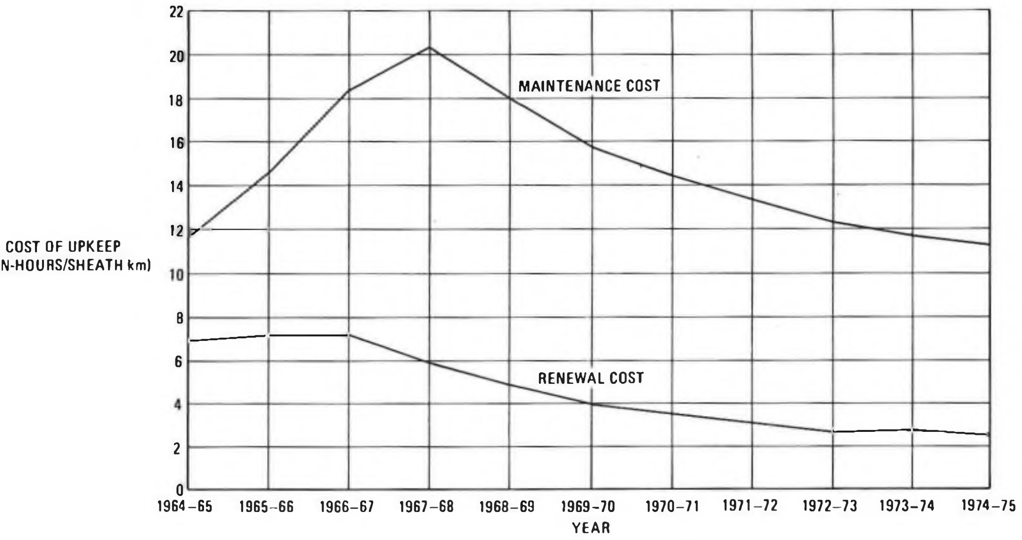


FIG. 2—Cost of upkeeping the main-underground and junction-cable network

The first tubing used for air feeds was 6·4 mm bore nylon, but this was soon found to suffer from osmosis (the drawing-in of moisture through the nylon due to differences in vapour pressure). This tubing was replaced by PVC-covered aluminium, and this is still used for air pipes within buildings. Aluminium tubing was not, however, satisfactory for external use due to its susceptibility to corrosion damage. It was therefore superseded, for external use, by tubing consisting of an aluminium-foil moisture barrier sandwiched between inner and outer polyethylene tubes.

As both lead and polyethylene cable sheaths and joint-closure sleeves are used in cable networks, it is necessary to have 2 types of test valve available: one for plumbing into lead sheaths and sleeves, and the other for fitting into polyethylene sheaths and sleeves. A special pressure-test valve is also used, mainly by Precision Testing Officers (PTOs), to enable extra pressure readings to be taken on lead-sheathed cables without disturbing the air flow or losing pressure in the cable. This valve is designed in 2 parts. Its base is plumbed to the lead sheath with no hole being made in the cable; the top of the valve is then screwed to the base, and a plunger fitted with a cutter is pressed down and turned until the sheath is penetrated. This is indicated by a pressure reading appearing on a manometer connected to the valve. The need for this valve is diminishing as more joints on the older lead-sheathed cables are fitted with standard test valves.

RETROSPECTIVE PRESSURIZATION

Although a decision had been taken to pressurize retrospectively most existing cables in the main-underground, junction and local main networks, Regions and Areas were, in general, left to determine their own priorities in the light of staff available and other urgent commitments. In Guildford Telephone Area, first priority was given to pressurizing junction cables feeding isolated exchanges. As many of these cables were of the smaller, older types, and sometimes aerial, they proved initially to be extremely difficult to pressurize and, in retrospect, it was an unfortunate choice of priority. Later, coaxial and carrier routes were chosen, and pressurization of these was found to produce quicker results.

A mistake made at the beginning was to think that, by feeding air into a cable at both ends, the pressure would build up more quickly and the work would be more rapidly completed. However, it soon became apparent that this was so on only the newest cables. Many leaks existed on the older cables when pressure was first applied. The best method was found to be pressurizing the first loading-coil section of a cable and clearing the major leaks before connecting through to the next section. In this way, pressurization was progressively extended along the cable.

To obtain the benefits of pressurization in advance of the installation of permanent air compressors and desiccators in exchanges and repeater stations, it was necessary to obtain supplies of dry air from air cylinders. Because of the number of defects existing in the cables, and the pneumatic capacity of the cables, it was often found that an air cylinder would discharge overnight, with no rise in the cable pressure. Systematic attention to the clearance of major leaks rapidly overcame this problem and reduced the incidence of service failures.

CABLE-PRESSURIZATION EQUIPMENT

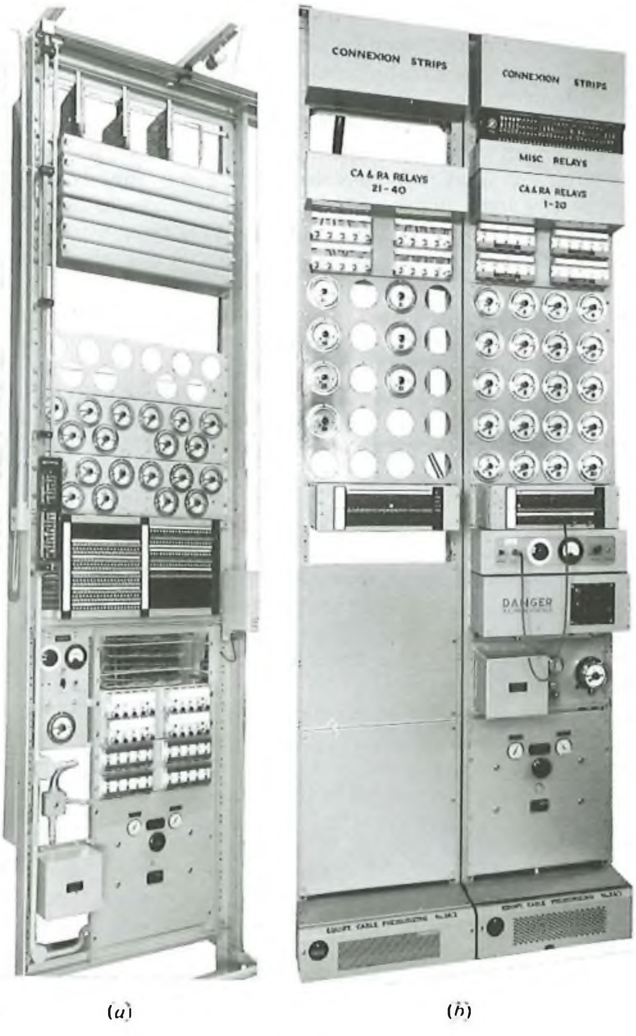
Cable-pressurization equipment, known as *Equipments, Cable-Pressurizing* (*ECPs*), examples of which are shown in Fig. 3, are of different types to suit the number and type of cables to be fed with air. Certain principles apply to all, and these have been fully described in earlier issues of the *POEEJ*.[3] Basically, each consists of a compressor, a desiccator, flowmeters and pressure gauges, with tubing connecting forward to the cables. Each main-underground and junction cable has a gauge and flowmeter. Local cables have only flowmeters. A master gauge monitors the pressure from the desiccator, and this gauge is fitted with alarm facilities. A humidity detector is fitted in series with the air tube on the output side of the desiccator, and this is also provided with an alarm.

The flowmeters show when a known leak rate increases, possibly requiring early attention. A regular check of these meters is essential for this early-warning system to work, as alarms are not provided.

ALARM SYSTEMS

Main-Underground and Junction Cables

Each pressure gauge is connected to an alarm lamp on an indicator panel on the ECP. A RECEIVING ATTENTION button can be operated until an alarm is dealt with. Remote-contactor alarms are brought back to the ECP on one wire of a looped cable-test pair, and usually terminate on the same alarm position as the gauge alarm associated with that cable. A Murray bridge, built into the ECP, can be connected by a test cord to a jack at the alarm position to identify the location of the operated contactor by measuring the resistance to the earth applied by the contactor. The resistance is expressed as a decimal reading in the range 0–1, and a record of the



(*a*)　(*b*)

(*a*) ECP No. 3
(*b*) ECP No. 5A

FIG. 3—Examples of cable-pressurization equipment

reading appropriate to each location is kept at the ECP. Alarms from contactors within repeater cases on coaxial and pair-type routes are similarly extended to the ECP. All alarm circuits are self-monitoring, and an alarm is given if any circuit is disconnected.

Local Cables

Pressure alarms on local cables are provided by gauges fitted in primary cross-connexion points (which are mainly cabinets) and extended to the ECP. A lamp is lit on the alarm panel and stays on until the RECEIVING ATTENTION button is operated. Several alarm gauges can be mounted in a cabinet, and all are connected to a common alarm circuit to the exchange. On receipt of an alarm, a visit to the cabinet is necessary to identify the defective cable.

To economize on alarm equipment at the exchange, a number of alarm circuits are commoned, via individual RECEIVING ATTENTION buttons, to each alarm relay. To identify the alarm circuit giving an alarm, it is necessary to operate a number of buttons until the alarm is extinguished. A record of these alarms, cabinet numbers and cable codes is kept on the ECP rack. As the alarm circuits from a number of cabinets are connected to each relay, they cannot be made self-monitoring. A TEST button is therefore associated with each alarm to enable a continuity test to be made periodically.

INSTRUMENTS FOR LOCATING FAULTS

The basic instrument used for fault location is the Manometer No. 1B, a mercury manometer covering the range 0–65 kPa (0–650 mbar). This, when used with a magnifying cursor, is quite accurate down to 100 Pa (1 mbar). For most pressure measurements, this instrument is entirely satisfactory, and its simplicity makes it easy to use. Its only disadvantage is that dirt accumulates on the mercury, and regular cleaning is necessary. This is usually done by filtering the mercury through chamois leather. Readings taken with this manometer can be corrected for altitude when it is used in conjunction with a barometer.

For small leaks, pressure measurements on cables with low pneumatic resistance† and for greater accuracy, PTOs use a Manometer No. 3A, which is a precision aneroid instrument.

A differential manometer is sometimes used to determine the flow of air at a jointing point when one of 2 cable lengths is suspected of leaking. In addition to the test valve on the jointing sleeve, an additional test valve is fitted to the cable on one side of the joint, and 2 connexions made from the instrument to the valves. The instrument consists of an inclined glass tube with reservoirs at each end, partly filled with a coloured liquid. Any difference in air pressure between the 2 valve points is shown by a movement of the liquid along the glass tube towards the lower pressure; that is, in the same direction as the air flow.

Initially, only PTOs were issued with mercury manometers for fault location but, as pressurization progressed, maintenance jointers took over all the basic work and simple fault location, PTOs being called in for within-length locating.

In about 1962, tracer-gas techniques were introduced using Arcton gas* mixed with air. The tracer gas was injected into the cable in the vicinity of the suspected leak, and a detector was used to find a leak within a jointing chamber. The use of this detector, with other equipment that when pushed through a duct extracted samples of air, made it possible to locate precisely the position of a leak within a length of cable. Thus, a fault could be repaired *in situ*, where practicable, and the costly replacement of a cable length avoided.

At this stage of pressurization, the non-service-affecting fault rate was rising rapidly (see Fig. 1). This was partly due to finding sheath faults that had not shown up before pressurization, and partly caused by the increased stress on cable sheaths, especially in corrosion areas where sheaths were considerably weakened.

Later, a more sensitive tracer-gas test, using sulphur hexafluoride (SF_6), was introduced.[4] This test relies on the electron-capturing properties of SF_6 to reduce the electron flow within a detector cell. The detector cell consists of an electrode mounted centrally in a stainless-steel cylinder lined with a tritium radioactive source. A small polarizing voltage is applied between the electrode and the cylinder, and a stream of pure nitrogen acts as a carrying agent for the gas being sampled. Nitrogen does not restrict the flow of electrons and, hence, under normal conditions, the electron flow is a maximum. If, however, the nitrogen is diluted by the presence of a gas having electron-capturing properties, the electron flow is reduced, and this is indicated on a meter. A suitable range switch is incorporated so that very high and very low concentrations can be measured. The power source consists of rechargeable cells. The instrument is in the shape of a gun, with 2 different lengths of nozzle. A short nozzle is used for testing around joints and duct-mouths, and a long nozzle is used for probing holes made in the ground when locating faults on directly-buried cables or when searching for damaged cable in broken duct-lines.

Depending upon the size and immediate environment of a leak, the escaping air can generate an audible or ultrasonic noise. The accurate detection of audible noise has proved to be a practical method of locating leaks, and a new detector using this principle is soon to be introduced in quantity. This detector can locate leaks in wet conditions, where a tracer gas cannot be used.

Ultrasonic leak-detection equipment has also been tried, but with only limited success so far.

FAULT-LOCATION TECHNIQUES

All fault location should start with a series of pressure measurements, called a *pressure run*, taken over the cable and plotting the results on a pressure/distance graph. The degree of accuracy achieved depends on the type and size of cable (which are related to the pneumatic resistance), the size of the leak, the frequency of test-valve points, and the proximity of the leak to the gas-sealed end of the cable, as well as the care with which the readings are taken and plotted.

Main-Underground and Junction Cables (Static System)

Ideally, on main-underground or junction cables, a pressure run is taken over the suspect section, or over the whole cable if necessary, with the air in a static condition. If the leak is a severe one, it may be necessary to apply air at both ends or even introduce intermediate air cylinders to obtain an adequate pressure gradient. Sufficient time must be allowed for the pressure to equalize within the cable before taking readings. At least 3 pressure readings on each side of the point of lowest pressure should be taken. Preferably, the test points should be approximately equal distances apart. The object is to achieve a reasonable measure of the pressure gradient on each side of the lowest point. The readings are plotted as illustrated in Fig. 4.

It can be seen from Fig. 4 that the pressure falls to the fault in a curve on each side. The intersection of lines drawn through the last 2 points of each curve gives the approximate position of the fault. If it is not clear to which side of the graph the lowest point belongs, that point is ignored, and

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† A cable with low pneumatic resistance has only a small pressure drop along its length

* Arcton: dichlorodifluoromethane (CCl_2F_2 (freon 12))

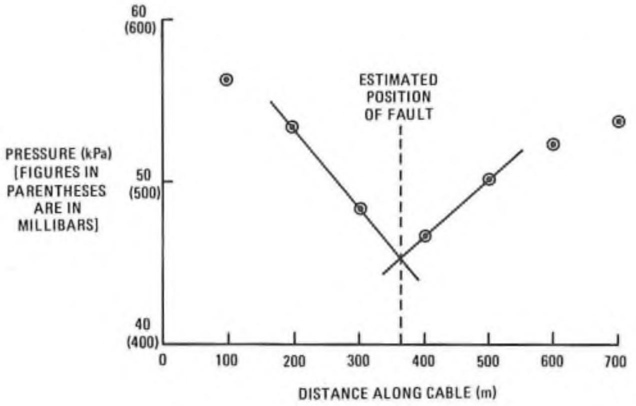

FIG. 4—Example of pressure/distance graph for main-underground or junction cable

lines are drawn through the 2 points each side of it. The lowest point is then likely to be indicated as the position of the fault. The tendency for the pressure to fall in a curve is more noticeable in cables of high pneumatic resistance than in cables of low pneumatic resistance, such as coaxial cables, where the effect is almost non-existent.

After drawing the graph, the joints on each side of the lowest point are examined for leaks. If a leak is not found, an audible-noise detector or a tracer gas can be used to verify that a within-length fault exists. If more accuracy is needed (for example, to pin-point a leak within a length or to locate a leak in a cable of low pneumatic resistance), a precision-testing technique is used. This consists of using a Manometer No. 3A and taking into account correction factors for time and altitude, as described below.

Manometer No. 3A

The Manometer No. 3A is an absolute-pressure-reading instrument, that is, it reads cable pressure plus atmospheric pressure, and is graduated in inches of water (1 in of water = 249 Pa = 2·49 mbar). This is a more accurate instrument than a mercury manometer, but it is essential to make corrections for altitude when using it. By means of a clamp on the air tube connecting the manometer to the cable, a reservoir of pressurized air can be retained in the tube and manometer between readings. This considerably reduces any error due to connecting the manometer at each joint, since only a small amount of air is then withdrawn (or replaced).

Correction for Time

To eliminate the effect of loss of pressure during the time taken to make a pressure run, a 2-way pressure run is used. This should be timed so that the interval between tests made at 2 valve points going in one direction is the same as on the return journey. The average of the 2 readings for each valve point can then be used to plot the graph. It is more usual to use this time-correction method only when the pressure in a cable is known to be falling quickly, although, for precision testing, it is advisable to use it at all times when using a Manometer No. 3A.

Correction for Altitude

There are 2 factors that affect the accuracy of readings when a change in altitude occurs. The expected effect is that, with an increase in height, barometric pressure falls and, therefore, cable pressure is apparently higher. However, a greater and opposite effect is caused by gravity, air in the cable tending to run downhill, thus reducing pressure at the top of a hill. The residual effect is that the manometer reading is lower than it should be. Therefore, when testing with a Manometer No. 3A, the absolute-pressure readings obtained at each test point (other than the reference point) should be corrected by subtracting the correction factor $(\pm b) \times A/B$, where A is the absolute pressure at the reference point, B is the barometric pressure at the reference point, and $\pm b$ is the barometric-pressure difference between the reference point and the test point. Barometric-pressure readings are obtained using the Manometer No. 3A as a barometer, and taking readings at every test point after the completion of the pressure run.

Corrections for time and altitude can also be made when using a Manometer No. 1B, but the altitude-correction formula is different. The barometric pressure, β, is measured at each test point using a separate barometer, and all the manometer readings corrected relative to the normal atmospheric pressure of 101·4 kPa (1·014 bar) by multiplying by $1014/\beta$, if β is in millibars, or $101{\cdot}4/\beta$, if β is in kilopascals.

Corrections for the Manometer No. 1B are much smaller than those for the Manometer No. 3A, since the former is a less sensitive instrument. To eliminate tedious calculations, correction tables are published.

Graph Drawing

The scales used in the pressure/distance graph can be varied to suit the range of pressures measured and the distance covered. For normal pressure runs, a coarse horizontal scale (say 1 mm = 10 m) is sufficient for proving a fault into a length of cable. For precision testing, a finer scale (say 1 mm = 2 m) is more suitable. The vertical scale must suit the range of pressures measured. The aim should be to obtain a horizontal scale the same length as, or slightly longer than, the vertical scale. This keeps the pressure-gradient lines at reasonable angles for indicating the fault point.

Summary

To summarize, when it is more economical to repair a cable *in situ* than to renew a length, the best way of finding the leak is to take a corrected 2-way pressure run, using a Manometer No. 3A, and draw a graph to find the indicated leak point. If the leak appears to be near a joint box, the exact point of the fault can be ascertained by means of an audible-noise detector or a tracer gas. If the graph indicates the leak to be some way from a joint box, and it is not possible to pin-point it by either of these methods, it is necessary to excavate at the fault point indicated by the graph and, if necessary, make further tests.

Local Cables (Flow System)

Many of the above techniques can be used for locating faults on local cables. Initially, however, a pressure run is made on the flow system, and a graph produced which takes the shape illustrated in Fig. 5.

The graph drops steeply towards the fault, and then levels off when the leak point is passed. This reflexed bend indicates the approximate locality of the fault. The leak is closer to the high-pressure end of the cable if there is only a small pressure difference between the last 2 test points before the graph levels off, and closer to the low-pressure end if the difference is large.

With a local cable, the many branches and spurs that occur can all be plotted on one graph, and the indicated fault points examined. If difficulty is encountered pin-pointing a particular fault, it is necessary to introduce a back-pressure by applying air towards the remote end of the cable, to enable pressure gradients each side of the leak to be plotted. The fault position is then determined as for main-underground and junction cables.

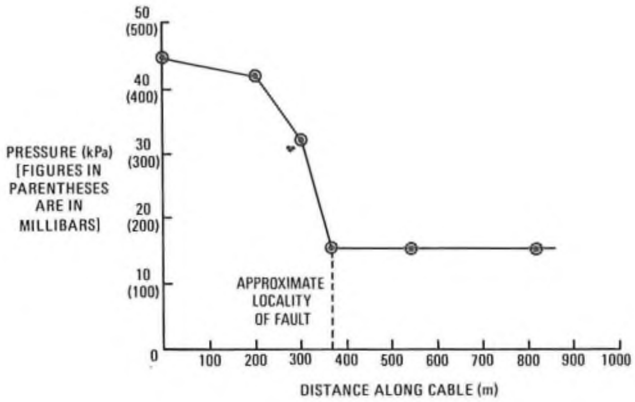

FIG. 5—Example of pressure/distance graph for a local cable

On local cables, differing pneumatic resistances are encountered, and the graph indicates these by changes of angle between test points. This factor must be borne in mind when interpreting the graph, as it can lead to incorrect interpretation.

EXTERNAL PLANT MAINTENANCE CENTRES

External Plant Maintenance Centres (EPMCs) are responsible for organizing the maintenance of the main-underground and junction-cable network in a telephone area, and the repair of non-service-affecting faults and the larger service-affecting faults on local cables. Part of the function of EPMCs is to record and scrutinize the main-underground and junction pressure-gauge readings sent or telephoned in from the various exchanges or repeater stations. The system of recording and acting on the information gathered varies according to local circumstances.

In the Guildford Telephone Area, books are kept, recording the pressure readings for each gauge at each exchange, whether air supplies are connected to a cable, and flow rates if these are excessive. The frequency of taking readings varies, but is daily at manned exchanges and at least once a week at unmanned stations. The readings are examined by the maintenance staff controlling the cables and by the EPMC officer, who draw attention to cables where the pressure is dropping. Action can then be taken to find and repair the leak, and the cable is subsequently recharged with air for approximately 1 week.

Pressure alarms are usually reported directly to the EPMC as they occur; the EPMC arranges to clear them as soon as staff are available.

Local cables are similarly dealt with, and cabinet alarms are reported to the EPMC.

If information is given regularly to the EPMC by exchange and repeater-station staff, and the records kept correctly in the EPMC, an up-to-date analysis of the state of all cables is constantly available. Work can be planned to cover pressurization faults on a well-regulated basis, and the high standard that was envisaged when the project was launched can be maintained.

CONCLUSIONS

There is no doubt that the objects of pressurizing all main-underground, junction and local main cables have been accomplished. By about 1970, the original aims had virtually all been achieved, and teams of jointers and PTOs had worked regularly to improve the standard of maintenance and reduce out-of-service time. However, it has become equally clear that, unless this initial effort is kept up, standards will again drop. It is true to say that the effects of pressurization are long-term; it took 5–6 years to achieve them, and the effects of neglect could take that long to show up.

The danger inherent in pressurization is that it gives a false sense of security, and it is surprising how bad a cable can get before loss of service makes the situation apparent. Nominally, performance appears to be good, with very little out-of-service time, and it is easy to think that perfect pressurization has been achieved. But constant vigilance is needed to ensure the continuing effectiveness of pressurization, and it would be a pity if such a well-conceived system of protection were to suffer from want of this vigilance.

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Book Review

Hybrid Microcircuit Reliability Data. Illinois Institute of Technology. Pergamon Press Ltd. 208 pp. £22.

Some 90% of this book comprises sets of 3 standardized report forms giving classified particulars of 159 different types of hybrid microcircuit, showing respectively, for each circuit,

(*a*) the manufacturer, function and essential technological features,
(*b*) life or testing experience, and
(*c*) details of malfunctions.

Most of the results given on form (*b*) describe the outcome of the application of specification requirements such as those of the American military component documents. Less than 20 entries report field data, but these are used to estimate service-failure rates. Other summarizing tabulations show the proportions of failures yielded by the various specification requirements classified by, for example, the test method and failure mode. Form (*c*) is invariably blank.

For a book presenting such a large volume of acquired data, the descriptive content is lamentably inadequate; the text totals less than 2 pages. A comparison, for example, between the results of a hybrid failure-rate prediction model and actual experience (which are hopelessly incompatible) receives no comment. The reader is, however, told that the book "provides objective information for government and industry use", but it is not clear how, say, a designer faced with technological options will really be assisted. Perhaps the most interesting outcome of the limited analysis is the message to hybrid-microcircuit manufacturers that hermetic-sealing problems stand well above all others, whether detected by screening tests or in the field.

F. H. R.

The Junction Network

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UDC 621.39: 621.395.6

This article describes the British Post Office junction network in terms of size, growth forecasts, transmission limits, plant and utilization, and concludes with an outline of the possible future trends for the network.

INTRODUCTION

Any telecommunication network divides naturally into switching and lines interests, using different technologies and demanding different skills for design, manufacture, planning, installation and maintenance. The lines side of this division with its cable, duct and transmission equipment may sound like a complete monolithic structure, but, even here, a tripartite split into local distribution, junction and trunk lines is universal, even if the names used for the 3 parts are different in different administrations.

The local distribution network, connecting subscribers to their local exchanges, is generally well known and parts of it are on display in the streets for all to see. The trunk network, or in modern British Post Office (BPO) parlance the main network, attracts the glamour of advanced technology and its form and purpose are also well known. Much less is known about the junction network, and it is the purpose of this article to draw attention to a part of the BPO telephone system in which more money is invested annually than in the main network.

DEFINITION OF THE JUNCTION NETWORK

The principal functions of the junction network are to carry local traffic between exchanges and to interconnect with the main network. It was given its present definition in 1968, which in the simplest terms, can be expressed as "consisting of all those circuits carrying traffic between exchanges, at least one of which is a local exchange." In the more specific terms of the official definition, it comprises all circuits between

(*a*) local exchanges, whether in the same or adjacent charge groups,

(*b*) local exchanges and group switching centres (GSCs) or sector switching centres (SSCs), whether in the same or adjacent charge groups,

(*c*) local exchanges and GSCs in non-adjacent, but dependent, charge groups,

(*d*) exchanges wholly within numbering groups, and

(*e*) auto-manual centres and any exchanges in the same or adjacent charging groups.

Some junction routes therefore carry wholly local traffic, some wholly trunk traffic, and some a mixture of both local and trunk traffic.

SIZE AND LAYOUT

The junction network currently consists of about 900 000 public telephone circuits forming some 56 000 traffic routes. About 300 000 private, miscellaneous and shorter main network circuits are also carried on the plant forming the network. Mention has already been made that public junction circuits carry trunk as well as local traffic. Of the 56 000 routes, the 3 component categories are

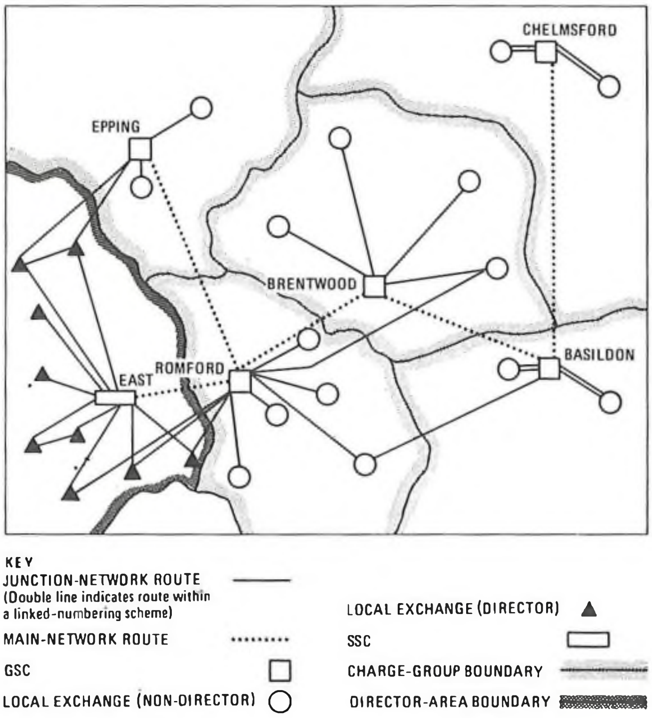

FIG. 1—A typical part of the junction network

(*a*) routes carrying mainly ($>90\%$) local traffic: 37 000,

(*b*) routes carrying mainly ($>90\%$) trunk traffic (including 270 routes carrying international traffic: 8000, and

(*c*) routes carrying a mixture of local and trunk traffic: 11 000.

A block diagram of a typical part of the network is shown in Fig. 1. Although the exchanges are shown as if interconnected by a single route, in many cases, several traffic routes are required. For example, outgoing traffic from a local exchange to its GSC requires the following 4 routes:

(*a*) level 0 ordinary } both carrying mainly trunk traffic,
(*b*) level 0 coinbox }
(*c*) level 1: auto-manual board and other services, and
(*d*) level 9: local traffic.

[†] Operational Programming Department, Telecommunications Headquarters

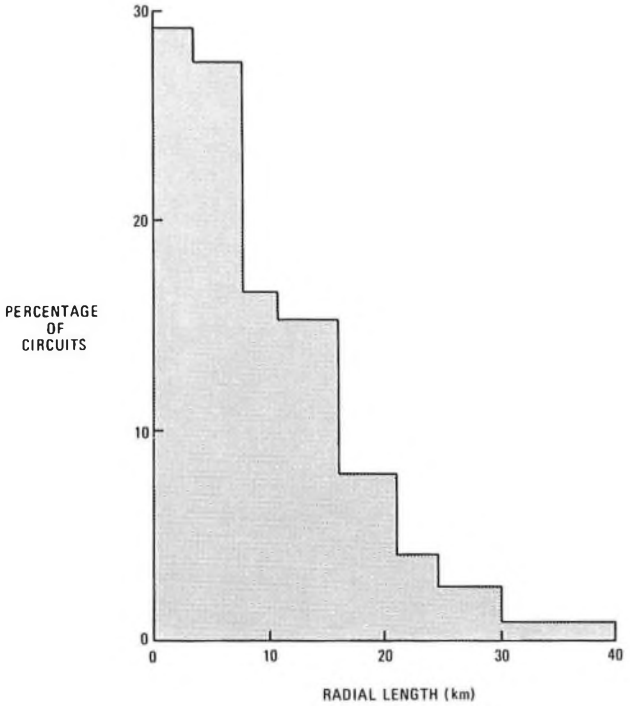

FIG. 2—Distribution of radial lengths of junction circuits

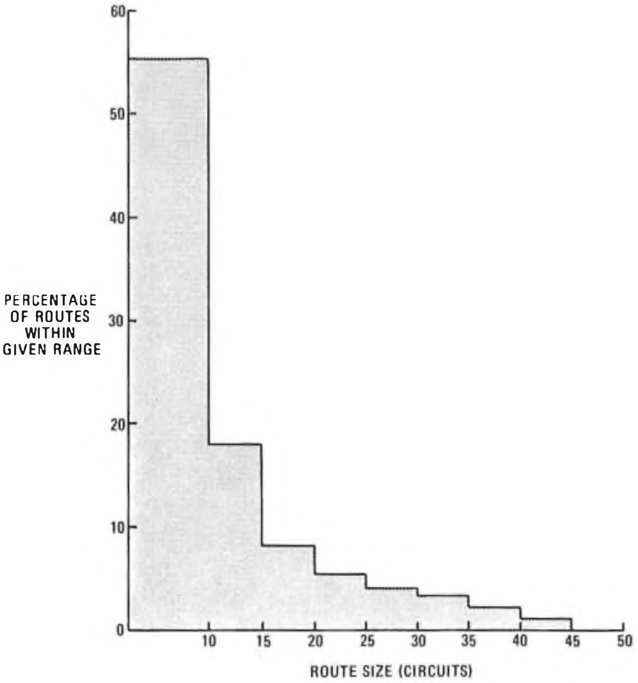

FIG. 3—Distribution of routes according to size in circuits

At least one route incoming to the local exchange from the GSC is also necessary.

Local exchanges within a director area each have routes to incoming and outgoing trunk units. They also have routes to and from the director tandem and sub-tandem exchanges to carry the smaller amounts of traffic between 2 local director exchanges that do not justify direct circuits between them. When SSCs are provided in London and Birmingham, each will combine the functions of outgoing and incoming trunk units for the local exchanges they serve, and will also provide director tandem switching facilities.

Because junctions carry traffic between exchanges within the home and adjacent charging groups, they are comparatively short. The average radial distance between the 2 ends of a junction circuit is about 8 km, although a small percentage extends to 30–40 km. A complete distribution of circuit lengths is shown in Fig. 2.

Partly because of the quantity of traffic generated in each local exchange, and partly because of switching policies and economics, junction routes also tend to be small. The present average traffic route size is 16 circuits and the distribution of sizes is shown in Fig. 3.

GROWTH FORECASTS

Forecasting of any description is a difficult task and forecasting traffic growth in the junction network is particularly difficult. The difficulties spring from several sources. Most routes are small, and the measurement of small amounts of traffic is increasingly dominated by random variation as traffic to be measured decreases. At present, 50% of junction routes carry less than 5 erlangs. As an example of the variability encountered in measuring small quantities of traffic, 1 erlang of true traffic flow can be measured at any figure between 0·8–1·2 erlangs with 90% confidence, whereas measurement of 20 erlangs varies between only 19·5–20·5 erlangs for 90% confidence.

The second difficulty arises from the mixture of trunk and local traffic on about 20% of junction routes. The ingredients of the total forecast for such routes are thus: the trunk traffic growth, the local traffic growth and the way in which the proportions of each will vary over the period.

A third factor is the location and measurement of traffic during the route busy hour. It has recently been shown that the precise location of the busy hour is unimportant, but that it is important to measure traffic in the morning, afternoon or evening, according to the period in which the busy hour is experienced.

Forecasting on past trend, and making allowances for known departures in the future from that trend, has been a method used for many years. It contains 2 problems. What is the true trend? What factors will cause departure from this trend? Because small traffic quantities can be measured only between quite wide limits of accuracy, it can be virtually impossible to determine a growth trend on small routes, even with comparatively frequent records. A further difficulty is encountered with unit automatic exchanges 12 and 13 which at present have no permanent traffic recorders at all.

Routes carrying traffic of less than 5 erlangs are now dealt with specially. It can be shown that the number of circuits likely to be required in the future is relatively insensitive both to the level of traffic assumed to be carried at the commencement of the forecast and to the forecast growth. A fixed growth is, therefore, used for these small routes unless there is good reason to do otherwise. The actual growth rate used is reviewed at 3-yearly intervals.

Most routes in director areas carry only local traffic, and these present a simpler problem that can be defined sufficiently for the forecasting process to be computerized. Local traffic from an exchange is a function of the number of subscribers on that exchange and their calling rate. The distribution of the traffic is determined by the number of subscribers available to be called and the community of interest between subscribers at the originating exchange and subscribers on other exchanges in the area.

A computer system known as *DAME* (Director-Area Mechanized Estimating) has been developed along these lines for use in director areas. In this system, the total originating junction traffic for each unit in the director system is assessed. Individual route growth factors are calculated from forecasts of connexions and calling rates for both the unit and the distant exchanges served by each route. The route growth factors are applied to the currently-assessed levels of traffic to produce year-by-year forecasts of traffic in erlangs for each route. For each unit, the aggregate of all outgoing route traffic for each year is compared with the corresponding forecast of total outgoing junction traffic and if the 2 quantities are not equal, matching is achieved within a small tolerance by an iterative process applied to the route traffic, while maintaining the pattern of distribution.

Forecasts for routes in the junction network that are not at present in the small category, or do not use the DAME system, are still projected on trend, although special adjustments have had to be made during the last 2 years to allow for the unusual conditions. A system for use outside director areas, employing the principle of apportioning a total outgoing junction traffic over individual routes is, however, under consideration. A second system, based on the principles used in quality control, is also being tested. This method requires the establishment of a trend line, but uses limit lines on either side of the trend, the upper limit being used for the forecast, which is amended only if a predetermined number of traffic measurements fall outside the limit lines.

TABLE 1

Transmission Limits in the Junction Network

Type of Circuit	Maximum Loss (dB)
LE–GSC	4·5
LE–Director Tandem	4·5
LE–LE	6·0
LE–Principal LE	3·0
LE–Auto-Manual Board	4·5

LE—Local exchange

TRANSMISSION LIMITS

The principal transmission limits applied in the junction network are shown in Table 1.

Where, however, a circuit is amplified, every endeavour is made to ensure that the loss does not exceed 3 dB. In such cases, losses up to the maximum for the type of circuit should be incurred only on 2-wire amplified circuits that exceed the length over which a 3 dB loss can be attained. The maximum lengths of circuits to achieve the loss requirements using unamplified cable pairs and 2-wire amplifiers are summarized in Table 2.

PLANT USED

Cables

Paper core quad trunk (PCQT) cable, mainly laid in earthenware ducts or deep-level tunnels, is still used almost exclusively to provide junction circuits. Until 1966, the diameter of the copper conductors was 0·9 mm, although there were, and still are, very small quantities of cable with larger conductors. From 1966, the conductor diameter has been standardized at 0·63 mm and, at present, there is about the same amount of the 2 types of cable in use. Some 0·9 mm cable is still being added to the network for spurs to existing 0·9 mm cables, and for a few exceptionally long routes, mainly in Scotland. Radio links are in use mainly to connect islands and are important locally, but form a very small group of plant in the network as a whole.

Most cable pairs used for audio-frequency circuits are

TABLE 2

Maximum Lengths of Junction Circuits

Maximum Loss (dB)	Maximum Junction Circuit Length (km)						
	Unamplified		Amplified				
	0·63 mm Conductors	0·9 mm Conductors	Type of Amplifier	0·63 mm Conductors NEW STANARD		0·9 mm Conductors PRIOR 1966	
				End-Connected	Mid-Connected	End-Connected	Mid-Connected
3	6·6	13	Theoretical	17·7	35·4	34·8	69·6
			Negative-impedance	15·8	Nil	29·5	50·0
			Hybrid	Nil	33·2	Nil	66·0
4·5	10	19·6	Theoretical	19·4	38·8	38·0	76·0
			Negative-impedance	17·6	26·8	35·5	51·5
			Hybrid	19·4	36·0	38·0	71·0
6	13·3	26·1	Theoretical	21·1	42·2	41·4	82·6
			Negative-impedance	19·9	30·0	38·0	58·8
			Hybrid	21·1	38·1	41·4	74·4

loaded with 88 mH coils spaced at 1·83 km intervals and provide an adequate frequency response over the range 300–3000 Hz. About 6% of the total pair-kilometres in the network is unloaded and is used to provide junction circuits up to 3·6 km in length.

Many circuits used at audio frequencies are set up over cable pairs and achieve the relevant transmission performance without further assistance. Where, however, transmission limits would be exceeded, amplification is used. Practically all amplified public junction circuits use 2-wire repeaters, and most of these are of the negative-impedance type. Under certain circumstances (for example, in a circuit made up of more than one conductor size where the amplifier is located at the point of transition), the much more costly hybrid amplifier must be used. A higher gain is also possible with this type of amplifier, although, as with the negative-impedance type, only one can be used in each circuit. The required transmission standard for the comparatively few audio circuits beyond the range of 2-wire amplified circuits are met by the use of 4-wire circuits.

Pulse-Code Modulation

The capacity of many cables can be increased by using selected pairs as bearers for transmission systems using pulse-code modulation (PCM). This involves disconnecting the loading coils, inserting regenerators, and connecting the pairs via terminating equipment to multiplexing equipment and signalling units at each end.

There are restrictions on the use of cable pairs in this way. The first is on economic grounds. PCM terminal equipment is expensive so that, although 24 or 30 circuits can be provided over 2 pairs of wires, there is a minimum distance—at present, 8–10 km—before the savings in cable costs equate with the extra cost of terminal equipment. The initial size and growth rate of the circuits required also affect the economic justification for PCM. At present, it is necessary to reconvert any PCM transmission to the original audio frequencies before switching through an exchange. When digital switching is introduced, this will be unnecessary where PCM systems are working into a digital switching unit and the economics will alter dramatically in favour of PCM.

It is at this stage that the other factors restricting use of PCM systems will be most relevant, although they play an important role now. These are restrictions due to the electrical properties of PCQT cable. This cable was, and still is, specified for use at audio frequencies, and much of the present network was laid before the advent of PCM. Both the 24-channel and 30-channel systems had, therefore, to be designed to work as well as possible over existing plant and inevitably demanded compromise. One compromise adopted was that the GO and RETURN channels of a PCM system must use pairs in different balancing groups in a cable. This implies that the smaller cables with only one balancing group cannot be used for PCM systems which, at present, restricts PCM systems to cables with 60 pairs or more. Within a balancing group, there are further restrictions to reduce crosstalk difficulties. Taking all limiting factors into account, the proportion of pairs that can be used for PCM is restricted to 25–45% depending on the particular size of cable. The use of PCM is also restricted, at present, because certain signalling facilities are unavailable, although this will eventually be remedied.

The number of circuits actually carried by PCM systems is still relatively small. About 2% only of public junction circuits are provided by this means, mainly limited by economics; because of signalling requirements, virtually no private circuits are carried by PCM systems. The number of PCM systems in the junction network is growing steadily at about 500–600 systems/annum, and this is likely to continue until the swing of economic advantage comes with digital switching.

UTILIZATION OF PLANT

Although this article is primarily about the junction network and, in traffic terms, this means those circuits that are part of the public switched network, plant which is provided under the financial heading of *junctions* is also used in other ways. Table 3 shows how the total cable pair length available is used. The rather surprising fact is revealed that, of the cable paid for out of the junction allocation of funds, slightly less than half is actually in use for public junction circuits.

TABLE 3

Percentage Distribution of Use of Junction Cable Pair Length

Category	Proportion of Total Junction Cable Pair Length Used (%)
Telephone (Main)	3·0
Telephone (Junction)	48·9
Telegraph	3·2
Spare (Not Earmarked)	24·2
Spare (Earmarked)	5·5
PCM	2·1
Exchange Line	0·6
Private Wire	10·2
External Extension	0·5
Miscellaneous Engineering	1·8
$\frac{\text{Private and Miscellaneous}}{\text{Public Telephone}}$	30·2
$\frac{\text{Spare (Not Earmarked)}}{\text{Working Pairs}}$	31·9

About 24% of all the cable is not yet in use and this gives rise to considerable misunderstanding. It is often thought that it would be ideal if there were no spare plant at all, or perhaps only just enough to be able to provide circuits when required, without having to wait for a new cable to be installed. This is far from the truth if "ideal" means "the most economic."

Every cable provided entails planning effort, stores ordering, contract placing, checking of the route and so on, and most of the cost of this effort is more or less independent of the size of cable provided. It can be shown that, for any set of conditions to be met by the provision of a new cable over a certain route, there is one size of cable that provides the most economical way of meeting the forecast circuit requirements. The actual size of cable to be provided in a particular case depends on the rate of growth of the circuits to be carried and the period for which the cable is intended to last. In the junction network, the average period for which it is most advantageous to provide cable is about 6 years. Fig. 4 shows the optimum periods for different growth rates of circuits. Fig. 5 shows the theoretical spare capacity existing in a network in which every cable is provided to last for 4, 6 and 8 years. It can be seen that, if circuits are being added at an annual rate of about 9%, which was the growth rate in the junction network prior to the present depression, spares should ideally be around 22–23% if all cables are provided to last for 6 years.

Nevertheless, averages can, and do, cloak large variations. Inevitably, cables provided some years ago are larger than they need have been because, at present, traffic growth is depressed. While this gives rise to comparatively large amounts of spare plant for a period and may look wasteful, the reverse effect, when traffic builds up quickly, can provoke even greater criticism.

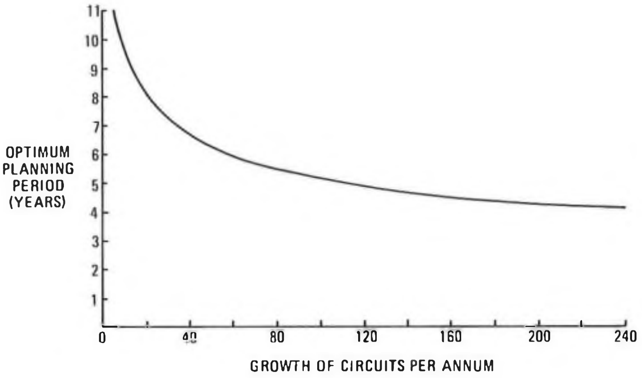

FIG. 4—Optimum planning periods for different circuit growth rates

FUTURE TRENDS

Although junctions are, at present, provided over audio-frequency circuits or PCM channels, a major change is likely to start during the 1980s. Analysis of requirements forecast for the early-1980s has shown that growth of junction circuits between pairs of exchanges will be greater than 50 circuits/annum in a sufficiently large number of cases to justify increments of 100 or more channels every 2 years. This brings such cases within the range of an 8 Mbit/s digital system with a capacity of 120 channels. In the main, however, these larger routes tend also to be the shorter ones (that is, 0–10 km), and justify the use of digital systems only when working into a digital switching exchange. This statement is valid whatever medium is used as a bearer for the PCM systems.

Nevertheless, it is not too early to be considering the future of the junction network in conditions in which digital switching is used. Under such conditions, economics will probably favour the concentration of traffic into larger routes with at least one switching stage, and direct routes between pairs of exchanges will be less prevalent. Routes to tandem switching points will grow at the expense of direct routes between local exchanges which will, in time, atrophy. However, no capital expenditure is incurred in leaving circuits where they are, whereas new plant must be provided to route, via a centralized switching point, calls that had previously been routed direct between 2 local exchanges. Alternative routing with spill-over from the direct to tandem routing could well be a useful mid-term answer as local switching units with this facility (for example TXE4) become available.

With the need for 8 Mbit/s, and later on 34 Mbit/s transmission systems in the junction network, the era of PCQT cables will start to draw to an end. With a value at today's prices of around £600M, the replacement of these cables will not happen overnight, and does not need to. Much depends on the introduction of services other than voice communication that demand much larger bandwidth.

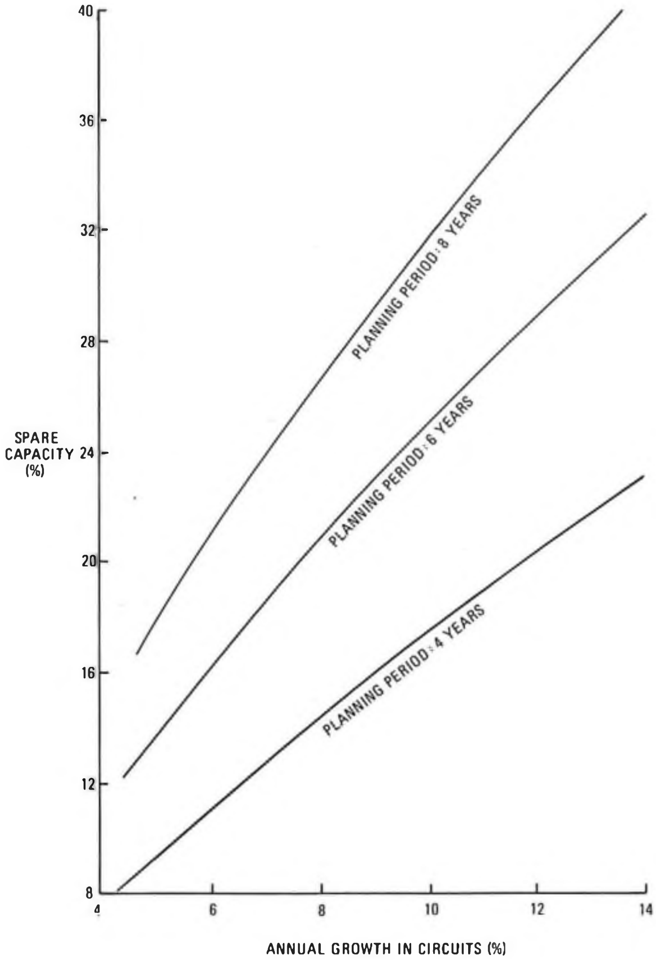

FIG. 5—Spare capacity for different growth rates and planning periods

The advent of 8 Mbit/s digital systems seems likely from around 1985 onwards, and these cannot be carried on existing cables. The alternatives on offer are likely to be either microcoaxial cable or optical-fibre cable. The former is being extensively used now in Italy: the latter is just entering the field-trial stage, but will undoubtedly be available for use by the mid-1980s. Microcoaxial cable reaches its limit at 34 Mbit/s, whereas optical-fibre cable is likely to be capable of carrying a wide range of systems and looks like being a cheaper option.

By the early part of the next century, digital systems on optical-fibre cable will no doubt occupy an important place in the junction network, which will already have begun to lose much of the separate identity it has today. It is, however, fairly safe to forecast that a great deal of the cable and duct in use today will still be working then.

A Computerized Spare-Plant Return for Local Lines—SPRET

E. C. DUDMAN, C.ENG., M.I.E.E., R. N. WILLIAMS and D. R. BURT†

UDC 681.31: 621.395.743: 621.315.2

The availability and use of cable pairs in the local network were previously measured by 6-monthly counts of pairs shown as available and spare on the line-plant allocation records. Now, a computer-based system has been developed and introduced to provide a larger range of information more quickly, for use by local-line planners and network managers. This article describes the new system and its uses.

INTRODUCTION

There are some 6250 exchanges in the UK, varying in size from small rural exchanges with less than 50 subscribers to large multi-unit installations serving up to 40 000 lines. The local-line networks which radiate from these exchanges are of tapering form, separated into main and distribution parts by flexibility cabinets, known as primary cross-connexion points (PCPs). In some instances, pillars or secondary cross-connexion points (SCPs) are interposed between the PCP and distribution points (DPs), but, with increasing telephone penetration, SCPs are reducing in number.

Fig. 1 is a block diagram of the UK local-line network; from this it can be seen that 13% of distribution pairs terminate directly at the exchange, 77% at PCPs and the remaining 10% at SCPs. On 31 March 1976, there were 20·6-million main pairs in the network, and 24·7-million direct and flexible DP pairs. The importance of the plant involved is shown by the fact that the local network accounts for nearly 20% of telecommunications plant assets and has a current replacement value well in excess of £2000M. With a capital investment of this order, a reliable means of measuring plant utilization is essential, both for effective network management and to enable the scale, timing and budgetary cost of future plant extensions to be assessed. Previously, a manual method of measuring and recording pairs available and spare was used, but this has recently been replaced by a computer-based system.

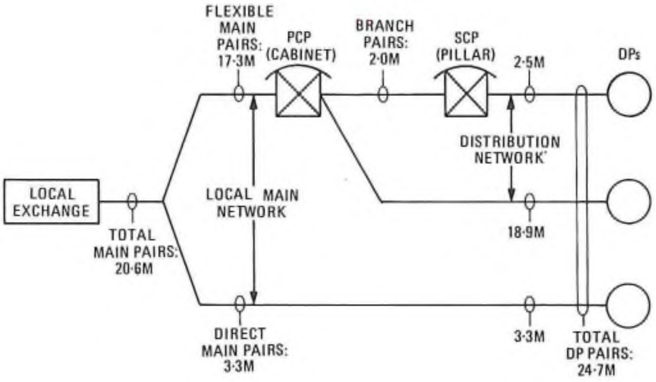

FIG. 1—The UK local-line network

HISTORICAL

In the manual system, the number of pairs terminated and spare were counted and totalled, using information from the circuit-routing cards held in routing and records offices; this was known as the spare-plant return, and was compiled at the end of March and September each year. The information was used by external planning groups to determine the need for, and the timing of, main and distribution relief schemes and for local-network management purposes. Forms were used to record the plant situation at directly-connected DPs, flexible DPs, SCPs and PCPs. Results for a General Manager's Area were then summarized on a form (the well-known A2041 return); these were combined at Regional level into a Regional return and finally at Telecommunications Headquarters (THQ) into a national summary. This manual form of pair-utilization measurement, although it fulfilled an important purpose, suffered from shortcomings: its preparation was inherently time consuming, creating inconvenient work peaks during the 2 months of counting and recording; there were limits to the amount of information that could be collected and processed.

In recent years, the need for more frequent returns became apparent; for example, productivity calculations required a knowledge of the number of main and distribution pairs added to the local network each month. This indicated that the spare-plant return was an obvious field for the application of computerized methods. Consequently, when the local-line computer project was set up in the mid-1960s to investigate the introduction of a comprehensive line-plant recording and data-acquisition system to facilitate the provision of service, information on pair utilization was to have been produced as one of its outputs. In the event, the high cost of creating the tenancy-address records, and of setting up and maintaining the large computer files required, outweighed the expected benefits, and the local-line computer project was abandoned.

No further action was taken, but, in 1971, terminals with access to time-sharing computers were introduced into a number of General Managers' Areas. A proposal was made to record running totals of pairs terminated and spare on DP cards and store this information on file in a computer so that, by suitable processing, a print-out of distribution-pair utilization could be obtained. Because of its evident potential, a programme was written and the method given a field trial

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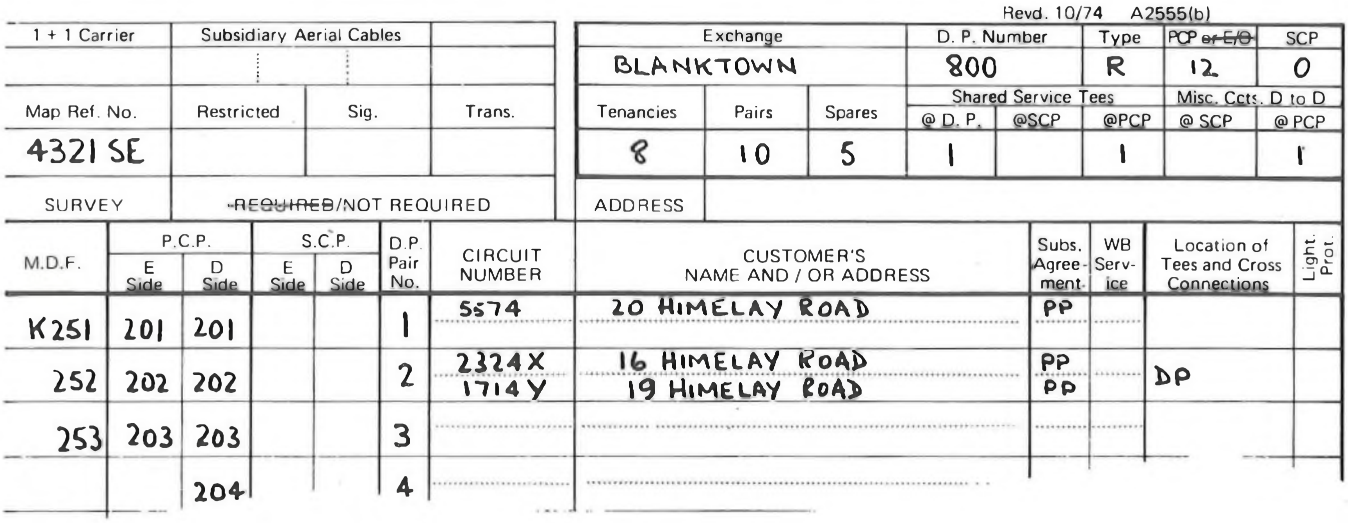
† Mr. Dudman and Mr. Burt are in Operational Programming Department, Telecommunications Headquarters, and Mr. Williams is in Sheffield Telephone Area



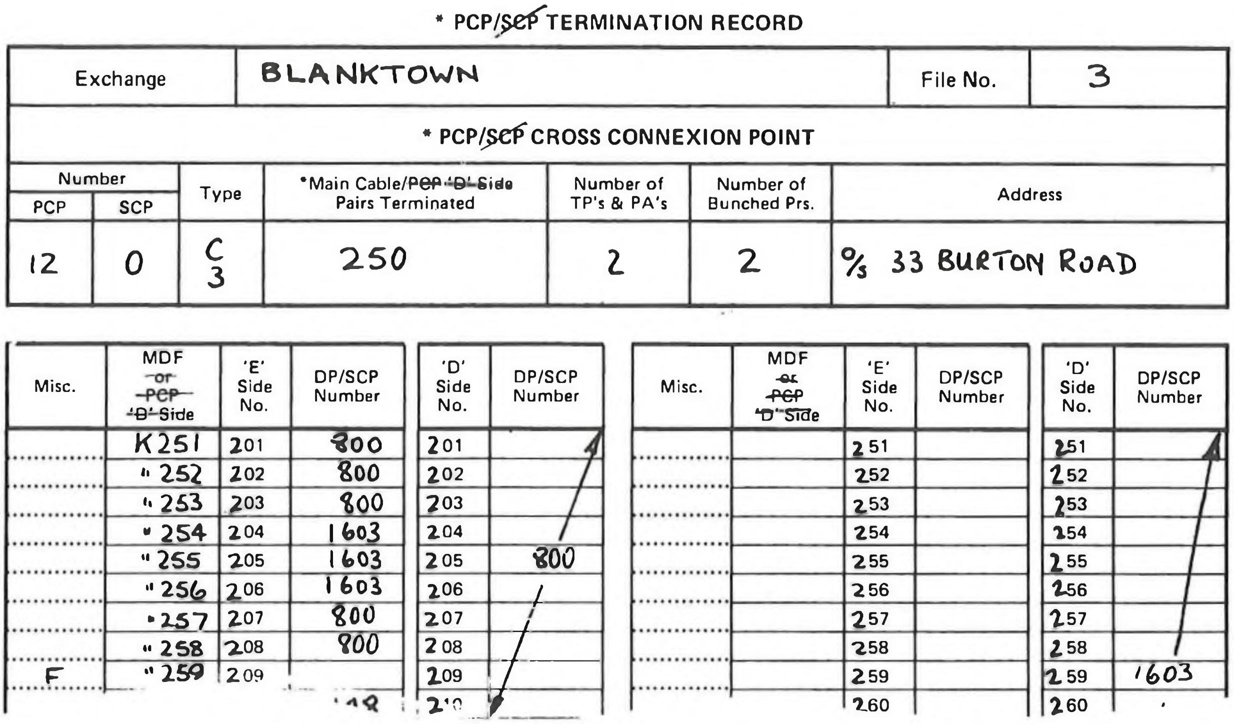
Revd. 10/74 A2555(b)

1 + 1 Carrier	Subsidiary Aerial Cables		
Map Ref. No.	Restricted	Sig.	Trans.
4321 SE			
SURVEY	~~REQUIRED~~/NOT REQUIRED		

Exchange			D. P. Number		Type	~~PCP or E/O~~	SCP
BLANKTOWN			800		R	12	0
Tenancies	Pairs	Spares	Shared Service Tees			Misc. Ccts. D to D	
			@ D. P.	@SCP	@PCP	@ SCP	@ PCP
8	10	5	1		1		1
ADDRESS							

M.D.F.	P.C.P.		S.C.P.		D.P. Pair No.	CIRCUIT NUMBER	CUSTOMER'S NAME AND / OR ADDRESS	Subs. Agreement	WB Service	Location of Tees and Cross Connections	Light. Prot.
	E Side	D Side	E Side	D Side							
K251	201	201			1	5574	20 HIMELAY ROAD	PP			
252	202	202			2	2324X 1714Y	16 HIMELAY ROAD 19 HIMELAY ROAD	PP PP		DP	
253	203	203			3						
		204			4						

FIG. 2—DP record card



* PCP/~~SCP~~ TERMINATION RECORD

Exchange	BLANKTOWN	File No.	3

* PCP/~~SCP~~ CROSS CONNEXION POINT

Number		Type	*Main Cable/~~PCP 'D' Side~~ Pairs Terminated	Number of TP's & PA's	Number of Bunched Prs.	Address
PCP	SCP					
12	0	C 3	250	2	2	c/o 33 BURTON ROAD

Misc.	MDF ~~or PCP 'D'~~ Side	'E' Side No.	DP/SCP Number	'D' Side No.	DP/SCP Number
	K251	201	800	201	
	" 252	202	800	202	
	" 253	203	800	203	
	" 254	204	1603	204	
	" 255	205	1603	205	800
	" 256	206	1603	206	
	" 257	207	800	207	
	" 258	208	800	208	
F	" 259	209		209	
			[illegible]	210	

Misc.	MDF ~~or PCP 'D'~~ Side	'E' Side No.	DP/SCP Number	'D' Side No.	DP/SCP Number
		251		251	
		252		252	
		253		253	
		254		254	
		255		255	
		256		256	
		257		257	
		258		258	
		259		259	1603
		260		260	

FIG. 3—PCP/SCP termination record

which embraced 12 exchanges in Sheffield General Manager's Area. The system was code-named SPRET. Coincidentally, a field trial was under way in another Region which widened the scope of the manual return so that it included information on shared-service pairs to enable programmes for conversion to exclusive working to be formulated. The considerable advantages obtainable by extending SPRET to include local main, distribution and shared-service pairs were apparent and, with the agreement of the Experimental Changes of Practice Committee, it was decided to conduct a field trial of a programme enhanced in this way in Gloucester, Peterborough and Sheffield Telephone Areas. At the end of 1974, when this enhanced programme was seen to be achieving the expected results, a decision was made to proceed with national implementation.

SYSTEM DESCRIPTION

The data sources for SPRET are the DP card and the PCP/SCP termination record, illustrated in Figs. 2 and 3 respectively. The DP card has a distinctive panel in the top right-hand corner which gives

(*a*) the exchange, DP, PCP and SCP details,
(*b*) the forecast number of tenancies within the DP service area,
(*c*) the numbers of pairs terminated and spare,
(*d*) the number of shared-service tees at the DP, SCP and PCP, and
(*e*) the number of D-side-only miscellaneous circuits at the SCP and PCP.

The PCP/SCP termination record shows

(*a*) the PCP/SCP number and type,
(*b*) the number of main pairs at the PCP,
(*c*) the number of branch pairs at the SCP,
(*d*) the number of test pairs and pressure-alarm pairs, and
(*e*) the number of bunched pairs.

The foregoing information from all record cards is input to a central computer. The file is then updated whenever a change in circuit routing or pair availability occurs by re-inputting the complete information in the SPRET panel; this precaution avoids the possibility of cumulative errors occurring.

If the routing and records office is near to the local computer terminal, the updated cards are placed in a special box and, later, taken to the terminal for data inputting; afterwards, they are returned to the routing office for refiling the same day. When the routing and records office is not close to the computer terminal, it is necessary to convey the updating information to the terminal by other means. One method widely used is to photocopy a group of cards, arranged so that the top of each card is separately visible; the photocopies are then dispatched to the terminal operator. Alternatively, a locally-printed record sheet can be used, a separate line being used to enter the information for each updating change.

To economize in computer and telephone-circuit occupancy time, the data are not input directly from the machine keyboard, but are keyed on punched tape, after which the local record is checked and any punching errors corrected. The operator then calls the computer centre and runs the tape to transmit the data to a temporary file in the computer. Finally, on transmission of an EXECUTE command, processing takes place. This proceeds serially, the programme dealing with and processing the data for one DP at a time. Range and validity checks are applied, and only if these are satisfied is the database updated. If the last pair on a DP has been taken into use, the computer detects this and, if required, a message to this effect can be printed at the local terminal for planning group use.

NATIONAL IMPLEMENTATION

To introduce SPRET, all DP cards had to be provided with the special summary panel. New cards were printed with it, but existing cards were adapted by using a suitably printed adhesive label. Altogether, nearly 2-million cards had to be treated in this way, a task which took several months to complete. Then, all DP cards for a particular exchange area having been modified, the information was input to the computer. The availability of a print-out listing all gaps in the numerical sequence of DPs greatly facilitated the task of checking that the data for all DPs in an exchange area had been input correctly. Similarly, a PCP and SCP summary provided confirmation that information for these had been input correctly.

As was to be expected, some Areas took longer than others to complete the work of modifying DP cards and inputting data; nevertheless, by February 1976, a complete national output had been obtained. In the space of little more than 12 months, SPRET had been successfully introduced into every Area in the UK.

SPRET OUTPUTS

A series of complementary outputs was developed, with changes being made in the light of experience, to meet the requirements of local-line planners and of network and operational managers. The range of these outputs extends from a straightforward analysis of the plant situation in one flexibility area (PCP, SCP or Direct Area), through exchange, Area and Regional summaries, to a national presentation of

```
                                 OUTPUT 1

                      OUTPUT FOR PLANNERS (PCP AREA)
EXCHANGE—CUDWORTH                                       DATE THURS APR 29, 1976
PCP NUMBER 12
MAINS
                              SPARE      SHARED
                     PAIRS    PAIRS      PAIRS     NIL
                      200      83         22        0
DISTRIBUTION PCP 12                                       NIL
  DP         DP               SPARE      SHARED           NOT                 TENANCIES
NUMBER      TYPE     PAIRS    PAIRS      PAIRS     NIL    SAT     CAT
  56         R        15        6          1        0      0       A            13
  57         O        15       10          0        0      0                     0
  58         O        15        2          0        0      0       B             0
 269         JP       20       14          0        0      0                    20
 301         O        15        0         13        1      1       D             0
 302         C        15       12          0        0      0                     0
 303         O        15        2          0        0      0       B             0
 304         E        10        6          0        0      0                     0
 305         O        13       11          0        0      0                    12
 306         O        10        8          0        0      0                    10
 307         U        13       13          0        0      0                     0
 308         O        12       11          0        0      0                     0
 309         O        15        0          1        1      1       C             0
 310         O        15        4          0        0      0       A             0
 311         UR        8        2          0        0      0                     8
 353         O        14        8          0        0      0                    14
 354         I        20       12          0        0      0                     0
 355         I        20       13          0        0      0                     0
 356         O        18       14          0        0      0                    18
  TOTALS
  19                 278      148         15        2      2                    95
```

O — Overhead, route
R — Overhead, radial
JP— Jointing post
E — External block wiring
U — Underground
UR— Underground, radial
I — Internal
C — Continuous aerial cable

FIG. 4—An example of an output 1

each Region's plant situation. The lower-order outputs, intended for planning office use, are obtainable on demand at the local terminal, but those intended for management purposes are produced monthly and dispatched to the user by post. To ensure time consistency between Area, Regional and national figures, these outputs are produced in a single batch run initiated by THQ. The principal outputs and the uses which they serve can be summarized as follows.

DP Analysis

The DP analysis is a list of DPs, in a PCP, SCP or Direct Area, showing

(*a*) the pairs available,
(*b*) spare pairs,
(*c*) shared pairs,
(*d*) a zero-spares indication,

```
                                   OUTPUT 3

          OUTPUT FOR PLANNER (CATEGORIZATION OF DP'S, SCP'S & PCP'S)
EXCHANGE—KUMPSTUN                                        DATE TUES MAR 23, 1976
                    CAT      DP'S
                  OF SCP     NOT       DP'S       DP'S       DP'S       DP'S
AREA CODE         OR PCP     CAT       CAT A      CAT B      CAT C      CAT D
DIR    E/0                   33        20          8          1          0
PCP    1            2         8         7          3          2          0
SCP    1/1          2         4         5          3          0          0
PCP    2            2        23        11         10          0          0
PCP    3            0        24        11          3          0          0
PCP    4            2         7        23          6          0          0
PCP    5            1        15        11          8          0          0
PCP    6            1         7        22         12          0          0
PCP    7            1        31        14          9          0          0
PCP    8            0        32         6          3          0          0
PCP    9            1        23        13         13          0          0
PCP   10            0         8        11          4          0          0
PCP   11            0        17        12         11          0          1
PCP   12            1        12        17          3          0          0
PCP   13            2        20        14         10          0          0
PCP   14            0         6         3          0          0          0
PCP   15            0         0         0          0          0          0
TOTALS

DP'S            NOT CAT    270   CAT A  200   CAT B  106   CAT C  3   CAT D   1
SCP'S             CAT 0      0   CAT 1    0   CAT 2    1   CAT 3  0   CAT 4   0
PCP'S             CAT 0      6   CAT 1    5   CAT 2    4   CAT 3  0   CAT 4   0
```

Fig. 5—An example of an output 3

```
                                   OUTPUT 4

                        SPARE PLANT RETURN (GM'S AREA)
GM AREA—BRADFORD                                             TUES APR 20, 1976
                NUMBER
                OF DP'S                                          NIL
                SCP'S &             SPARE     SHARED             NOT
AREA DETAIL     PCP'S      PAIRS    PAIRS     PAIRS      NIL     SAT   TENANCIES
ADDINGHA
DIRECT AREAS
O/H DP'S          33        338      100        1         4       4        0
OTHER TYPES       35         35       24        1         2       2        0
TOTAL             38        373      124        2         6       6        0

PCP AREAS
MAINS              4        570      140        3         0
BRANCH             0          0        0        0         0
DISTRIBUTION
O/H DP'S          45        616      230        3         3       3       23
OTHER TYPES        7        100       52        0         0       0        0
TOTAL             52        716      282        3         3       3       23

AIRTON
DIRECT AREAS
O/H DP'S          16        137       47        1         1       1        2
OTHER TYPES        4         31       26        0         2       2        0
TOTAL             20        168       73        1         3       3        2

PCP AREAS
MAINS              1        144       51        3         0
BRANCH             0          0        0        0         0
DISTRIBUTION
O/H DP'S          16        144       52        3         1       1        0
OTHER TYPES        1          1        0        0         1       1        0
TOTAL             17        145       52        3         2       2        0
                 Note: Exchanges are identified by first 8 characters
```

Fig. 6—An example of an output 4

(*e*) whether, in the case of zero spares, the DP is saturated (provided with enough pairs for all potential subscribers in its service area),

(*f*) the usage category (see below), and

(*g*) the number of tenancies to be served (where this is known).

In addition, the main and branch pair details are presented for PCPs and SCPs.

Two varieties of the DP analysis are available, designated *output 1*, for a single flexibility area, and *output 8* for an exchange or General Manager's Area. An example of an output 1 is illustrated in Fig. 4.

The DP analysis is primarily intended to provide the planning engineer with information needed to prepare distribution-cable relief schemes; in addition, it is used by the sales forecasting group in preparing line-plant forecasts.

Exchange-Area Summary

Known as *output 2*, the exchange-area summary provides a summary of individual service areas, followed by exchange-area totals. The distribution-pair totals are presented in overhead DP and other-type DP categories to facilitate derivation of overhead and underground working circuit statistics.

Output 2 is intended to facilitate the preparation of area planning programmes; it can also be used to identify districts in which the line plant situation is sufficiently favourable to permit the launching of a selling campaign.

DP/SCP/PCP Usage Categories

The DP/SCP/PCP usage category, which is known as *output 3* and is illustrated in Fig. 5, classifies DPs, SCPs and PCPs into one of 5 usage categories that are defined by the working-circuits-to-total-pairs ratio, as shown in Table 1.

Output 3 provides a ready indication of where relief is required and, also, the relative urgency. Working-circuit-to-total-pairs ratios in excess of 100% result from shared service, and the output identifies plant deficiencies that need to be remedied if an all-exclusive service is to be given.

Area, Regional and National Summaries

The Area, Regional and National summaries, known as *outputs 4*, 5 *and 6*, present the plant situation in an Area (by exchanges), in a Region (by Areas) and for the UK (by Regions). The information thus provided has a wide range of uses, including added-pair cost and productivity measurement (Area and Regional outputs), the determination of future pair requirements (Area, Regional and national outputs) and the calculation of asset utilization factors (national output). Fig. 6 shows a portion of the plant summary for a General Manager's Area.

TABLE 1

Usage Categories for DPs, SCPs and PCPs

DPs		SCPs and PCPs	
Category	Working-Circuits-to-Total-Pairs Ratio (%)	Category	Working-Circuits to-Total-Pairs Ratio (%)
Unclassified	<50	0	<50
A	50–80	1	50–85
B	80–100	2	85–100
C	100–130	3	100–115
D	130–200	4	115–200

COST EFFECTIVENESS

A discounted-cash-flow appraisal, taking into account the costs actually incurred during the setting-up period showed that, in comparison with the former manual system, SPRET will cost-in within 6 years. This was on the basis of a straight comparison between the costs of the 2 methods; no attempt was made to quantify the considerable benefits which will accrue from the availability of a more up-to-date and wider range of information to planners and network managers.

CONCLUSIONS

As a consequence of the speedy development and introduction of SPRET, the BPO Telecommunications Business has been provided with rapid and reliable information on the growth and utilization efficiency of cable pairs in the local-line network. At the same time, the new system possesses considerable potential for further development; attention, for example, is currently being directed towards predicting PCP and SCP exhaustion by trend projection methods. The development of a comparable means of measuring duct utilization is also being investigated.

Book Review

Problems and Solutions in Logic Design. D. Zissos, with contributions by F. G. Duncan. Oxford University Press. viii + 146 pp. 54 ills. £3·50 (hard cover); £1·75 (paper cover).

This book divides naturally into 2 halves, dealing respectively with sequential and combinational logic.

In the first half, the author explains the analysis of sequential systems using state diagrams and state tables, and goes on to show how the logic implementation of such a system can be derived from its state description, and how logic hazards can be avoided. Design procedures for unclocked and clocked systems are explained, and a chapter is given on the design of counting circuits.

The second half of the book deals with combinational circuits, and the author shows how logic is minimized, how fan-in restrictions can be taken into account, and again how hazards are avoided. Boolean algebra, and the reduction and minimization of Boolean expressions, are treated in an appendix.

The main criticism of this book is that the explanations given of the various techniques are always brief, possibly to the extent of insufficiency for a reader not familiar with this subject. Also, the section on counters is rather long, and it would perhaps have been useful to treat some other classes of circuit in some depth.

On the other hand, the large number of examples and problems given throughout the text will be of benefit to anyone studying the subject, and the book is therefore useful rather as an aid to study than as a primary reference work.

R. B.

ISSLS 1976—The Local Telecommunication Network: The International Scene

UDC 621.391:621.395

From 3–7 May 1976, the Institution of Electrical and Electronic Engineers and the Institution of Electrical Engineers (IEE) jointly held in London the second International Symposium on Subscriber Loops and Services. Some 368 delegates attended; they represented 29 countries with telecommunication systems which had reached widely different degrees of advancement.

The technical sessions covered local network planning and management, maintenance, local system electronics and customers' equipment. Future network evolution was inherent in the theme of other sessions devoted to integrated digital systems and wideband systems strategy. The British Post Office (BPO) complemented the discussion in one other important area, external plant, by arranging at Yeading a comprehensive exhibition of plant and equipment which all the delegates were invited to visit. Fig. 1 shows a general view of the exhibition.

The 4 days of presentation and debate began with 3 sessions in which papers by speakers from US Bell, Bell Canada, AT and T, ITT's Spanish Laboratories, CNET and the Telecommunications Headquarters of the BPO all emphasized the magnitude of the labour-cost element in local network provisioning. One group of papers discussed progress in computer-aided network planning and management to cut costs and rationalize operations. US Bell were implementing a co-ordinated group of software systems with which they aimed to control their overall loop operations and, within a decade, hoped to be saving around $1000M annually. Other administrations were adopting the more cautious approach of mechanizing specific work functions on a piecemeal basis. The BPO, for example, demonstrated its spare-plant return for local lines (SPRET) computer programme for assisting local network management; this was one of several demonstrations at the IEE in support of symposium papers.

Another group of papers triggered a debate on the use of pair-gain systems (for example, carrier multiplexes) as a permanent feature of local-line planning to reduce cost. There was common agreement that the loop distances at which such systems became attractive would shorten as costs of electronics fell and direct pair costs rose. The increasingly widespread use of such systems in North America did not provoke a similar response in the UK because of the shorter line lengths. The BPO is beginning to install subscribers' carrier systems and loop extenders. But sufficiently low-priced electronics had not yet arrived to permit a wholesale revision of planning standards. However, it was noted that one American pulse-code-modulated carrier system was quoted as having per-channel costs much lower than any current UK values. Overall, delegates registered an expectancy of significant changes in the use of these cable saving devices in the local network.

Papers on maintenance and servicing underlined the widespread intention to mechanize the whole process of fault handling, testing and monitoring of service facilities. Bell appeared to be well ahead with their implementation of computer-based fault-recording systems; fault rates per station were being held, but a number of special problems such as those of coin boxes (maintenance costs 4 times those of an ordinary line) were causing headaches. This came as no surprise;

FIG. 1—General view of the BPO external-plant exhibition at Yeading

there were many administrations with similar experiences. Greater use of on-site replacement through a centralized repair facility was being advocated, although a blunt warning from a South African delegate that such a philosophy had resulted in unnecessary replacement of 30% of customers' instruments was typical of the valuable experience the discussion often revealed.

North American cable design had moved toward fully-filled cables for all the local network. Increasingly, the trend was toward underground distribution, but this had not yet reached a high level of standardization. The progressive change in the UK from copper to aluminium conductors for most local-network cables had not so far been echoed in the USA, where it was revealed that copper was supplied, for cable manufacture by Western Electric, at below world prices, and also that about 50% of the copper used was recycled.

The cable placement and jointing procedures of several administrations were compared. These showed many points of similarity, but were conditioned by the different environments encountered. The colder weather in North America, with ground frozen down to depths of over 1·2 m for much of the year, ensured that there would be no water pipes at depths less than 1·5 m; thus at least one hazard was eliminated from the trenching operation. Farther south, temperatures up to 40°C in the ground necessitated the adoption of solutions to the problems of cable jointing and filling different from those adopted, for example, in the UK. It was perhaps particularly in this sphere of outside plant that, despite the essential commonality of the fundamental requirements facing local systems throughout the world, local environmental differences threw up a variety of different solutions that mitigated against the worldwide development of unified equipment.

The BPO external-plant exhibition demonstrating current UK practices and developments was well appreciated by the overseas delegates. The new injection-welding equipment for sheath closures (Fig. 2), and the 2 jointing machines No. 4, coupled to give a no-break change-over, were in advance of American and Canadian practices. The hollow mushroom-topped pole with dropwire termination at ground level also aroused much interest. Also on show, were the bigger machines such as the heavy-cabling vehicles, platform elevators and pole-erection units; these are now commonly available overseas.

The developing potential which electronic devices offer to local network system designers was the theme behind a number of contributions. One paper from the USA looked fundamentally at the possibility of a new balance being struck between switching systems and loop plant, a balance that could significantly change both switching architecture and loop topology. A lively and informed discussion on the relative merits of amplitude-modulated/frequency-modulated analogue and digital systems confirmed that, at present, there is no single panacea for local system evolution. Clearly, application of electronic devices was accelerating and, particularly in North America, much effort was being directed toward introduction of digital systems; nevertheless, the advocates of analogue techniques continued to put up a strong case on grounds of cost and simplicity.

In the customer-equipment area, a survey of push-button telephone development followed the presentation of an interesting new telephone instrument from Denmark. BPO Viewdata progress and a British (GEC Ltd.) low-cost data telephone introduced the debate on new data facilities; the question left unanswered was the extent of the likely demands for such services.

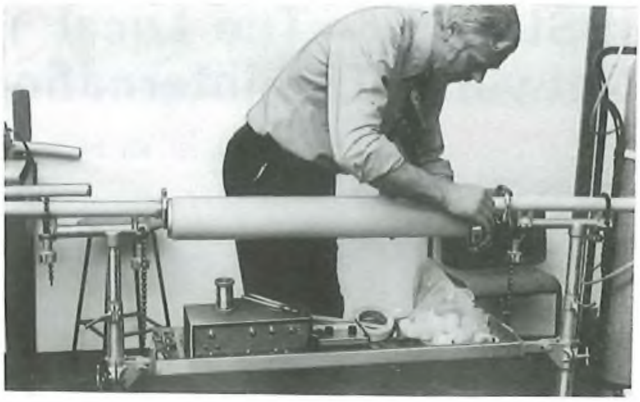


FIG. 2—Injection-welding equipment for sheath closures

There was obviously continued evidence of a world-wide interest in digital local networks. Would these be entirely digital out to the customer's equipment? Would the local exchanges be digital, with analogue–digital interfaces within the local-line system? These were matters that remained unresolved. There seemed to be no hardening of opinion on common modulation systems, types of network topologies, or traffic concentration and multiplexing. With papers from such diverse places as America, Sweden, Australia and the UK, perhaps uniformity of approach could not be expected. It appeared, however, that apart from brave Finland, no administration was currently planning to introduce an integrated digital system into its local switching and loop plant. The Finns expected to bring into service their first system, at Houtskar, at the beginning of 1978.

No conference on local networks could be concluded without consideration of the state of the art of distribution of wide-band services. It was generally agreed that no techniques so far known permitted more than one broadcast-standard television picture to be carried in existing network pairs (pair-to-pair crosstalk and attenuation limits cause hazards even for special point-to-point use). Thus, it was accepted that a separate transmission medium—coaxial cable or glass fibre—would be introduced into the network, and degrees of integration were explored. Apart from the optimists who thought that technology might yet accommodate all on the existing pair, people were looking at the prospect of multi-cable schemes. The basic questions in most advanced countries were when and how much.

The theme of world resources in relation to telecommunications, chosen by Professor J. H. H. Merriman, BPO Board Member for Technology and Senior Director: Development, in his invited address on the first evening of the symposium, may well have left delegates with the thought that the wide issues facing the evolution of man's biggest and most complex machine would be the fundamental ones influencing the development of its outermost tentacles.

C.E.C.
A.G.H.

Installation of the UK–France No. 1 Cable: Brighton Telephone Area's Involvement

R. N. SMITH†

UDC 621.315.28:621.395.7

This article describes some of the problems encountered by Brighton Telephone Area staff in installing the land-section of the UK–France No. 1 Cable—the first coaxial repeatered submarine cable in the Brighton Area. Some of the unique and imaginative solutions adopted are described.

INTRODUCTION

The first ever submarine cable was laid between the UK and France in 1850. This telegraph cable was the forerunner of a communication network across the English Channel which has built up over the years to the present-day figure of some 2700 telephone circuits. In recent years, growth in the network has been achieved by a radio-relay link from Tolsford Hill, in Kent. With the planning of the sixth transatlantic cable (TAT 6), which is to land in France, it was decided that the circuits to be routed to London should be extended to the UK over a new submarine cable of French design to be laid between Courseulles and Eastbourne—the *UK–France No. 1 Cable.* This 2580-circuit cable (43 supergroups in each direction) is the first of 2 new systems to land in the Eastbourne area. The second will be of British design, with the larger capacity of 3900 circuits, and is planned to be ready for service in 1979.

After the agreement between France and the UK was concluded, a suitable site, at Cuckmere Haven, was chosen for landing the No. 1 Cable. Brighton Telephone Area then became involved in the installation of the land-section between Cuckmere Haven and Eastbourne repeater station.

PLANNING THE ROUTE

Initial planning considerations favoured the use of an existing duct track, and modifying manholes and boxes to the specifications required for a high-capacity submarine cable. However, this route proved to be too long, and a shorter, completely new and more economical route had to be provided. Wayleaves were applied for from the various landowners on the line of the new duct route and, where practicable, visits were made to the wayleave grantors to assure them that the British Post Office (BPO) plant would not be generally visible after completion of the cable works. Fig. 1 shows the route of the land-section of the cable.

The requests appeared to be receiving favourable reactions, and planning was proceeding normally. The Area then had a setback when the responsible committee stated that they did not wish the BPO to go into the Seven Sisters Country Park with the cable. Many months of negotiations took place. The main basis of the committee's objection was the fear that BPO vans would be regularly in the Park while engineers were clearing faults in the system. The committee was finally convinced by the argument that existing submarine coaxial cables had a reliability better than 1 fault in 25 years, and there was no reason to suspect that this cable would be any worse.

A requirement of the system was that the cable should be laid so as to be subject to the minimum of disturbance, especially at repeater points. There were to be 2 repeaters in the land-section, one in the Country Park and the other in the middle of a field. The repeaters—the same as those used at sea—were to be buried to a depth greater than 1 m. They both required jointing points for their tails, and buried boxes were to be provided for this purpose.

At the landing point, the main physical barrier was the shingle beach, in which, to obtain a good line, the shore-end cable would have to be buried to a depth in excess of 6 m. Colleagues in Regional and Telecommunications Headquarters (THQ) recommended that a horizontal auger borer would be the most economic method of providing a deep duct track, and would cause the least disturbance. The Area prepared a specification, and this work was contracted out after trial bore holes had established the nature of the subsoil.

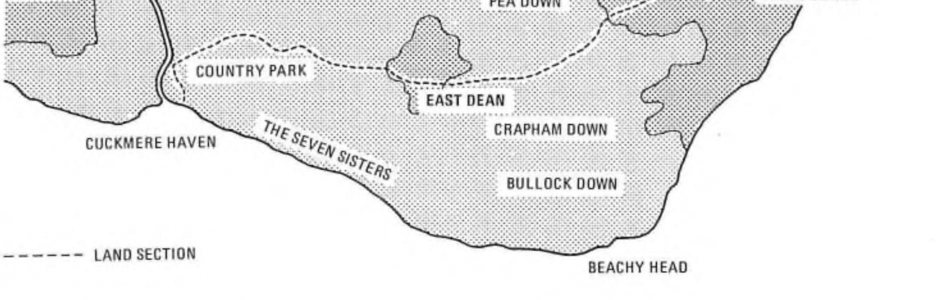


FIG. 1—Route of the land-section of the UK–France No. 1 Cable

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† Brighton Telephone Area

AUGER BORER

The auger-boring method used by the contractor required a trench to be excavated at least as long as the total length of the sections of steel lining pipe that were to be augered under the beach (30 m). At the working end of the trench, and at right angles to the line of thrust, a section of steel pipe was buried to act as an anchor with which to pull the boring machine forward by its own winch. The auger, resembling a large wood drill, 450 mm in diameter, was inserted into the sections of steel pipe, and the rear end of the pipe was fixed to the machine. By winching the boring machine towards the transverse steel pipe, and turning the auger inside the steel pipe, the pipe was made to edge forward under the shingle bank. The turning auger cleared away the spoil from inside the pipe. Once the steel liner was in position, the auger was removed and 150 mm diameter plastics ducts inserted. The voids between the ducts were filled with concrete. Fig. 2 shows the auger borer in operation. The advantage of this method was that a good duct line was obtained without damage to the shingle bank, which constitutes the sea defences for the area.

CONSTRUCTING THE ROUTE

One requirement of the wayleave for the Country Park was that the ducts should be laid during the winter months. The early part of 1975 was the wettest for several years, and this caused some difficulty with working conditions and also meant that extra care was needed to leave as good a reinstatement as possible.

Over the main section of duct track, manholes were constructed such that the UK–France No. 1 Cable would remain separate from any other cables (for example, by using opposite walls) to achieve the dedicated route required.

FIG. 2—The auger borer in operation

The auger borer met with some problems. It reached a point where it was unable to go any further forward, and the cause could not be fully resolved because it was felt the problem was not entirely due to obstructions in the shingle. The exit point for the pipe, being below the high-tide mark and at a depth of 2 m, meant that the contractor had to continue by open-cut methods, but now working between the tides. While carrying out this work, the contractor had a number of operational problems. Cranes, hired specially for the job, broke down at crucial moments, and the tide filled in the excavation, which then needed to be cleared on the next tide.

Finally, the beach duct-track was laid, encased within the steel pipe, to the beach manhole, where the armoured shore-end cable was to be jointed to the polyethylene-sheathed land-section.

With the duct work complete, an independent earth was necessary at each repeater and at the exchange. As the 2 repeaters were sited in barren spots, there were no problems with providing their earths, but the main earth for the system had to be placed in a local park, as this was the only location that satisfied the requirement of being at least 100 m from any other service. Fortunately, the wayleave for this was obtained reasonably easily and, on completion of the BPO's excavations, a local archaeological society took the opportunity to carry on digging to establish part of the route of Eastbourne's old town wall.

CABLING THE ROUTE

The cable that was delivered to the works-order stores from the French manufacturer could not be unloaded with the standard equipment, but required a special crane because of the unusual combined height of the lorry and drums. The French cable drums, each of 3 m diameter, exceeded the normal British maximum of 2·74 m, and it was soon confirmed that standard cabling equipment would not be of any use for such large drums. The assistance of the External Plant Development Division of the Operational Programming Department (OPD), THQ, was sought, and they were able to procure a 4-wheeled drum trailer that was used at the BPO's Dollis Hill Research Station. The trailer proved to be capable of handling the cable.

Installation of the cable began, and it was then found that several of the lengths were short. A check was made of the lengths planned and ordered, and the lengths marked on the drums were found to correspond with the planned lengths. It appeared that the cable lengths had been measured and cut short, probably by machine, before arrival in the Area. The cable lengths were therefore placed in duct sections different from those planned to avoid having to order more cable, and one small section of track had to be relaid. Consequently, only one length of cable needed to be replaced by the manufacturer.

The cable, being polyethylene-protected, presented difficulties at the repeater station, where it had to be housed in metal trunking to prevent the creation of a fire hazard. The internal staff carried out this work, which required some large-radius bends in the trunking to prevent the cable sustaining damage by kinking. Installing cable from the cable chamber through the building in this trunking presented quite a few problems, but these were satisfactorily resolved after some of the existing cable racking had been altered.

STRONG-POINT

Jointing of the cable was carried out by OPD staff and, while this was progressing, plans were in hand to land the shore-end of the cable. Area staff were aware that a "strong-point", consisting of 3 poles set up in a triangular formation, would be required to help land the cable. These had presented

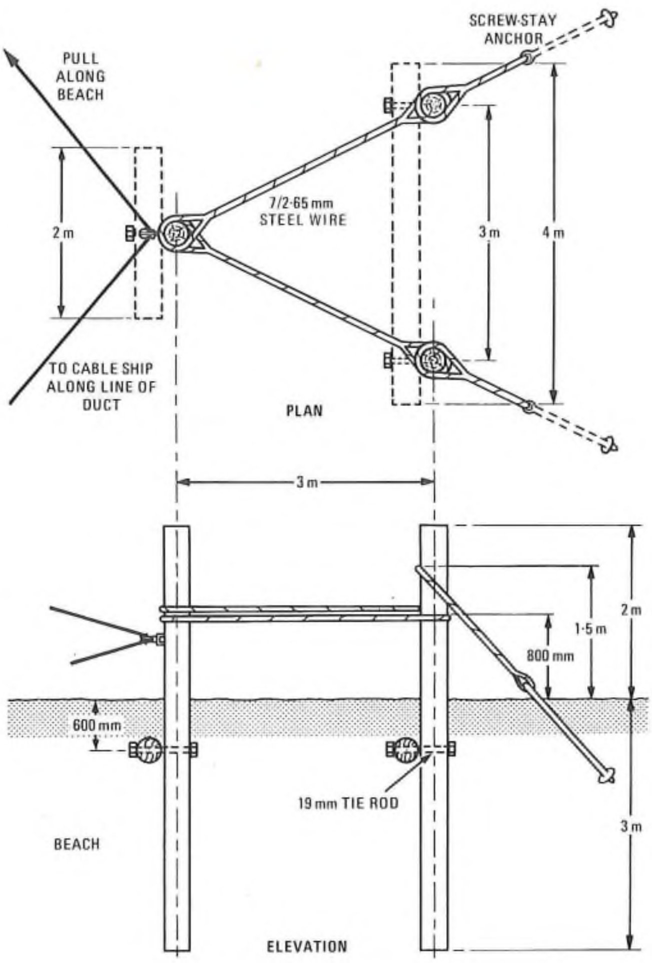

FIG. 3—The strong-point

problems in other telephone areas, and it was decided that, because of the shingle beach, detailed calculations would have to be made to ensure that all would go smoothly on the day of the landing. In shingle, it was found to be difficult to establish the materials into which the poles were to be set, and insufficient data were available to enable a reliable "first-off" theoretical design to be made. A simple test was therefore devised, using a pole-erection unit (PEU) to set up 2 poles in shingle. Water and soil were used to bind the beach and, with the aid of a dynamometer and chain-puller, readings were taken of the tension necessary to move the poles. Using this information, the Area Drawing Office was able to design a satisfactory anchorage (see Fig. 3).

To provide the strong-point, holes were drilled in the beach by the PEU, and bottomless dustbins were used to hold back the beach material. As the PEU drilled deeper, a soil-and-water mixture was placed in the dustbins to give firm sides to the holes, and the dustbins were gradually pushed flush into the beach. When the required depth was reached, the poles were placed in position and the excavated material replaced around them. The poles were braced just below the surface of the beach.

LANDING AND SECURING THE CABLE

On the day the shore-end cable was to be landed, in October 1975, 20 of the Area staff, with locally-hired divers, bulldozer and Land Rovers, were made available to the Marine Division of the Network Planning Department, THQ, who controlled the operation. The bulldozer was required to haul the cable ashore, and the 20 Area staff to protect the cable from damage by guiding it over wooden rollers and preventing it from kinking as it floated ashore from the ship. Fig. 4 shows the cable being floated ashore from the Dutch cable ship, the *D. G. Bast*, with supporting floats tied to it at regular intervals. As each float arrived at the shore, it was cut away by the Area staff until, finally, sufficient cable had been pulled ashore, leaving a line of floats still tied to the cable between the beach and the ship. The divers then swam along the cable, cutting away the remaining floats. As each float was cut away, the cable's unsupported weight caused it to sink progressively, taking the remaining floats down with it. The divers were easily able to recover these.

FIG. 4—Preparing to cut away the first float as the cable is brought ashore

(Photograph by courtesy of Frederick Wackett, Brighton)

The following day, the shingle bank was excavated to expose the exit point of the previously-laid beach duct-track. This took longer than expected, the ducts being at a considerably greater depth than expected. Added to this, the protection that had been placed over the ends of the ducts was found to be displaced and, during the excavation, the ends were damaged. This meant that it would be difficult to seal the ducts from the ingress of water and so prevent it entering the beach manhole once the cable was in position.

As the ducts were at a depth greater than expected, less time was available between tides to feed-in the cable, but this operation was successfully completed at the third attempt.

The next problem was how to seal the beach manhole. A major operation would be required to expose completely and remake the damaged exit point under the shingle bank. It was therefore decided to seal the ducts at the manhole, complete the jointing, and then carry out remedial work in the future if this became necessary.

A temporary seal was provided using a jack and wooden bungs. This was successful but, because the jack straddled the manhole, it prevented jointing being carried out. The final solution was to provide a steel plate across the wooden bungs, and bolt it to the manhole wall. Jointing then proceeded satisfactorily.

INSTALLING THE REPEATERS

Brighton Area's final task was to install the 2 repeaters in the land-section. The repeaters, being comparatively delicate, were transported in elaborate and heavy timber frames which required a crane to handle them. A crane was also needed to lower the repeaters into the previously-excavated holes. The sides of the holes were supported by jacks, and these had to be removed and replaced in a set sequence to maintain the safety of staff as the repeaters were lowered.

The repeater tails were extended into the buried boxes and the jointing carried out. Tests were made from the beach manhole and, with these successfully completed, the repeater pits and ancillary boxes were covered with soil and the surface reinstated. Local assistance was given to the OPD jointers in such tasks as fixing the cable anchors. The necessary high-precision jointing of the coaxial cable, with high-voltage testing and X-ray examination, took on average about 4 d per joint.

CONCLUSION

The completion of the beach joint, between the land-section and the shore-end cable, brought to a close this phase of the operation and the involvement of Brighton Telephone Area staff in the project. Similar tasks have been undertaken by the French telephone administration between Graye-sur-Mer and Courseulles, and terminal equipment has been installed at Eastbourne and Courseulles. The sea cable was laid in May 1976 by the French cable ship *Vercors*. The system was ready for testing at the end of June and was brought into service in September.

Local-Network Line-Plant Statistics for the United Kingdom

UDC 621.395.743 : 311.3

On page 180 of this issue of the *Journal*, a new computerized method of measuring local-network pair availability and utilization is described. Information from the 31 March 1976 pair count by this method is summarized in Table 1.

The British Post Office has measured its local networks continuously since the introduction in 1946 of flexibility cabinets and pillars, now termed *primary cross-connexion points* (PCPs) and *secondary cross-connexion points* (SCPs). The trends of data, which are available for the last 20 years, are indicated in Fig. 1.

It can be seen that the number of pairs at distribution points (DPs) considerably exceeds the number of households. This is because a number of these pairs serve business premises, which require many lines. Nevertheless, even when allowances are made for this, the number of DP pairs is approaching one per household and should reach this figure in the early-1980s.

The pair utilization in the local main network of 67% is significantly higher than in the distribution network at 57%, and this is the justification for the provision of PCPs. The average length of the less-efficiently-used distribution part of the network is only about a quarter of the whole.

The new computer measuring system also records the extent to which pairs are used twice over by shared service. Currently, about 0·9 million, or 4%, of main-distribution-frame (MDF) pairs and 0·7 million, or 3%, of DP pairs are shared. These numbers are considerably less than half the number of shared exchange lines existing, indicating that about 9% of shared connexions have exclusive pairs. It can be deduced that about 7% of MDF pairs in the local network are used for purposes other than exchange service.

The apparent decline in the rate at which MDF pairs were brought into use in 1975–76 is, in part, due to errors revealed by the computer system. On the old records, there was a tendency not to update the PCP record when service on a pair ceased. In the new system, local main pair utilization is deduced from DP records which are more up to date.

H. J. C. S.

TABLE 1

Local-Network Line-Plant Statistics

Item of Line Plant	Total (Thousands)	Percentage in Use
MDF Pairs	20 600	67
Flexible Main Pairs	17 300	68
Direct Main Pairs	3 300	61
Branch Pairs	1 960	69
Distribution Pairs	21 400	56
Total DP Pairs	24 700	57
Exchange MDFs	6	—
PCPs	59	—
SCPs	24	—
DPs	2 030	—

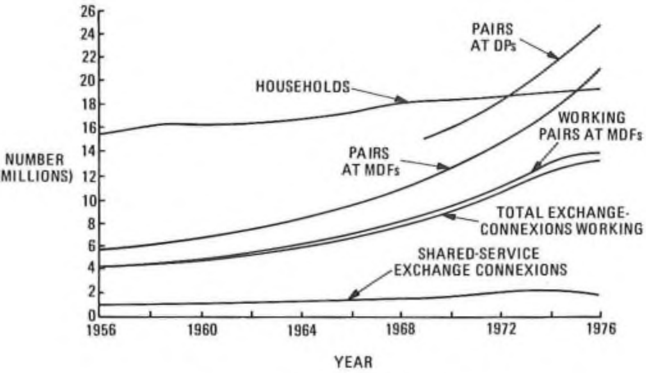

FIG. 1—Local-network data trends

A New Maintenance Aid for International Exchanges

N. V. WEST, B.SC.(ENG.), and D. J. SYLVESTER, DIP.E.E.†

UDC 621.395.3: 621-7

The development of accounting equipment for automatic international telephony has led to very sophisticated exchange and circuit monitors. This article describes the history and development of International Accounting and Traffic Analysis Equipments (IATAEs), how these have been turned to the engineers' advantage, and how the latest generation of IATAEs can be used as very powerful maintenance aids.

INTRODUCTON

Until 1963, all international telephone calls were made with the assistance of a telephone operator, who set up and timed calls, recording appropriate information on dockets for accounting purposes. However, when international subscriber dialling (ISD) was introduced, an automatic method of accounting became essential, though operators and dockets were retained for those countries without ISD facilities, and for subscribers who required assistance. To perform the accounting function, the accounting machine needed direct access to the parts of the international exchange providing the same information as that required by an operator.

The International Telegraph and Telephone Consultative Committee (CCITT) recommendations[1] require the international accounts to be calculated from the call-duration times within an accuracy of 2%. The basic information required from the exchange by the accounting machine is

(*a*) when the circuit was answered,
(*b*) when the circuit was cleared,
(*c*) where the call came from, and
(*d*) where the call went to.

The CCITT also recommends that automatic means of traffic recording should be used. This could be combined with the accounting function into one machine if, as well as the basic information, the following were included:

(*a*) when the circuit was seized, and
(*b*) when the circuit is busy for maintenance.

An International Accounting and Traffic Analysis Equipment (IATAE) was designed and built by BTR Ltd., now Plessey Telecommunications Ltd. (PTL), for the first British Post Office (BPO) automatic international exchange at Faraday building. Experience with this equipment showed that valuable information on the engineering performance of the exchange could be deduced from its output and, hence, the next IATAE (for the BPO Wood Street international exchange) incorporated engineering-performance statistics. Included in these statistics was a new concept, that of *norm* tests. These tests, described later, compared the measured performance of the exchange with the average value expected in practice; deviation from the expected performance resulted in a printed output indicating areas of possible fault conditions.

When the next international switching centre (ISC) was proposed, it was decided that its IATAE would provide even more engineering-performance statistics, and a very powerful and sophisticated system was proposed. This IATAE was eventually installed in the De Havilland international exchange, and a second similar system is being produced for Mondial House.

This article covers briefly the history of these IATAEs and their development, shows how they have evolved into a very valuable and powerful maintenance aid and how they can be used to the best advantage, and gives considerations for future IATAEs.

FARADAY IATAE

Faraday ISC was the first British international exchange to be provided with ISD facilities; it was also the first to be provided with an IATAE and this is still operational.

This IATAE used the latest technology available in the late-1950s/early-1960s: discrete transistorized logic for the control function, magnetic drums as the storage medium, and reed relays in the interface which is essential to convert signals from the Strowger exchange into a form that the IATAE can handle (see Fig. 1). It takes information in the

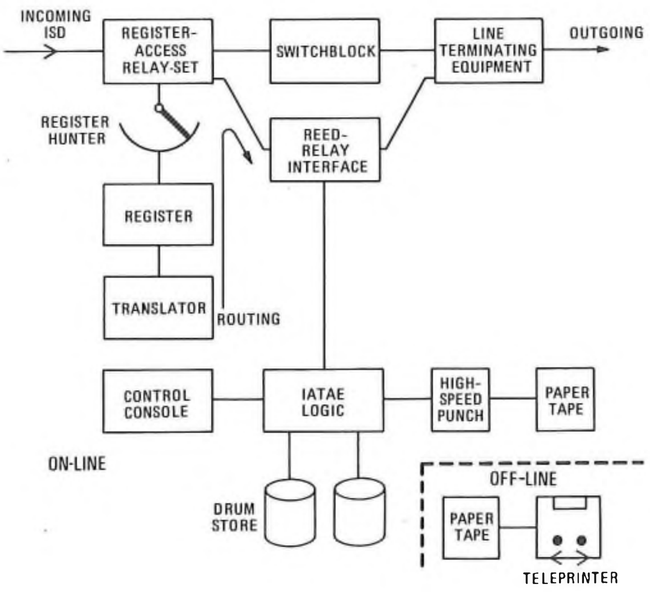

FIG. 1—Block diagram of Faraday IATAE

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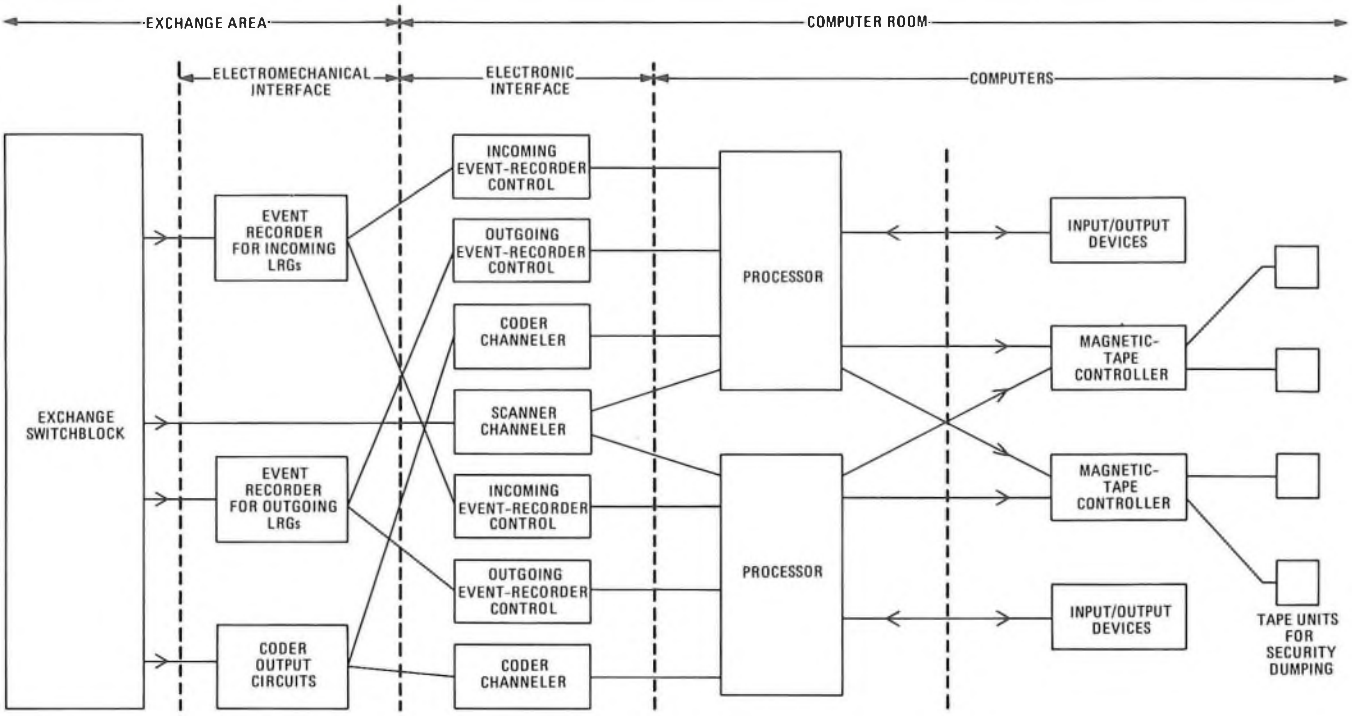
† Telecommunications Development Department, Telecommunications Headquarters



LRG—Line relay-group

FIG. 2—Block diagram of Wood Street IATAE

form of *events* from approximately 1000 incoming and 1000 outgoing line terminating equipments, an event being a *seizure*, *answer* or *clear* signal. Routing information, in digital form, relating to each call is passed via the register-access relay-sets to the IATAE, where it is stored together with the events associated with those calls. These data are processed to produce 3 types of output: route destination performance, destination performance, and circuit performance; associated histograms are also available. These outputs are on punched paper-tape for page printing on the off-line teleprinter, and can be selected to be output automatically or on demand by hardware switches on the control console.

This system has 2 drawbacks:

(*a*) lack of security,† which means that accounts must be estimated for periods of system failure, and
(*b*) lack of engineering-performance statistics.

Although little can now reasonably be done about the system security, improvements could, however, be made in the area of engineering-performance statistics. These can be obtained by rerouting the relevant output directly into a small computer, either local or remote, for processing into the required form.

WOOD STREET IATAE

When the second ISC at Wood Street[2] was proposed, its IATAE was to be an improvement over that of Faraday. This was simplified by the use of the PTL 5005T common-control crossbar switchblock for the exchange. Accordingly, it was decided to use a computer for the IATAE, instead of a purpose-built machine, providing a more flexible system (Fig. 2). Engineering-performance statistics, including *norm* tests, were to be added and the security improved by having a complete stand-by system.

However, in the event, the system (designed around two PTL XL9 military-standard computers) was split into 2 software complexes: in general, complex 1 handles the incoming side of the exchange and complex 2 the outgoing. Thus, complex 1 handles the important accounting function because, although only outgoing international calls need to be accounted, information relating to these calls can be obtained only from the incoming side of the exchange. Complex 2 produces the engineering-performance and traffic-analysis statistics. The system is arranged so that, if complex 1 fails, complex 2 is shut down and complex 1 loaded into the surviving computer to maintain continuity in accounting. Engineering-performance and traffic-analysis statistics are, therefore, lost under these conditions. Today, it is debatable which is the more important, accounting or performance monitoring; while accounts can be estimated, degradation of performance may pass undetected, and result in operational difficulties and lost revenue.

The capacity of this IATAE, commissioned in 1971, is much greater than that of Faraday, serving a switchblock of approximately 4500 incoming and 4500 outgoing circuits. However, only 4000 incoming and 2500 outgoing circuits are fully monitored for *seizure*, *answer* and *clear* signals, limited monitoring of only *seizure* and *clear* signals being possible on a further 1000 circuits.

A limitation with this system is its inability to recognize when an item of equipment has been deliberately busied for maintenance to prevent its use for public traffic; hence, circuits in this condition must be kept to a minimum. The system can also monitor up to 1336 common equipment points for *seizure* and *clear* conditions, thereby giving some of the information required for more detailed engineering-performance reports.

Output from the system is available in 3 forms: teleprinter, punched paper-tape and magnetic tape, either produced automatically or as the result of requests input from an on-line teleprinter. The on-line teleprinters are also used to output system messages and *norm-fail* messages, the paper-tape punch is used to output requested file information (the off-line teleprinter being used to produce the printed page), and magnetic tape is used for accounting and traffic information.

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† Security: all methods used to minimize the loss of data by computers or related systems

FIG. 3—De Havilland IATAE

The magnetic tapes are processed to produce printed output by the BPO Data Processing Service (DPS). There are about 20 different types of output available, including those produced off-line, but most require reference tables to interpret their meaning adequately. Some of the reference tables are used by the DPS during the off-line processing and this introduces an updating problem; others are manual tables for the use of IATAE staff. Although better than Faraday's, this system is a long way from the ideal. For instance, it cannot monitor all circuits, though proposals are being considered to rectify this. At 10 characters/s, some outputs take hours, and post processing, remote from the site, is also very time consuming. Worst of all, the system can be stopped from any on-line teleprinter. Therefore, strict operational discipline is mandatory.

MOLLISON

The Mollison international telephone services centre (ITSC) at Stag Lane[3] uses a proprietary switch-block and accounting machine, the system being opened to live traffic in 1974. Although the accounting machine is computerized, it provides the barest minimum of accounting information, recording total call-duration times to each route destination only, the numbers of seizures being estimated. This accounting machine is not an IATAE, and has been included solely to emphasize that Mollison ISC does not have an IATAE.

THE DE HAVILLAND IATAE

The latest IATAE forms part of the new De Havilland ITSC opened for public service in 1975 (Fig. 3). This IATAE is also connected to a PTL 5005T crossbar exchange. PTL developed the system using a commercially-available computer, a DEC System 10, wrote the software needed to perform the function, and also designed a special interface to connect the computer to the ISC.

The IATAE was designed for a capacity of 10 000 incoming and 10 000 outgoing trunk circuits, together with appropriate quantities of common equipment. A 2-stage interface is used to convert high-level (50 V) slow-speed signals from the ISC to low-level (5 V) high-speed signals suitable for input to the computer. The first stage (exchange interface), in the ISC near to the trunk circuits, concentrates signals from 1000 circuits into a 10-wire highway to the second stage of the interface; similarly, the routing information is assembled by encoders ready for the computer to read. The second stage (control interface), in the computer room, takes the 5 V outputs of the first stage and further concentrates a number of these 10-wire highways into the input/output highway of the computer. The interface equipment is duplicated for reliability which, in turn, enables certain cross checks to be made. The exchange interface is constructed in modified T 10 000 equipment practice mounted in a standard crossbar rack, and is powered by the −50 V exchange battery. The control interface is built in a standard proprietary equipment practice and powered by the 240 V a.c. mains.

The central computer configuration (Fig. 4) consists of an on-line and off-line system. The on-line system, which performs most of the necessary tasks, consists of one central processing unit, 112 kilowords of core memory, 2 disc storage systems[4], a line printer, teleprinters and other slow-speed peripheral devices. All of these are standard proprietary equipment, the only exception being the input/output bus switches which were specially built for this system by DEC UK. The off-line system consists of one central processing unit, 48 kilowords of core store, 4 magnetic tape units, a line printer and a teletypewriter. It performs several functions: the major function is to act as stand-by to the on-line system; another is to process magnetic tapes from the De Havilland IATAE accounting programme.

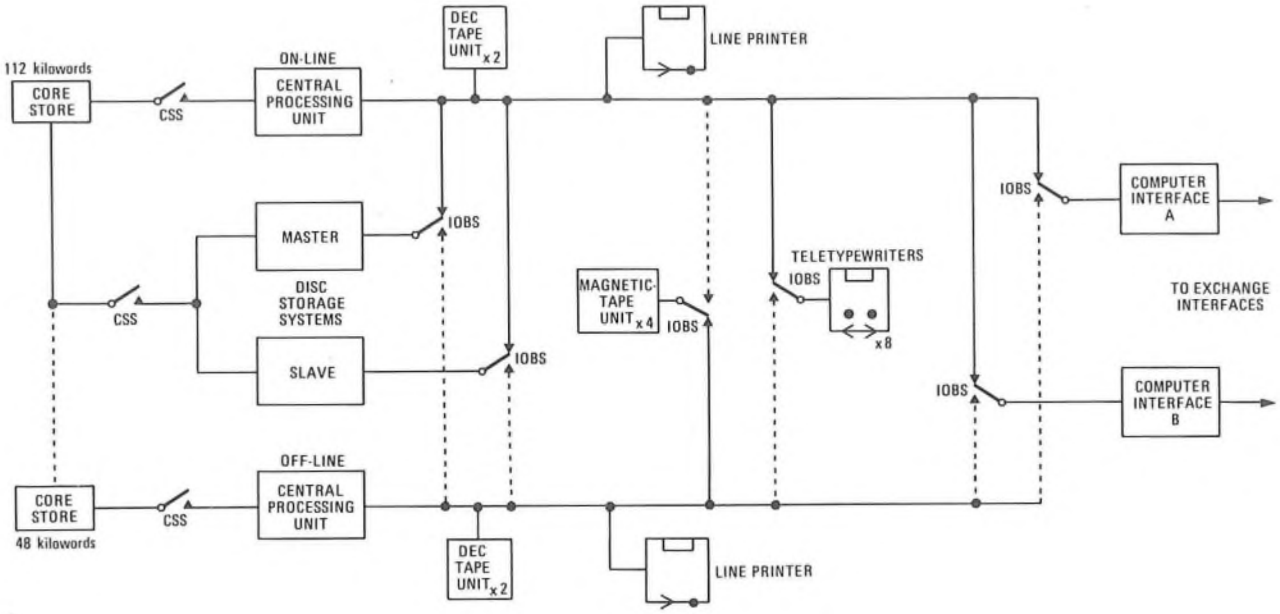
The IATAE takes information from the ISC through a number of paths. Each incoming and outgoing circuit, and each item of common equipment, is connected via concentrators and scanned by the computer at various rates. Information gathered from the trunk circuits is *seizure*, *clear*, *answer* and *busy for maintenance*, and from the common equipment *seizure* and *clear*. To determine the destination and outgoing route of the call, further routing information is collected from the incoming coders (Fig. 5).

The central computer system consumes less than 60 kW from the 415 V, 3-phase 50 Hz public mains supply. To keep the IATAE functioning during periods of power disturbances, a static-inverter type of no-break power supply is used. Air conditioning for the computer uses chilled water provided by the central chilling plant used for the ISC and international repeater station.

As the BPO preferred language, Coral 66, was not available on this machine, all the software programmes were written in the computer's assembler language, MACRO-10. The software is composed of 2 major areas:

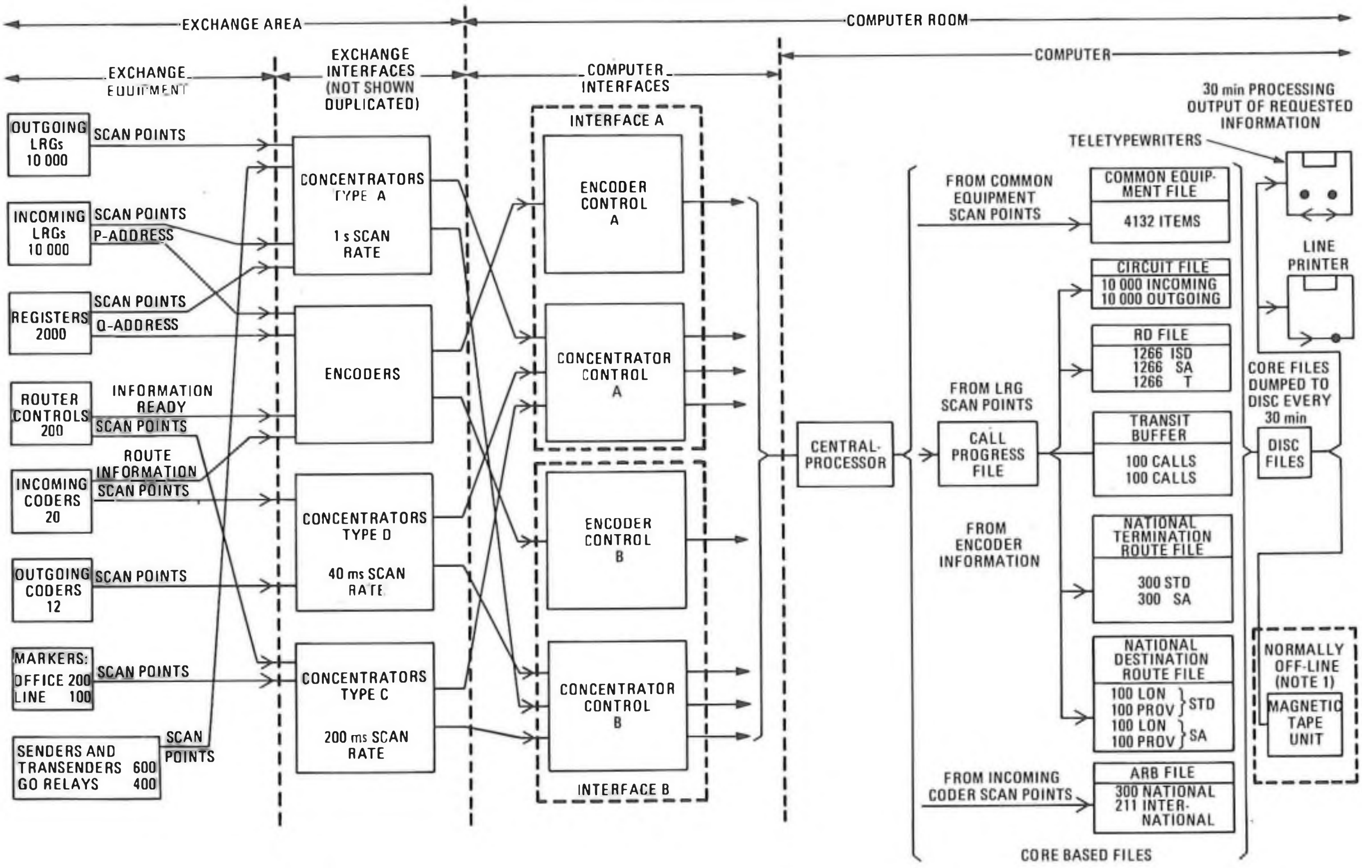
(*a*) supervisor, and
(*b*) application programmes.

The supervisor is the software that schedules running of the application programmes, together with optimizing the use of the system hardware to maximize system throughput.



CSS—core-selection switch
IOBS—input/output bus switch

FIG. 4—Hardware configuration of De Havilland IATAE



LRG—line relay-group
SA—semi-automatic
ARB—all routes busy
T—transit

Note 1: Disc files are dumped to magnetic tape every midnight, on-line; the tape is processed, off-line, at the month's end

FIG. 5—Information flow in De Havilland IATAE

It consists of a number of programme modules which perform the following major functions:

(*a*) priority interrupt handling,
(*b*) device input/output,
(*c*) job scheduling,
(*d*) multiprogramming,
(*e*) overlay programming,
(*f*) teletypewriter command handling,
(*g*) debugging,
(*h*) general support; for example, error logging,
(*i*) central processor unit switch-over and recovery,
(*j*) scanning (of the ISC) and plotting, and
(*k*) spooling and formatting output.

The supervisor is core resident and generally constructed to minimize its own running time, especially for time-critical input/output.

The application programmes are those that fulfill the particular IATAE functions. A predefined sequence of events takes place every half hour, as defined by a timing programme in the supervisor. A suite of programmes is activated which takes the basic data collected from the ISC, performs validation and confidence checks and further processes them, in response to requests or *norm* failures for output at the required locations. A comprehensive operator communication language enables users to give instructions to the IATAE.

One of the more onerous design parameters was that of system reliability. The specification required not more than 8 system stoppages/month and/or a total data lost time of not more than 4 h/month, with a confidence level of 95% in each case. To achieve these figures, additional hardware was provided to enable items to be manually exchanged when they fail. Certain items can fail and not cause a system stoppage, the system recovering automatically. However, hardware failures are not the only problem. Another major cause of system stoppages is software errors; an external device, regularly reset by the software, generates an alarm if this is not done. This device is powered by the exchange 50 V battery so that, in the unlikely case of complete mains-supply failure, an alarm can still be given.

The facilities offered by this IATAE evolved from the previous 2 units. There are nearly 200 different basic types of output available, most of which can have several variants. Information is provided for the following functions.

(*a*) *Accounting* The accounting facility provides monthly data on the number and duration of calls to each route destination served by the ISC. The output is sub-divided into European, Extra-European and Commonwealth countries, and also into ISD and semi-automatic traffic. Transit traffic is recorded, though only one charging rate is defined, compared with a maximum of 3 rates for other types of traffic.

(*b*) *Traffic Statistics* Traffic statistics are gathered from each circuit and each item of common equipment for use by planning departments. This information, recorded on an hourly basis, is available only if requested by a user and is output on the line printer.

(*c*) *Engineering Performance* Engineering performance, including the use of *norm* tests, is discussed in detail below.

ENGINEERING PERFORMANCE

To enable faults to be located quickly, ISC maintenance staff must have easy access to relevant up-to-date information in a readily understandable form. Information of 2 types is required: the condition of the exchange (mainly the common equipment) and the condition of each circuit.

The IATAE scans all the incoming and outgoing circuits every second, most common equipment items at 200 ms intervals, and coders at 40 ms intervals. Information gathered from the circuits is recorded in a circuit file, which then contains the number of seizures, the holding time (time between seizure and clear), the duration (time between answer and clear) and, for outgoing circuits only, the busied-for-maintenance time. These data are accumulated for each circuit for each half hour and, after a predetermined time, the information is overwritten. Similarly, for common equipment, the number of seizures and the total holding time per item is accumulated on a half-hourly basis. Engineering-route information is also provided, a route being a collection of circuits useful to aid maintenance. Each route can have a maximum of 70 circuits and the system can be used to obtain information about small groups of circuits. Other files are created as shown in Fig. 5.

Information is output only if it has been specifically requested. Information is stored on a rapid-access device (a magnetic disc), which is overwritten every half hour; thus, if data are not requested, they are lost (unlike accounting data, which are accumulated over a 1-month period). Each user has access to a teletypewriter for input of requests to the system and the reception of limited amounts of output. The user can request up to 47 half-hour periods of information in advance of the current period, and one previous to the current period. As the teletypewriters are slow-speed devices, the quantity of output is limited and each request is carefully checked to see if time is available on the teletypewriter for output. If a larger amount of data is required, the user can request it to be output on the line printer in the computer room. To ease the system operation, each of the 8 teletypewriters is located near to its prime user. Some are in central London (about 16 km from the ISC) in the international switching co-ordination centre (ISCC), some are in the international transmission maintenance centre (ITMC), and others are in the international switching maintenance centre (ISMC) in De Havilland ITSC. An example of part of an engineering-route print-out is given in Fig. 6.

Norm Tests

A major part of any on-line fault-location aid is some form of automatic performance monitoring and exception reporting, so that any degradation in service can be rapidly brought to the attention of the appropriate maintenance staff. *Norm* tests provide this facility.

Norm tests compare the performance of individual items of equipment or circuits with the mean of a group of similar items or circuits. If the ISC is working as designed, the average holding times and the distribution of seizures of items of common equipment should fall within narrow bands. A *norm* test, comparing the difference between the average holding time of one individual item and that of a group of similar items, is undertaken. The difference is compared with a preset figure and a *norm* failure may occur. Similar tests are made for seizure distribution (Fig. 7). *Norm* failures do not necessarily indicate fault conditions, as peculiarities in holding times can be caused by abnormal traffic. Circuit *norm* tests are based on the measurement of traffic flow on each circuit. If, during predefined busy periods of the day, no activity is recorded on a circuit for a number of consecutive half-hour periods, something may be wrong with the circuit. Also, if there are a large number of seizures on that circuit during a half-hour period (that is, the average holding time is low), the circuit is probably faulty.

A *norm* test is performed on each engineering route to detect a rise in the number of ineffective calls; that is, calls not answered, either because the called party fails to respond, the equipment is faulty, or the network is congested. Congestion is more likely at particular times that depend upon the route being considered. For example, the peak traffic period for the North American route is 15.00–18.00 hours and, for the Far-Eastern routes, it is 07.00–10.30 hours and 20.00–24.00 hours. During these busy periods, the ratio of effective-

```
SERIAL NO 076    2-DEC-75    1202    SHEET NO 1
ENGINEERING RECORDS FOR STAG LANE DE HAVILLAND UNIT
CIRCUIT PERFORMANCE     I/C LRG'S

REQUEST PERIOD  1130-1200
REFERENCE PERIOD  1130-1200

                                                                    HALF
CIRCUIT     IDENTITY                          HOLD     AV HT IDLE NORM  HOURS       ?
ENGROOT     CCT  LRGNO      SEIZ     EFF      TIME      /SEIZ  CATEGORY  IDLE    INHIBITED

ATHC        135  10626        11       1        13       1·18      7        0        NO
ATHC        127  10636         6       1        14       2·33      7        1        NO
ATHC        131  10676         3       1         7       2·33      7        0        NO
ATHC        125  10836         3       1        14       4·66      4        0        YES
ATHC        133  10846         5       4         7       1·40      4        0        YES
END OF OUTPUT
```

I/C LRG'S—incoming line relay-groups
ENGROOT—engineering route
EFF—effective
AV HT—average holding time

Fig. 6—Example of part of engineering-route print-out

```
22-OCT-75   1306

L/ISC/SD                       ROUTER CONTROLS              NORM FAILURES 1230-1300

NORM                                 9        15                        9                 15

I/C      SX      HTX    AVHTX      DS%    S2X    S2%      SY    HTY     AVHTY   DS%    S2Y    S2%
RTR              MIN    SEC                                     MIN     SEC

3        23      0·44   1·16      −9←     0      0        20    0·34    1·04    +4      0      0
4        31      0·55   1·07      −6      0      0        36    0·77    1·28    +9←     2      5
5        49      1·17   1·43      −3      2      4        54    1·12    1·24    +5     10     18←

END OF OUTPUT

22-OCT-75   1334

L/ISC/SD                               I/C CODERS       NORM FAILURES 1300-1330

NORM                                                                          34

NO     SX    HTX     AVHTX                               SY    HTY    AVHTY   DS%
             MIN     SEC                                       MIN    SEC

1      378   0·95    0·152                              113    0·26   0·140
2      293   0·70    0·143                                0    0·00   0       −71
```

I/C RTR—incoming router
SX, SY—seizures on X and Y paths respectively
HTX, HTY—holding times on X and Y paths respectively
AVHTX, AVHTY—average holding times on X and Y paths respectively
DS%—deviation of seizures (%)
S2X, S2Y—second-attempt seizures on X and Y paths respectively
S2%—deviation of second-attempt seizures (%)
Arrows indicate for each router control which test has failed (*norm* value equalled or exceeded)
Failed coder group (4 coders) has calculated deviation displayed (−71%)

Fig. 7—Examples of *norm* failure outputs

to-ineffective calls varies, depending on the traffic level. Hence, for each 2 h period, a different *norm* value is set for each route, or group of routes, as defined by a *norm* category table. An effective-to-ineffective calls ratio below the set value indicates either failures in the routes or abnormally high traffic. *Norm* tests can be inhibited to prevent unnecessary print-out if, for example, abnormal conditions prevail for any length of time.

Information from *norm* tests should be received by only those staff who need it, and 3 teletypewriters are provided exclusively for the output of *norm* test failures. Circuit *norm* failures are output at the ITMC, engineering-route-performance *norm* failures at the ISCC, and common-equipment *norm* failures at the ISMC and ISCC. *Norm* tests are performed on the half hour on the previous half-hour's data; therefore, the information must be output immediately if it is to be of any use to the maintenance staff. Hence, if any of the teletypewriters fail, output is automatically diverted to the line printer in the computer room to avoid the loss of this information and the operator is informed. The computer operators can then inform the appropriate staff.

FILES

One of the largest operational aspects of the system is the upkeep of the files and tables stored within the computer. De Havilland ISC is large, and records must be kept of every circuit, every route, every route destination and every item of common equipment. As the network is dynamic, many parameters have to be changed in line with the changing network and these have to be correctly recorded in the IATAE's files. Incorrect circuit or route information output is no use to the maintenance staff and may even be misleading; this is equally true for accounting and traffic data.

A conversational language was developed to permit only the operator to input commands to change the data. With this language, checks are made on the input and the value to be changed is repeated to the operator, enabling him to ensure that the correct item has been changed. The language leads the operator through a sequence of dialogue to avoid the need to remember the sometimes complicated interaction of the file data. Certain parameters can only be changed at specific times, though the amendments can be typed into the system at any time. Only the control teletypewriter (or its stand-by) can be used for parameter amendment. The ISC and the IATAE record duties must co-operate closely to ensure that all ISC file changes are recorded on the IATAE. Also, since operational commands can be input only from the control teletypewriters, the operational security is improved.

IMPORTANCE OF ENGINEERING STATISTICS

All of the present IATAEs have been one-off developments and, as such, are relatively expensive. Although they are maintenance aids, they themselves need to be maintained and, because of the advanced technology used, IATAE staff must learn a new discipline; hence, the maintenance costs are high. However, IATAEs are justified because international circuits have high revenue-earning capacity, and are also heavily loaded (average occupancy 0·7 erlang); thus, any reduction in the out-of-service time increases the potential earning capability of the ISC. When Faraday and Wood Street were first installed, the BPO had a severe shortage of external line plant such that any circuit out of service inevitably increased the route congestion. Without an IATAE, various alarms can be used to detect the rise in the ineffective call ratio on certain common equipment groups; other test equipment can then be coupled and the fault identified. Certain conditions can be detected on meters, which, in large exchanges, may take several man-hours of effort to read plus clerical effort to manipulate before being interpreted by the maintenance staff. Thus, with an automatic fault-reporting system, savings in time can be considerable.

FURTHER POSSIBILITIES

One of the facilities inherent in such large computer systems is the ability to produce vast amounts of paper output. This can create the following management problems.

(*a*) Computer stationery is expensive and a lot of the output is needlessly generated; for example, several users may request the same information, or a large range of output may be requested due to uncertain requirements. Furthermore, much of this information is for immediate use and is soon discarded. So the first problem is to reduce the amount of output.

(*b*) Some requests generate a lot of output and this must be read to extract trends. Thus, the second problem is to provide a form of presentation (for example, graphically) that could reduce the output and assist understanding.

The introduction of visual display units (VDUs)[5] would solve the first problem, but hard-copy output must be retained for certain applications. The VDU would enable large blocks of information to be displayed without generating any paper whatsoever. Having determined the precise requirement, it can then be requested as hard-copy output. Terminals are now commercially available that provide all 3 facilities: screen, keyboard and printer.

The second problem could be solved by interfacing a graph-plotting unit to the system and providing the necessary software. The user would then be able to request, for example, the daily traffic pattern to a particular route destination and have this output as a graph. An even cheaper solution would be to provide software enabling histograms to be displayed on the VDUs, or be output as hard copy on the existing line printer.

The outputs of the IATAEs at Faraday and Wood Street could be processed by the De Havilland IATAE, to provide a more comprehensive range of analytical and statistical outputs. The physical transportation of the data (paper tape from Faraday, magnetic tape from Wood Street) is cumbersome; an improved method would be to use a data link, with magnetic tape readers at the remote station feeding the data into the link, the results being distributed to remote printers. A further stage of sophistication could be to use the Faraday and Wood Street IATAEs as data concentrators, feeding on-line data to the De Havilland IATAE via a link.

The De Havilland crossbar switchblock is provided with an equipment monitor, which prints out, albeit slowly, all the pertinent details associated with failed calls. This has to be analysed by the engineering staff (a none too easy task in view of the format) to determine, if possible, the cause of call failure. This analysis could be performed more easily by the De Havilland off-line computer system. If the results of the IATAE's *norm* tests were included in this analysis, it should be possible to determine faults, or fault trends, from seemingly unconnected events which would otherwise go undetected. This could reduce the quantity of output, while improving its effectiveness.

One very obvious job for the IATAE would be to combine the outputs from all the IATAEs and Mollinson, to produce accounting information for all UK ISD calls on a monthly basis. This is only a small sample of the uses that could be made of the present system.

FUTURE SYSTEMS

As exchanges progress from Strowger to crossbar, electronic (TXE) and then full stored-programme control (SPC) by computer, the function and form of the IATAE will change. When the exchange is controlled by a number of central processing systems, whether they be wired logic or computers, there is great scope and need for more comprehensive performance monitoring. In many such systems, the central control has an intimate knowledge of the condition of the switchblock. Inherently, this information refers to the state of items of common equipment and the outputs from the exchange. This is precisely the information required for performance monitoring (and, for international exchanges, for the accounting information). To include performance monitoring on a TXE type exchange, additional logic circuits would be needed, so that the basic data could be obtained from store and output in a form suitable for computer processing. With an SPC exchange, controlled by computer-type equipment, only additional programmes are needed, plus some extra storage and output devices; if many facilities are required, additional processing power may also be needed. No extra interface equipment is necessary as it is already provided as part of the exchange. With SPC exchanges, all functions, such as routining and fault location, could be controlled from the central computer. As switching networks become more complex, and especially when digital switches are introduced, it will become increasingly more difficult to trace faults physically; hence, the need for performance information is even greater, but the use of central control simplifies the task of gathering it.

At present, maintenance techniques used on switching systems are of the *locate, repair part, and replace* method. However, with the advent of integrated-circuit-logic techniques, the maintenance method may become *locate to a board, throw away, and replace with new board.* This, therefore, places emphasis on rapid location of the fault to a board. The techniques used to do this will be automated as far as possible and should be designed into the system, the faulty board either being scrapped or sent to a specialist centralized repair centre.

In the inland telecommunications network, several centralized maintenance schemes have been tried, or are proposed. The original scheme, which is still operational, was the Computer-Aided Maintenance Project[6] in the Leicester Telephone Area. A number of exchanges are connected to a central computer where faults, recorded by the local exchange call-failure detection equipment, are analysed, enabling faults in the network to be pinpointed. This principle of network surveillance was extended and is now being developed for the London sector switching centres (SSCs)[7]. Each SSC will be connected via a local computer to a central computer, which collates and analyses the fault reports. In a new nationwide project to set up measurement and analysis centres, outputs will be taken from virtually every exchange in the country, and used to detect performance degradation of the whole network.

At present, within the IATAE, information is available which enables useful analysis to be undertaken to predict performance degradation. For example, if suitable programmes were written, the engineering-route and route-destination performance could be used to detect trends in the effective call ratio. This could be used to predict the impending congestion of any particular route or destination, so that other testing aids could be used to identify any fault. The signalling system CCITT No. 6[8,9] uses digital signals removed from the speech channel and concentrated into a signal channel. Use of the ability to transfer supervisory and information signals between exchanges without setting up a speech path will enable the prediction of faults to be extended.

CONCLUSION

There are undoubtedly alternative methods of preparing accounting data and, particularly if international accounting procedures are simplified, this function alone cannot justify the use of such complex equipment as the IATAEs. However, experience from Faraday, Wood Street, Mollison (from its lack of performance-monitoring information) and to a limited extent De Havilland, shows the value of such aids to the maintenance engineer. With a rapidly increasing switching capacity, but stable size of work-force, the maintenance staff must be given more aids to speed up fault finding. The new types of exchange equipment are inherently less fault prone than those of the previous generation and, hence, should require less maintenance. However, these exchanges are generally more complex than their predecessors and require more sophisticated techniques to locate faults.

The present IATAE systems are far from perfect and, over the next few years, many modifications may be deemed necessary in the light of operational experience and revised requirements. Immediate benefits could accrue if the output from the equipment monitor on the PTL 5005T exchange could be correlated via the *norm* test results from the IATAE. If the 2 sets of information are merged, there is a greatly increased probability of correctly identifying the faulty equipment; each individual fault report may itself be inconclusive.

Feedback from the existing exchanges with IATAEs will enable the new systems (for example, System X) to be designed to give the maintenance engineer the most powerful fault-finding aids possible.

ACKNOWLEDGEMENTS

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Book Review

John Logie Baird: 50 Years of Television. M. Exwood, C.ENG., F.I.E.R.E. Institution of Electronic and Radio Engineers. 32 pp. 7 ills. £1·25.

This interesting monograph is published by the Institution of Electronic and Radio Engineers to mark the fiftieth anniversary of Baird's first public demonstration of television. On 26 January 1926, in his attic workshop in Soho, Baird demonstrated, to a group of members of the Royal Institution, live moving pictures using a standard of 30 lines with 5 pictures/s; crude, but nevertheless, real television. This event can justifiably be claimed to mark the beginnings of practical television, although more than 4 years elasped before the first experimental broadcasting of vision (on slightly improved standards), with accompanying sound, took place in the UK.

Mr. Exwood's monograph concentrates on the period between the first demonstration and the start of the experimental broadcasts, and deals mainly with the problems encountered by Baird and his associates in getting the broadcasts started, rather than with the technical issues. Baird was a fertile inventor, too full of new ideas to develop them properly, but he and his business associate, Capt. Hutchinson, were also entrepreneurs, keen to make money from the inventions as quickly as possible. This led to much controversy, particularly with the BBC and the British Post Office (BPO), and it is on this aspect of Baird's career that the monograph is particularly enlightening. It is interesting to note that the official BPO records, to which Mr. Exwood had access, show that the BPO took an extremely far-sighted view of the future of television, and showed remarkable tolerance in dealing with exaggerated claims, manoeuverings and outright obstruction from Baird and his associates.

The monograph makes interesting reading and can be thoroughly recommended to anyone interested in the history of television. It is not intended to be a complete biography of Baird, but it throws new light on an important period of his career which helps to explain why his reputation as an inventor became tarnished by controversy and bitterness.

I. F. M.

Regional Notes

NORTH WEST TELECOMMUNICATIONS BOARD

Electronic Analyser for Traffic Recorders

The purpose of analysing a traffic record is to find the cause of any imbalance in the traffic carried by a grading, or in the total traffic between gradings.

Imbalance within a grading occurs when traffic is unevenly distributed over the inlets to the grading. For example, a uniselector–first-selector grading could have 20 inlets and a total of 200 trunks outgoing to first selectors. As each inlet has access to only 24 trunks, a total of 24 calls from one inlet can cause congestion at that point, and cause uniselectors to hunt continuously, giving no-dial-tone conditions.

However, the total traffic into the grading can be such that many trunks are idle on other grading inlets. The traffic recorder measures only the total traffic in erlangs on the whole grading of 200 trunks; thus, the capacity of the grading may appear adequate from the traffic record, but many subscribers will experience delay before receiving dial tone.

An analysis of the traffic record requires the measurement of the total traffic in erlangs carried by each individual trunk, and thus requires one traffic meter per trunk. When these readings are checked against the grading chart, it is a simple matter to identify the source of the imbalance and take steps to correct it. Regrading can thus sometimes be done without the expense of providing additional trunks.

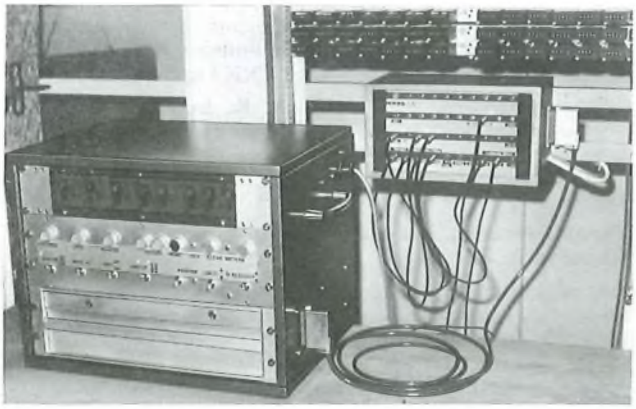
An electronic analyser for traffic recorders has been developed in Liverpool Telephone Area. The only previous method of analysing traffic distribution over a grading was by means of electromechanical equipment using six 150-outlet uniselectors whose outlets were connected by means of a patchboard to 200 resettable meters. The magnets and wipers were connected to the required points on the traffic recorder. Only one large grading with a maximum of 200 trunks could be analysed on one traffic-recorder run, and engineering setting-up time could be quite considerable. When the run was completed, the meters had to be read manually and reset before another analysis could be taken.

The electronic equipment has the equivalent of six-thousand 3-digit resettable meters in a data store, and requires 7 magnet-monitoring wires from the traffic recorder. These are left connected for the duration of all analyses in the exchange. The connexion of 12 wiper-monitoring wires then enables a traffic analysis to be made on any 3 complete long-holding-time-equipment control uniselectors and one short-holding-time-equipment control uniselector. Before switching on the traffic recorder, all the hypothetical meters are reset simultaneously by 2 interlocked buttons; this arrangement prevents the accidental resetting of the meters. No further setting-up is required. All the connexions can be made on the traffic recorder or the intermediate distribution frame, and can be made even simpler by cabling-out the traffic-recorder wiring to a jack field and multi-way socket for the analyser. The required control uniselectors are then patched-in by double-ended cords.

When the traffic-recorder run is complete, the information obtained can be printed out on a standard teleprinter in the same format as the traffic-recorder schedule, A2925. The capacity of the analyser is 20 access uniselectors, or 10 complete pages of the schedule. This normally takes 1·75 h to print out at the standard speed of 50 bauds. If required, the information can be read out manually by means of a digital display and selection buttons. This can be done for monitoring purposes while the analysis is in progress. The printer can be in the exchange or remote from it, connected via the public switched network over an ordinary exchange line.

As only half the meters are used in one analysis, a second analysis can subsequently be made, using the second half of the data store, on 4 different control uniselectors by re-connecting the 12 wiper-monitoring wires. This can be done while the results of the first analysis are being printed out.

Spare capacity in the data store is used to check the correct functioning of the traffic recorder. This information is presented at the end of the meter print-out, or can be read off the display manually.



The electronic analyser and jack field

The principle of the analyser is best illustrated by taking the short-holding-time-equipment control uniselector as an example, as this has only one access uniselector.

The access uniselector has three 50-outlet banks, but only one of these need be considered for this example. When a traffic record starts, the access uniselector takes 50 steps at 5 steps/s, this being repeated at 18 s intervals for 1 h. The wiper is connected via the control uniselector to the allocated traffic-recorder meter and, each time it is stepped on to a busy trunk, the traffic meter is operated once, thus giving the total number of busy trunks on each cycle of the recorder.

If a 50-state counter is connected to the drive magnet of the access uniselector, the outlet on which the wiper is standing at any time is known by reference to the counter. A monitoring wire, connected to the wiper wire, will indicate by an earth potential when a trunk on which the wiper is standing is busy, and the state of the counter will indicate the trunk's identity Thus, a separate (hypothetical) meter in the analyser is associated with every outlet on the access uniselector, whether the outlet is connected to a trunk or not. The meter is incremented once each time an earth on the wiper wire is coincident with its outlet identity in the counter. A record of the traffic carried by each trunk is thus obtained, as distinct from the total traffic indicated on the normal traffic-recorder meter, but 50 meters are required for this one bank, and 150 meters for the complete access uniselector.

It can be seen, however, that one magnet wire and 3 wiper wires are providing all the information for the 150 meters, due to the electromechanical time-division-multiplexing action of the access uniselector.

The multiplexing action of a long-holding-time-equipment control uniselector and its 6 access uniselectors enables information from 900 outlets to be derived from 6 magnet-monitoring wires and 3 wiper-monitoring wires.

All signals on the magnet-monitoring and wiper-monitoring wires, after being filtered and converted to electronic-logic-level signals, are scanned at 20 ms intervals. After processing to eliminate timing errors inherent in the electromechanical equipment, magnet-pulse counts and wiper-earth pulses are multiplexed into separate random-access stores.

There are 3072 addresses in each half of the main data store, of which 3000 are allocated for traffic meters, giving a capacity of 20 complete access uniselectors. The remainder of the store is used to record various aspects of the traffic-recorder operation. Each of the 3072 addresses is processed once every 20 ms, the central processing unit using the data from the magnet and wiper random-access stores to increment the binary count in each traffic-meter address as necessary.

All data-acquisition and processing circuitry uses standard integrated transistor-transistor logic, and data storage is by means of n-channel metal-oxide random-access memories. This enables a low unit cost per meter to be achieved. In fact, the cost of the equipment is not significantly different from the current cost of the 200-meter electromechanical type, but considerable savings in weight and size have been achieved. Projected future developments include a print-out in grading-chart form, and the preliminary design has been completed of a version for use in TXK3 exchanges.

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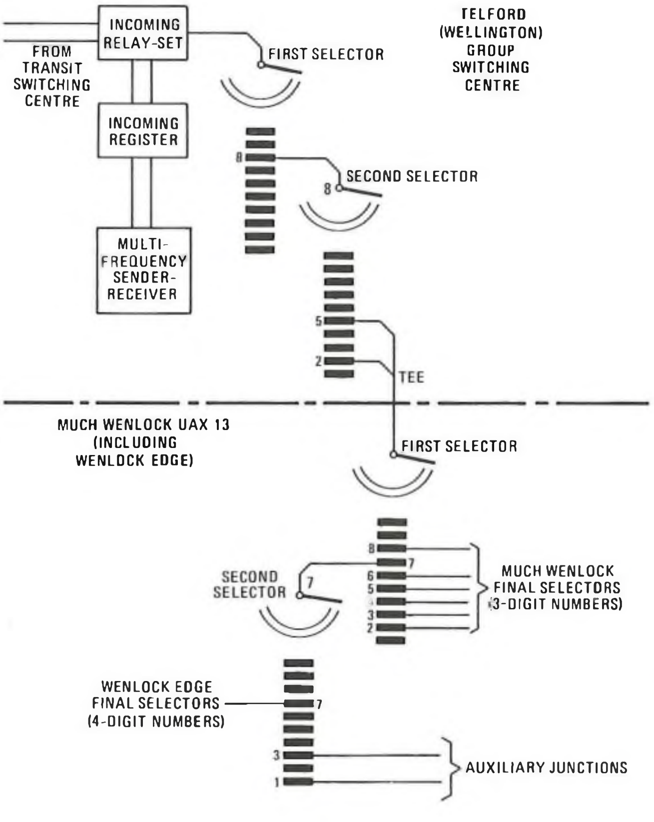
WALES AND THE MARCHES

Transit Access to a Mixed 3-Digit and 4-Digit Unit Automatic Exchange

Any proposal to extend a unit automatic exchange (UAX) 13 to provide a mixed 3-digit and 4-digit numbering scheme, where 2 digits are required to access the UAX from its group switching centre, must take account of the technical design of the incoming registers associated with the transit network. This is because the incoming register on a transit call needs to know when the complete number has been received. (It can then release all short-holding-time equipment associated with the setting-up of the call.) This it determines by examining the E-digit. In the case of Much Wenlock UAX 13, the E-digit is 5, and a further 3 digits are then expected. Much Wenlock recently became exhausted, and could be extended only by providing 4-digit numbers. A waiting list was threatened, and the TXE2 relief was 12 months away.



Trunking diagram for Much Wenlock and Wenlock Edge

Plans are in hand to modify incoming registers to examine the F-digit, but these may not mature for some time. Something had to be done to accommodate the waiters, and the expedient method adopted is illustrated in the sketch.

Four-digit numbers were provided, but they are accessed by an E-digit of 2, which is teed to E-digit 5. The existing junctions to, and switching equipment at, Much Wenlock are used. Unfortunately, the new subscribers connected to the 4-digit numbering range have to have a hypothetical identity of Wenlock Edge, with a national number 095 282 *XXXX*, but this is a small inconvenience relative to being unable to have a telephone because of the unavailability of a multiple.

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EASTERN REGION

Conversion of Braintree CB 10 to Auto-Manual Working

On Thursday 12 June 1975, the old Braintree CB 10 switchboard achieved the status of an auto-manual centre (AMC). This event followed the transfer of the 3200-multiple CB 10 exchange to a new TXK1 group switching centre (GSC) situated some distance from the AMC. Also transferred was a 2900-multiple expedient exchange served by 8 mobile non-director exchanges. A further multiple of 2300 is served by a complex expedient unit automatic exchange (UAX) having a separate exchange identity. Unfortunately, the expedient UAX cannot be incorporated into the TXK1 multiple until the completion of extensions 2 and 3 to the TXK1, which is due about May/June 1977.

It needs little imagination to picture the congested face panels of the CB 10 switchboards prior to the change-over (see Fig. 1) and the engineering problems that had to be solved during the preparations for the conversion of the switchboard to AMC working. The last few years before the change-over also posed some telephonist-recruitment problems. Since every available panel had been used for the multiple, long cords had had to be fitted; the tallest of telephonists had often to stand to reach the extremities of the multiple.

Fig. 1—Face panels at Braintree CB 10 before conversion

FIG. 2—Face panels at Braintree AMC after conversion

Planning for the conversion commenced as far back as 1969 but, because of protracted delays in bringing the TXK1 into service, many of the original thoughts had to be revised. The whole project posed something of a challenge to the Planning and Construction Groups, who worked in close liaison with their colleagues in Traffic Division.

The CB 10 switchboard consisted of a main suite of 26 positions, handling local originating traffic, and an island suite of 6 positions, handling incoming traffic. The switchboards had come from far and wide over the years as the CB 10 exchange had grown. Almost every position differed from its neighbours in detail of construction and wiring, and some had had to be renovated and rewired in 1970 following water damage several years previously. It was necessary, therefore, for each position to be examined individually before any detailed planning could be undertaken.

Twenty positions in the main suite were to be retained for incoming assistance traffic, while 4 positions in the island suite were to be retained for enquiry traffic, including service interception, changed-number interception and other miscellaneous services.

Assistance circuits were provided to accept all ordinary and pay-on-answer coin-collecting-box traffic from the new Braintree GSC area. Strip-mounted relay-sets, suitably modified to give coin-and-fee-checking control, were provided.

It was found necessary to provide special light-action push-button keys in the face panel associated with the circuit jacks to provide the required facilities. Restrictions in panel space prior to the change-over limited the number of appearances of the assistance circuits to 3. The remaining appearances were wired and secured in the back of the switchboards ready for fitting in the space made spare on recovery of the CB 10 calling lamps and jacks, immediately following the change-over.

The outgoing-junction multiple was provided in full prior to the change-over, following careful rearrangement of the existing working circuits. Six cord circuits were to be left on each main-suite position and 3 on each island-suite position. These cord circuits were modified in advance for dual-purpose timing, using chargeable-time clocks. In addition, the first 2 circuits had to be modified for coin-collecting-box timing up until the change-over, and then restored to dual-purpose timing.

Enquiry and other services to be served from the island suite were provided in full prior to the change-over in space made available by rearrangement of the circuits appearing in the existing face panels.

The work put in to the preparations ensured that there were few problems on the day of the change-over.

After the change-over, as the double doors and gantry serving the floor had long since been removed, the old enquiry suite and supervisor's console were dismantled for recovery. They were replaced by modern equipment tables.

All equipment made spare on the retained positions was removed, and the key shelves re-surfaced with plastics laminate to give a good writing surface. It was impracticable to remove the unwanted positions and, here, the equipment was also removed and the key shelves re-surfaced with plastics laminate to provide additional writing surfaces. On the enquiry suite, wells were recessed into the key shelves to hold record cards. On all positions, the dials were replaced by key-senders.

Fig. 2 illustrates the face panels after conversion. The recovery of the multiple enabled the height of the switchboards to be reduced. This work was carried out by the Factories Division with very little disturbance to the operating staff.

The conversion work is almost complete. Figs. 3 and 4 show the same general view of the switchroom before and after the conversion. The problems were many and varied: some foreseen, others discovered and overcome during the execution of the work. Exceptional care had to be exercised while working on the switchboards because of their age and general condition. In addition, the positions were extremely busy and not more than one or two positions could be taken out of service at any time. The fact that so much has been achieved with no interruptions to service is a tribute to the skill of the staff involved and the close liaison that has existed throughout the project between the Engineering, Traffic and Factories Divisions.

The authors would like to thank Dennis Mansell, Braintree, for Figs. 1 and 3, and John Beagle, Colchester, for Figs. 2 and 4.

J. REEVE (0206 74969)
D. LAWRENCE (0206 74779)

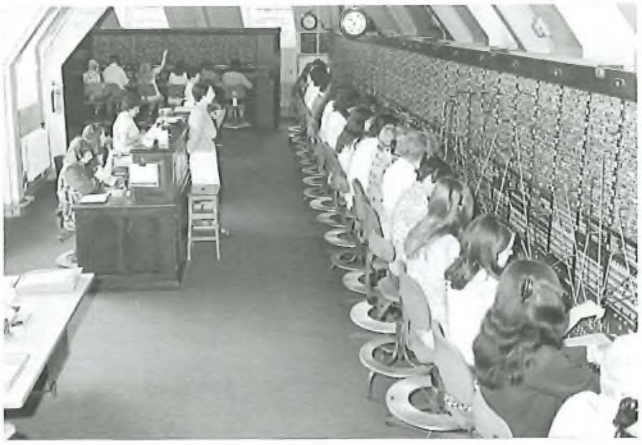


FIG. 3—General view of Braintree CB 10 before conversion, showing the main suite (right), the island suite (background), and the enquiry suite and supervisor's console (left)

FIG. 4—General view of Braintree AMC after conversion, showing the main and island suites, and modern equipment tables

LONDON TELECOMMUNICATIONS REGION

Early Advantage for MOST Register-Translator

The Pye-TMC Ltd. metal-oxide-silicon-transistor (MOST) register-translator has been designed to replace the electromechanical short-holding-time equipment in existing Strowger director exchanges; that is, the local registers, A-digit selectors and directors. The size of the register-translator has been minimized by the use of MOST large-scale integrated-circuit packages, and one 1·37 m rack accommodates 180 registers and 3 translators. A feature of the new register-translator is that the translations contained in the data stores can be readily altered, and this feature was used to advantage in the early stages of the product trial at Surbiton exchange, Surrey.

Road works in the vicinity were the cause of a local junction cable being severed, and routes to 12 local exchanges were lost. To avoid some restriction of service, the MOST register-translator was temporarily brought into full service. The translations for the affected exchanges were changed in the register-translator's data stores, an operation that took only about 15 min, to reroute the traffic via tandem exchanges. This allowed the director translations to be altered during the course of the day without further restrictions to service. The on-site assistance given by Telecommunications Development Department staff was greatly appreciated.

G. C. Markwick (01-879 1234)

Operator's Aid to Routine Check of Tariff Supplies

It is of the utmost importance that all possible precautions are taken by the British Post Office to ensure that customers are correctly charged for STD and ISD calls.

To facilitate the checking of tariff rates by operators, the London Telecommunications Regional Service Division has produced a unit which has successfully undergone field trial at Southbank and Romford. The unit requires connexion to the exchange battery, the TARIFF-IN-FORCE leads, the test-distributor access, and a 1 s earth-pulse supply.

The unit has 10 resettable timing meters and 10 pulse-counting meters. Before each test, the operator sets the timing meters to zero and the pulse-counting meters to values given on routine schedules. The code for the first supply rate to be checked is dialled and the receipt of number-unobtainable tone is verified. The START key is operated and the handset replaced. The unit then automatically tests each supply in turn, and the time, in seconds, of each count-down is recorded. Audible and visual indications are given at the end of the tests.

The operator can then check that the time-count meter readings are correct within specified limits. The procedure is repeated for each tariff equipment. Thus, the operator is involved only with setting-up each test and recording the results.

The STD and ISD tariff rate in force is indicated at all times by lamps incorporated in the unit, and an audible alarm is given if the distribution from any rack is interrupted.

The unit can also be used to monitor the change-over from one rate to another.

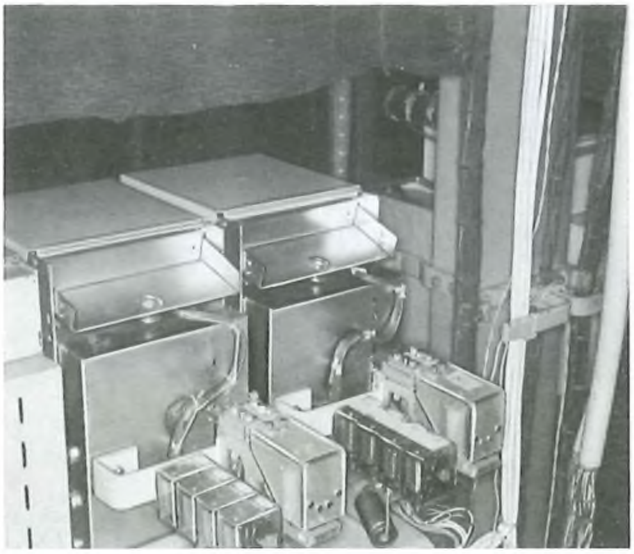
Operators have welcomed the introduction of this prototype unit, and consideration is now being given to the extension of this facility to all auto-manual centres in the Region.

R. J. Treacher (01-587 7417)

SOUTH EASTERN REGION

Discriminating Final-Selectors at Tonbridge

Tonbridge, a 10 000-multiple Strowger exchange, was expected to be partially replaced by a TXK1 unit during the summer of 1976, a short time before the issue of a new telephone directory. On conversion, all subscribers' numbers were to change from 4 or 5 digits to 6 digits. After the decision had been made to publish the 6-digit numbers in the new directory, it became apparent that the partial replacement would be delayed until some months after the issue of the new directory. Unfortunately, the new and old number ranges were such that any 6-digit numbers dialled prior to conversion would route to subscribers on 2 existing final-selector groups. Various steps were taken to alleviate the problem, but of particular interest was a locally-designed modification to the final selectors concerned to enable them to discriminate between 4-digit and 6-digit calls.


Discriminating final-selectors, showing the extra components attached to the capacitor boxes

Normal circuit operation was allowed to proceed up to the completion of rotary stepping, but the application of tones and ringing current was then delayed for approximately 5 s. If, during this period, additional pulse trains were received, a recorded announcement was returned to the caller, and tones and ringing current were not subsequently connected. If further digits were not received, tones and ringing current were connected as usual when the delay period expired.

A pen-recorder was connected to the extra circuit elements to provide a ready indication of the number of 6-digit calls being received. As was expected, one final-selector group had to cope with most of the incorrect calls, and for some weeks was dealing with 40–50 calls during the morning busy-hour.

The modification involved the provision of a high-speed relay and 4 Type-23 miniature relays for each final selector. As there was no space available within the selectors, the components were mounted on a bracket attached to the rear of the capacitor box, as shown in the photograph.

D. D. Brand (073 22 24318)
B. W. Frost (073 22 24812)

SOUTH WESTERN REGION

PABX 7 for CS Alert

In July 1974, Southampton Telephone Area was asked to replace the existing 10 + 49 PABX 1 aboard the CS *Alert* by a 20 + 100 PABX 7. It was clear that unusual difficulties would be experienced, not the least of which was the fact that the ship's visiting times to her new home base at the Southampton Central Marine Depot would be liable to unpredictable changes and that the nature of her work meant only a few days in port at any one time.

At the planning stage, the ship was undergoing a refit at South Shields, and the opportunity was taken to plan the installation while the refit was in progress. The accommodation available on the ship was confined but just acceptable, given that a small rearrangement of the standard layout would be necessary. It was decided that the best method of overcoming the restriction on the time available for installation would be to assemble and test the PABX 7 on-shore, interconnecting the units with connectors. The units could then be quickly separated ready for lifting on board.

The ship eventually arrived at Southampton on 26 July 1975 for an 8 d stay, but, as is usual, was on a 48 h stand-by for her cable-repair duties. The PABX 1 was recovered and lifted ashore, and the PABX 7 units lifted aboard. Work then commenced to place them in the planned accommodation. This involved securing the units to the metal deck, providing filling to take up the deck curvature, and fitting tie bars to restrain the units during normal and abnormal weather conditions at sea. This work was undertaken by the ship's crew under the direction of the Central Marine Depot. The connexion of the units to the ship's distribution system, and the subsequent call-through test, was commenced on 29 July and satisfactorily completed by 1 August 1975. The ship sailed to deal with a cable fault on 4 August.

The Southampton Area staff wish to record their appreciation of the very active co-operation which the Central Marine Depot and the officers and crew of CS *Alert* gave to the project.

C. T. Tame (0703 33251)

EXTERNAL TELECOMMUNICATIONS

Communications for Construction Barges in the North Sea

On p. 122 of the July 1975 issue of the *POEEJ*, the External Telecommunications Executive reported a special radio-teleprinter scheme set up to enable oil-construction vessels to communicate with their base offices via Stonehaven radio station. This scheme has been an outstanding success and, as forecast in that report, has now been extended to the British Post Office's radio station at Wick. This system uses a radio transmitter and receiver remotely sited on Unst, the northernmost island of the Shetland Isles. The error-correcting equipment is, however, located at Wick radio station. Telegraph signals are passed over landlines and submarine cable, using an inland voice-frequency system, to Unst, where they are reconverted to d.c. signals before being applied to the radio-path voice-frequency system for modulation of the transmitter carrier.

At the time of writing, 4 channels of the possible 6 provided on this system are operational. A public-correspondence channel is also available, as at Stonehaven.

J. A. Chambers (01-432 4035)

Associate Section Notes

Aberdeen Centre

The April 1976 meeting of the Centre was to have been a visit to an oil-rig construction yard. This unfortunately had to be cancelled. The session closed with the annual general meeting and dinner on 21 May 1976 at the Atholl Hotel, Aberdeen. The programme for 1976–77 has yet to be finalized, but the September meeting was a visit to the power station under construction at Peterhead, near Aberdeen.

I. Booth

Brighton Centre

Our annual general meeting was held on 21 April 1976, when the officers and committee were elected. A vote of thanks was passed to the outgoing secretary, Terry Brown, who has decided to stand down after many years' service in the post. A new constitution for the Centre has been drawn up and was accepted by the members at the meeting.

The Centre recently arranged visits to Kew Gardens, the RAF Museum at Hendon and Dungeness B power station. These trips attracted great interest and were well supported. It is hoped to arrange trips to Pirelli Cables Ltd., a television show, RAF Upper Heyford and the British Post Offices's cable ships.

T. C. Hills

Cardiff Centre

The Centre remains active although notes have not appeared for some time.

Recent events have included technical quizzes against teams from other centres in Wales, including successful experimental sessions using commercial microphones, amplifiers and loudspeakers over ordinary telephone links between Cardiff and Swansea.

A limited number of members were able to inspect an American cable ship lying in a South Wales port, and were made very welome by its crew.

An afternoon ramble at the beginning of the current (1976–77) session, in the Brecon Beacons area, afforded an opportunity for all members to meet informally. The first formal event will be a tour of the new BBC Wales radio and television studios at Llandaff. A visit to a local paper mill to see developments in electronic process control is also being arranged. As both visits are likely to be over-subscribed, early application for a place is advisable.

Your committee is anxious to finalize the session's programme, and will be pleased to consider members' suggestions.

P. F. Coleman

Colwyn Bay Centre

Our 1975–76 session started in October 1975 with a talk on cave archeology by Melvin Davies of the Nature Conservancy, Bangor. An aide to the Duke of Wellington in the Peninsular War, Col. John Hughes of Anglesey, was the subject of a talk by Bob Williams of Bangor on the same night.

In December, the RAF recruiting team from Wrexham gave an up-to-date film presentation on the RAF today, including a description of servicing a Hawker Harrier from a forward base. This was followed by an interesting question-time on the subject.

In February, Tim Dinsdale, a well-known author and researcher, gave a talk on the evidence in support of the view that there are large aquatic mammals in Loch Ness. This talk achieved the largest attendance of the session, with an audience of well over 100 people.

In April, our Honorary Secretary gave a talk simply titled *The Aurora*. This described the mystery surrounding this beautiful polar phenomenon, and the painstaking visual and radio observations that have led to a better understanding of it.

The session closed with a record attendance (over 40) at the annual general meeting, which was followed by a film about the new Shell pipeline crossing of the Menai Straits.

E. Doylerush

Dundee Centre

Our annual general meeting was held on 20 April 1976, following a dinner in a local hotel. The following office-bearers and committee were elected.

Chairman: Mr. D. A. Moore.
Vice-Chairman: Mr. I. J. McBean.
Treasurer: Mr. A. J. Vaughan.
Secretary: Mr. G. K. Duncan.
Assistant Secretary: Mr. D. H. Smith.
Committee: Messrs. J. Chisholm, J. Duncan, J. C. Howe, R. MacLachlan, R. C. Smith, M. Williamson and G. Lyall.
Co-opted Committee Member: Mr. R. T. Lumsden.

A vote of thanks was given to the retiring secretary, Mr. R. T. Lumsden, who has held the post for the past 14 years. As a co-opted committee member, his guidance and experience will be greatly appreciated by all.

Congratulations were offered to Mr. R. MacLachlan for the award of an Institution Certificate of Merit for his essay *Special Investigation of Customers' Complaints—The Importance of Human Relationships*. We hope that this award will stimulate interest in the essay competition.

G. K. Duncan

Evesham Centre

A centenary exhibition, to mark 100 years of the telephone, was staged in Evesham by members of the Associate Section of the Institution of Post Office Electrical Engineers. It was held in the Almonry Museum at the invitation of Evesham Historical Society, until September.

The exhibition was opened on 28 May by Lt. Col. Richard Burlingham, a descendant of subscriber 2 and 3 on Evesham's first exchange in 1898. It contained examples of telephones ranging from a copy of Alexander Graham Bell's original instrument through to telephones of tomorrow. Also on display were other types of communication equipment and details of telephone growth in the Evesham area.

The exhibits were lent by the British Post Office, private manufacturers, the National Museum of Wales, the Festiniog Railway Company, a private collector in Northampton, and many other sources.

Our members not only staged the exhibition, they ran it at their own expense. It is hoped that, as a result of the exhibition, the Evesham Centre will eventually be able to obtain suitable accommodation for a permanent display of its own collection.

J. Sharp

Exeter Centre

At the annual general meeting, held on 12 April 1976, the following members were elected as officers and committee for the 1976–77 session, Mr. J. Gregory, General Manager, Exeter Telephone Area, kindly accepting the office of President.

Chairman: Mr. J. J. F. Anning.
Vice Chairman: Mr. C. K. Sanders.
Secretary: Mr. J. W. Clark.
Assistant Secretary: Mr. G. E. Tout.
Treasurer: Mr. I. C. Elston.
Librarian: Mr. G. W. W. Abbott.
Committee: Messrs. J. Brown, I. P. Lightfoot, J. Tucker, D. N. Miller, W. J. West, R. W. Easton, E. A. Gould and C. L. Reynolds.

Our summer programme began with 4 evening visits, on 11, 12, 19 and 20 May, to the Devon and Somerset Gliding Club at Broadhembury. Each meeting enabled 7 members to participate in gliding which, I have been told, was an experience not to be missed. All the members who attended enjoyed themselves, and were very enthusiastic at the prospect of further visits in the future.

These events were followed by a visit to the British Post Office (BPO) earth station at Goonhilly Down, Cornwall, on 10 June 1976. Twenty-eight members attended. The party was welcomed to Goonhilly by the General Manager, Mr. Banner, and a conducted tour ensued. The visit was extremely interesting and demonstrated to our members another aspect of BPO technology. I would like to express the appreciation of Exeter Centre to Mr. Banner and his staff for a very pleasant visit.

J. W. Clark

London Centre

Our annual conference was held at the Institution of Electrical Engineers, Savoy Place, London, on 17 May 1976. The following officers were elected for the coming year.

Chairman: Mr. R. Gray (telephone: 01-921 8630).
Vice-Chairman: Mr. A. J. Dow.
Treasurer: Mr. N. V. Clark (telephone: 01-205 7404).
Assistant Secretary: Mr. C. J. Webb (telephone: 040 928 236).
Editor: Mr. B. C. Gardner.
Visits Secretary: Mr. D. Denchfield.
Quiz Organizer: Mr. D. Thomas.
Trainee Technician (Apprentice) Quiz Organizer: Mr. R. Shaw.
Radio Secretary: Mr. L. Wood.
Librarian/Registrar: Mr. D. Randall.

At the conference, it was agreed that the Centre should arrange an annual exhibition for its members, and that this should include technical exhibits and hobby subjects. It was decided to replace the points system used in quiz matches by a system of 3 points for the winning team, 2 points for a draw, and 1 point for the losing team in future. No points will be awarded to a team that does not attend.

The C. W. Brown Award was presented to 2 people this year, in recognition of their long and outstanding service to the IPOEE. They were Mr. R. D. Anstey, South Area, and Mr. D. Randall, East Area. The award was presented by Mr. E. W. Fudge, London Centre President.

The meeting learned with sadness of the sudden death of Eric Saunders, Chairman of the North Central Area committee.

With membership standing at 6940, the President urged all London areas to embark on a recruitment campaign, as this figure was only 25% of those eligible for membership.

C. J. Webb

Manchester Centre

Manchester beat London by 28½ points to 24 in the first Trainee Technician (Apprentice) quiz to be held over Confravision, on Wednesday 7 July 1976. The Manchester team was made up of 2 members from each of the 3 Manchester telephone areas, and consisted of Messrs. Edmond Jackson (captain) and John Kirby from Manchester Central Area, Steven Harper and Lionel Dawson from Manchester South Area, and Philip Cox and Robert Hardman from Manchester North Area.

Our 1976–77 programme has been prepared. It started with an evening visit to the Whitbread (West Pennines) brewery in September, and was followed by a lecture on modular power plants given by Mr. B. Reeve of the North West Telecommunications Board in October. In November, there is to be an evening visit to Piccadilly (Manchester) radio station for a tour of the studio and a lecture, *Telecommunications Seen in the USA*, to be given by Dr. G. White of the British Post Office Research Centre, Martlesham. A visit to Manchester Airport control tower is scheduled for December and, in January, there is an all-day visit to the British Leyland Bus and Truck Division at Preston. In February, a lecture on cable pressurization is to be given by Mr. K. G. Weaver of Manchester South Area and, in March, an all-day visit to BICC Ltd. at Prescot will be followed later in the month by a visit to the Ford Motor Company at Halewood. The annual general meeting will be held in April.

Visitors are welcome to attend lectures, which are held in Telephone House, Manchester. Applications to attend visits should be made to the Secretary (061-863 6606) as early as possible.

T. J. Rodin

Nottingham Centre

Our annual general meeting was held at the Civil Service Club, Wilford Lane, Nottingham, and the following officers and committee were elected.

Chairman: Mr. B. M. Smith.
Secretary: Mr. R. H. Marsh.
Treasurer: Mr. L. E. Smith.
Assistant Secretary: Mr. M. Rush.
Librarian: Mr. P. Birchmore.
Magazine Librarian: Mr. D. Cameron.
Committee: Messrs. J. D. Liley, B. Miller and R. Taylor.

Mr. K. Chandler agreed to remain as President for another year.

The programme for the 1976–77 session was agreed, and includes visits to the Royal Ordnance Factory at Nottingham and RAF Waddington.

Nottingham Centre was successful in the Midlands Region Technical Quiz, defeating Derby and Coventry in the preliminary rounds, and Peterborough in a close final at the Leicester Sports and Social Club. The interest generated by these events prompted the Derby and Nottingham Centres to organize a Trainee Technician (Apprentice) quiz. Questions (and, of course, the answers) were kindly supplied by the local training office, and the standard set by the teams was very high indeed. Congratulations again must go to Nottingham's team who were the winners in a contest that could have gone either way.

A fishing trip to Bridlington was thoroughly enjoyed by those who went, and ideal weather complemented the event. Two members took the opportunity of spare seats on the coach to enable them to play on one of the coastal golf courses in that area, and they were also delighted with the day's outing. Requests have been made for a repeat of this event, and it is hoped that this will be possible next year.

R. H. MARSH

Oxford Centre

After an active year, the annual general meeting (AGM) was held on 21 April, with a record attendance. The AGM's first item of business was to make our President, Mr. Peter Buck, an Honorary Life President in recognition of his devotion to, and encouragement of, the Oxford Centre. The following officers and committee for the 1976–77 session were elected.

Chairman: Mr. D. R. Ward.
Secretary: Mr. I. Warham.
Assistant Secretary: Mr. B. Post.
Treasurer and Librarian: Mr. B. Collins.
Committee: Messrs. P. Barrett, B. Edwards, T. Francis, B. Gurden, N. Hinchen, R. Hinchen, R. Manning, B. Morris, M. Taylor and C. Young.

Our Honorary Life President, on the earlier recommendation of the retiring committee, presented the Peter Buck Trophy—a splendid engraved example of a vintage brass telegraph relay—to the National Technical Quiz team. Finally, Brian Post gave an excellent illustrated talk entitled *To Katmandu and Back*.

On 8 June, 28 members visited the BBC Pebble Mill studio in Birmingham.

In honour of Peter Buck's retirement as General Manager, Oxford Telephone Area, the committee, on 11 June, wined and dined him at a local hotel, and presented him with an inscribed book.

RAF Brize Norton opened its doors to us on 16 July, and our next port of call was at the Central Marine Depot in Southampton on 6 October.

As for the rest of our programme—well, why not come along and find out? Better still, we want you and your ideas to make Oxford an even more flourishing centre.

D. R. WARD

Southampton Centre

During the 1975–76 session, visits by our members were made to a local flour mill, the Union Castle liner *Pendennis Castle* (docked at Southampton), and IBM to see their 3750 switching system. Our talks were *Working on Live Wires*, given by a representative of the Southern Electricity Board, and *The Software Aspects of Stored-Programme Control*.

The annual general meeting was held on 21 April 1976, and the following officers were elected.

Chairman: Mr. R. Genge.
Vice-Chairman: Mr. E. J. Green.
Secretary: Mr. P. E. R. Bates.
Treasurer: Mr. T. F. Axton.
Librarian: Mr. R. Playdon.
Committee: Messrs. K. J. Mann, D. Rolfe, G. Meering, B. Savage and R. de Turberville.

Prizes were presented to the winners of our local Trainee Technician (Apprentice) essay competition. The programme for the 1976–77 session is, at the time of writing, being finalized. A visit to the Kodak factory at Harrow and a talk on millimetric waveguides have been arranged.

P. E. R. BATES

Stirling Centre

Our annual general meeting in April brought to a close the 1975–76 session of activities with a cheese and wine party which, sadly, could attract only 8 members. The usual faithfuls once more will make up the committee for the 1976–77 session, as listed below.

President: Mr. T. S. Young.
Chairman: Mr. G. Nicol.
Vice-Chairman: Mr. A. Moffat.
Secretary: Mr. J. Hannah.
Treasurer: Mr. R. Henderson.
Committee: Messrs. W. McGregor, T. Hamilton and J. Niven.

We have some interesting visits and talks planned for the forthcoming session, and hope this will attract our reluctant members.

J. HANNAH

The Associate Section National Committee Report

Annual Conference

The annual conference was held on 22 May 1976 at the Technical Training College (TTC), Stone. The following officers were elected for the coming year.

Chairman: Mr. J. Hannah, Scotland.
Vice-Chairman: Mr. G. Rimmington, North East Region.
Secretary: Mr. C. J. Webb (telephone: 040 928 236).
Assistant Secretary: Mr. R. Calvert (telephone: 0254 666259).
Treasurer: Mr. D. B. Hickie (telephone: 035 281 3190).
Editor: Mr. C. F. Newton (telephone: 094 34 4071).
Quiz Organizer: Mr. K. Marden (telephone: 0204 35999).
Project Organizer: Mr. E. W. Philcox (telephone: 0234 61561).
Visits Secretary: Mr. J. J. F. Anning (telephone: 0626 3255).

Timer-and-Scoreboard Competition

After careful consideration by a panel of judges from the staff of the TTC and the National Committee, the winner of the timer-and-scoreboard competition was Tavistock's entry, designed and produced by Mr. S. Newcombe. The standard of entries was very high indeed. The judges marked on design specifications and a reliable production model, as well as the ability of the model to perform the functions required. The Committee wish to congratulate the winner, and the runners-up from London South Area and Worthing, on their technical achievements in producing the entries.

1976–77 Project Competition

This year's competition will take the form of a technical essay on film or slides, with a commentary. At the time of writing, no details are available; those interested should contact the Project Organizer.

IPOEE Associate Section Car Sticker

A windscreen sticker, approximately 75 mm in diameter, taking the form of our existing lapel badge, is available to members, price 10p. Please contact the Secretary if you are interested.

Information Required

One of our members is eager to obtain information concerning the first submarine telegraph cables between Cowes, Isle of Wight, and Southampton, used for the demonstration of the telephone by Alexander Graham Bell to Queen Victoria in 1878. Please contact the Secretary if you have any information.

C. J. WEBB
Secretary

Institution of Post Office Electrical Engineers

ESSAY COMPETITION, 1976–77

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:

(*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. 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 1977.

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.

ELECTION OF MEMBERS OF COUNCIL, 1976–77

The results of the recent elections of Members of Council are given below, the names being shown in order of votes counted.

Grade Representation

Members in the provincial regions holding posts in Bands 3–8 of the senior salary structure:

Mr. J. W. Rance, Mr. R. A. M. Light, Mr. J. Evans.

Members in the Headquarters departments (London) listed in Rule 5(b), with the exception of those in Group 14:

Mr. A. Haggerstone, returned unopposed.

Members in the London regions listed in Rule 5(b), with the exception of those in Groups 12 and 14:

Mr. J. E. Rosser, returned unopposed.

Members in the provincial regions and in the Headquarters departments (provinces) listed in Rule 5(b), with the exception of those in Groups 13 and 15:

Mr. R. C. Taylor, Mr. D. F. Ashmore, Mr. R. C. Willis, Mr. R. A. Spanner, Mr. J. W. Large, Mr. G. R. Chattaway.

Officers

Honorary Treasurer:

Mr. C. F. J. Hillen, returned unopposed.

CONSTITUTION OF THE COUNCIL

The constitution of the Council for the year 1976–77 is as follows.

Mr. J. F. P. Thomas, Chairman.

Mr. D. Wray, Vice-Chairman.

Mr. T. Pilling, Vice-Chairman.

Mr. C. F. J. Hillen, Honorary Treasurer.

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Mr. J. W. Rance, representing the members in the provincial regions holding posts in Bands 3–8 of the senior salary structure.

Mr. F. Bateson, representing the members in the Headquarters departments (London) holding posts in Bands 9 and 10 of the senior salary structure.

Mr. K. B. Hinchliffe, representing the members in the London regions holding posts in Bands 9 and 10 of the senior salary structure.

Mr. J. Farrand, representing the members in provincial regions and in the Headquarters departments (provinces) holding posts in Bands 9 and 10 of the senior salary structure.

Mr. R. Hall, representing the members in the Headquarters departments (London) listed in Rule 5(a), with the exception of those in Group 14.

Mr. F. L. Brooks-Johnson, representing the members in the London regions listed in Rule 5(a), with the exception of those in Group 14.

Mr. C. W. Read, representing the members in the provincial regions and in the Headquarters departments (provinces) listed in Rule 5(a), with the exception of those in Group 15.

Mr. A. Haggerstone, representing the members in the Headquarters departments (London) listed in Rule 5(b), with the exception of those in Group 14.

Mr. J. E. Rosser, representing the members in the regions listed in Rule 5(b), with the exception of those in Groups 12 and 14.

Mr. R. C. Taylor, representing the members in the provincial regions and in the Headquarters departments (provinces) listed in Rule 5(b), with the exception of those in Groups 13 and 15.

Mr. D. V. Gasson, representing the Inspectors in the London regions.

Mr. B. A. B. Wood, representing the Inspectors in the provincial regions.

Mr. K. J. B. Potter, representing the Draughtsmen and above and Illustrators and above, but below the senior salary structure, in the Headquarters departments (London) and in the London regions.

Mr. G. Warner, representing the Draughtsmen and above and Illustrators and above, but below the senior salary structure, in the provincial regions and in the Headquarters departments (provinces).

Mr. D. A. Barry, representing all affiliated members.

A. B. Wherry
Secretary

NORTHERN IRELAND CENTRE PROGRAMME, 1976–77

Meetings will be held in either the cinema or the coffee lounge, Dial House, and will commence at 14.30 hours.

18 November: Lecture by D. Kelson. (Title to be announced locally.)

8 December: *Development, Construction and Trials of Cable-Repair Ships* by D. N. Dick.

12 January: *Maintenance of Common-Control PABXs* by A. Cartwright and J. D. Stoate.

16 February: *Technology and Practices of the Evolving Telephone System* by A. Kane.

16 March: *The Purpose and Methods of Financial Control* by R. Chivers.

20 April: *Forecasting in Practice* by W. M. Turner.

STONE/STOKE CENTRE PROGRAMME, 1976–77

15 November: *The Purpose and Methods of Financial Control* by R. Chivers.

15 December: *Viewdata* by S. Fedida.

10 January: *Optical-Fibre Systems* by I. A. Ravenscroft.

14 February: *Pathfinder—An Experimental Stored-Programme-Control Exchange* by I. Park.

14 March: *Local-Exchange Modernization* by P. A. Lamont.

LONDON CENTRE PROGRAMME, 1976–77

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.

1 November (Fleet): *The Application of Value Analysis in the Post Office* by C. M. Halliday.

16 November (IEE): *The TXE4 Telephone Exchange System* by J. V. Goodman and D. G. Bryan. (Joint meeting with the IEE.)

1 December (Fleet): *The Use of Computers in Exchange Planning* by T. E. Longden.

12 January (Fleet): *The Evolution of the London Director System* by K. F. Aubertin and R. Wilkinson. (Joint Senior and Associate Section Meeting.)

27 January (IEE): *The Role of Factories Division in the Post Office* by J. C. Spanton.

9 February (Fleet): *Forecasting in Practice* by W. M. Turner.

24 February (IEE): *Patterns of Engineering Safety* by H. Brown.

9 March (Fleet): *Customer Data Networks* by C. Bullock, D. M. Copeland and A. K. Ainsworth.

31 March (IEE): *Optical-Fibre Transmission* by F. F. Roberts.

19 April (Fleet): *Post Office Public Mobile-Radio Services* by R. H. Tridgell.

11 May (IEE): Annual General Meeting of the Institution, followed by a lecture by D. Wray. (Title to be announced.)

Notes and Comments

Corrections

In Fig. 12 of the article *Push-Button Telephones*, published in the January 1975 issue of the *POEEJ*, there should be no connexion between the lower ends of the emitter and tuned-circuit windings of transformer T1. Instead, the node formed by the anodes of diodes D2 and D3 should be connected to that formed by the cathode of diode D11 and the lower end of the emitter winding of transformer T1, and not to the node formed by the right-hand plate of capacitor C1 and the right-hand side of the frequency-coding contacts. The node formed by the lower end of the tuned-circuit winding of transformer T1 and the left-hand side of the 697 Hz frequency-coding contact should be connected to that formed by the anode of diode D1, the cathode of diode D2, the middle contact of switch S2 and the left-hand side of the transmitter.

In the list of colours given for pairs 1–30 of the cable described in the answer to Question 37 in the Model Answer Book for Elementary Telecommunication Practice, pair 20 has been omitted. This should be slate-white paired with white (old colour code).

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 neccssary 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 by 8 November 1976.

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 encourage contributions suitable for publication under "Regional Notes", and short articles dealing with current topics related to engineering, or of general interest to engineers in the British Post Office (BPO).

The "Regional Notes" section is intended for engineers in Telecommunications and Postal Regions and Telephone Areas briefly to report items of technical or management content, and to describe the solutions adopted to solve specific problems that may be of interest to other Regions, Areas and departments. Also, items of general interest to engineers in the BPO are welcomed.

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; Regional Notes are generally up to about 500 words in length. 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.

Guidance for Authors

Some guiding 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 author's 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/Regional Controller/Head of Division (organizational level 5) level.

Each circuit diagram or sketch should be drawn on a separate sheet of paper; neat sketches are all that is 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 and slides can be accepted for black-and-white reproduction. Negatives are not required.

Special Issues and Back Numbers

Copies of the April 1974 issue covering sector switching centres, and the October 1973 special issue on the 60 MHz transmission system, are still available.

Back numbers can be purchased, price 60p each (including postage and packaging), for all issues from January 1972 to date, with the exceptions of July 1972 and January 1973.

Copies of the July and October 1970 issues are also still available.

The July 1970 issue contains articles on transmission measurements of connexions in the switched telephone network, interfaces for digital data transmission, and a line-transmission simulator for testing data-transmission systems.

The October 1970 issue contains articles on line-signalling systems for the transit trunk network, the principles of local telephone-cable design, the remote control of microwave radio-relay links, the identification of new cable pairs, and the design of contact switching circuits.

Orders, by post only, should be addressed to *The Post Office Electrical Engineers' Journal* (Sales), 2–12 Gresham Street, London EC2V 7AG. Cheques and postal orders, payable to "*The POEE Journal*", should be crossed "& Co.", and enclosed with the order. Cash should not be sent through the post.

Price of the Journal to non-BPO Readers

The Board of Editors regrets that, because of increases in the cost of paper, the price of the *Journal* to non-British Post Office readers will be increased to 45p (70p including postage and packaging); annual subscription: £2·80 (Canada and the USA $6·00). The increase takes effect from the January 1977 issue.

Post Office Press Notice

Report and Accounts, 1975–76

A change in the financial fortunes of the British Post Office (BPO) was the outstanding feature of 1975–76, states the Annual Report and Accounts of the BPO, published in July.

A loss of £306·6M in 1974–75 was turned into a profit of £147·9M in 1975–76. This has made possible a period of price stability, such that all telecommunications prices will be kept unchanged until 31 July 1977. It has also provided money for investment in essential equipment.

The £147·9M profit is made up from a profit of £154·7M on telecommunications, a loss of £9·2M on posts, a profit of £0·8M on Giro, a profit of £0·3M on remittance services, and a profit of £1·3M on data processing.

The fall in business during a year of general economic recession was in line with that expected. The price increases did not take the BPO to the point of diminishing returns. Although the postal service remained in the red, this was only because of losses on parcels. The letter service made a profit.

The profits were essentially from telecommunications, which is currently investing over £900M a year at today's prices. A continuing programme of this order is vital for the development and modernization of a service that is crucial to the industrial, commercial and social life of the country. To meet these demands effectively and efficiently in the years ahead, the Business needs to invest now and to go on doing so. To support such a programme, good profits are essential. Every penny is ploughed back for the eventual benefit of the user.

The most marked effect of higher charges and the general economic recession was in call growth. Local calls increased by only 1·6% to 13 736 million, and trunk calls by only 1·9% to 2356 million. However, international calls grew by a record 15·2 million to 92·1 million.

A total of 1·27-million new telephone connexions were supplied during the year, bringing the total number of connexions in service to 13·2 million.

There were fewer equipment faults, and the percentage of calls for which plant was satisfactory increased by 1·0% to 96·3% in the STD service and by 0·3% to 98·3% in the local automatic service. There were further improvements in the international dialled service, and the percentage of calls failing in the UK part of the network fell from 10·3% to 5·8%.

An improved staffing position led to 90·5% of day-time inland calls through an operator, and 91·1% of night-time calls, being answered within 15 s. Of international calls, 81% of day-time, and 69% of night-time calls, were answered within 15 s.

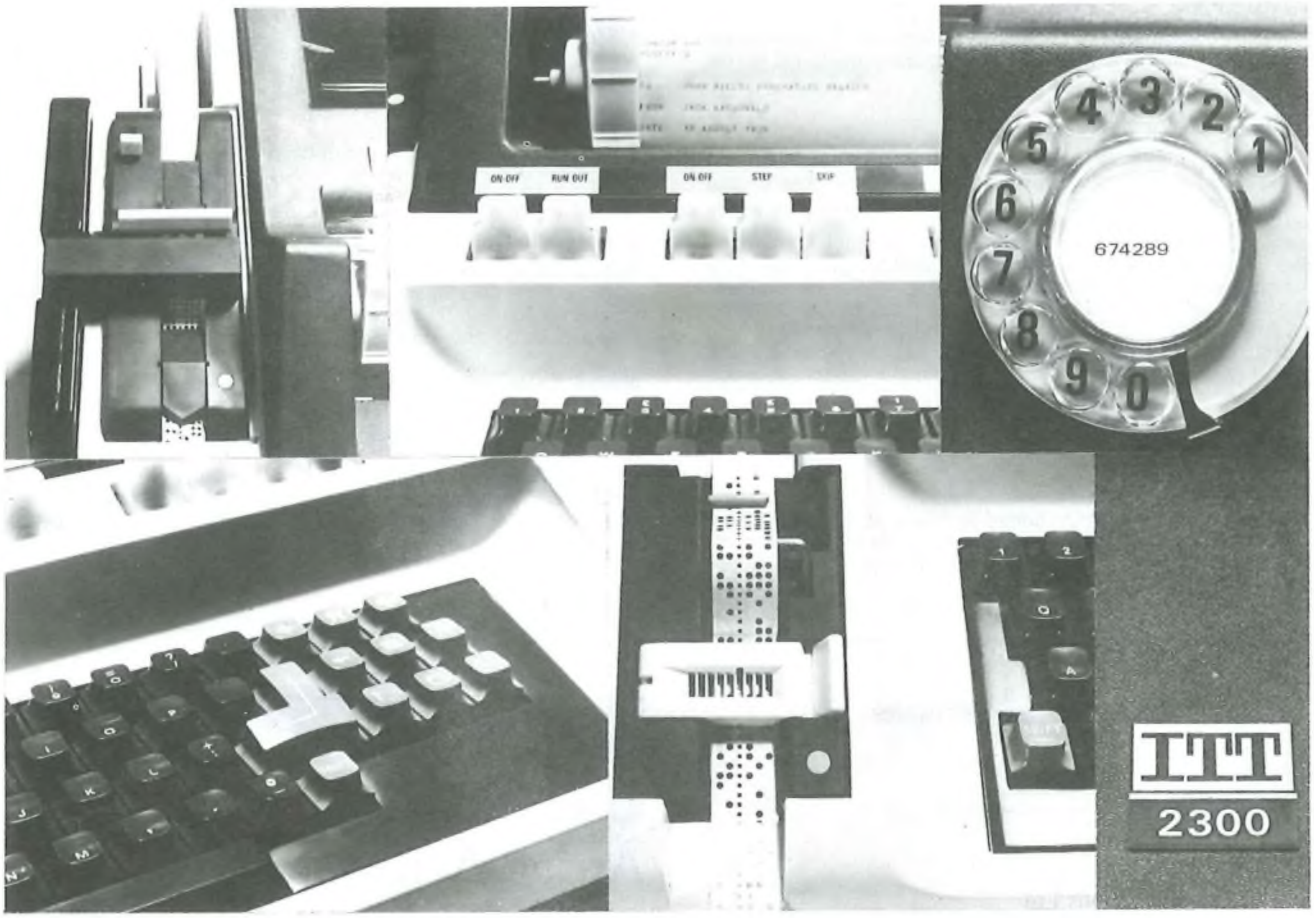
The inland parcel service lost £42·8M in 1975–76, whereas all other postal services, including the inland letter service, made profits totalling £33·6M. Over the whole year, 92% of first-class mail was delivered by the working day after posting. For second-class mail, just below 90% was delivered within 2 working days. There was a fall of 9% in the number of letters posted, and of 15·3% in the number of parcels handled. This fall was largely as forecast, and there were signs of recovery towards the end of the year.

There was further encouraging growth in Giro's business-deposit and local-authority rent-collection markets. Some headway was made with the recruitment of personal accounts in a difficult market and, at the end of the year, there were 517 000 accounts. Turnover was up by 50% to £30 000M, balances rose to £192M, and the number of transactions rose by 20% to 195 million.

Still under discussion with the Government at the end of the year was the responsibility for funding the element of the pension-fund deficiency attributable to the period before the BPO became a Corporation in 1969. Contributions to finance this deficiency amounted to £91·6M in 1975–76, equivalent to about 0·5p per inland letter and 0·3p for an inland telephone call.

The table summarizes the income and expenditure for 1975–76.

Business	Income (£M)	Expenditure (£M)	Profit/Loss (£M)
Telecommunications	2166·8	2012·1	+ 154·7
Posts	1088·6	1097·8	− 9·2
Giro	36·4	35·6	+ 0·8
Remittance Services	18·1	17·8	+ 0·3
Data Processing	34·7	33·4	+ 1·3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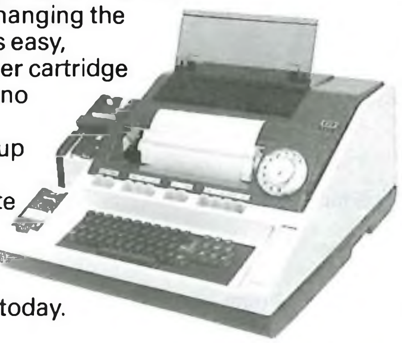

The Post Office Electrical Engineers' Journal

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Subscriptions and Back Numbers

The *Journal* is published quarterly in April, July, October and January, at 35p per copy, 60p per copy including postage and packaging (annual subscription: £2·40; Canada and the USA: \$6·00).

The price to British Post Office staff is 27p per copy.

Back numbers will be supplied if available, price 35p (60p including postage and packaging). At present, copies are available of all issues from July 1970 to date, with the exceptions of January, April, July and October 1971, July 1972, and January 1973.

Orders, by post only, should be addressed to *The Post Office Electrical Engineers' Journal*, 2–12 Gresham Street, London EC2V 7AG.

Employees of the British Post Office can obtain the *Journal* through local agents.

Binding

Readers can have their copies bound at a cost of £3·00 including return postage by sending the complete set of parts, with a remittance, to Press Binders Ltd., 4 Iliffe Yard, London SE17.

Remittances

Remittances for all items (except binding) should be made payable to "*The POEE Journal*" and should be crossed "& Co."

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All correspondence relating to advertisement space reservations, copy, proofs etc., should be addressed to the Advertisement Manager, *The Post Office Electrical Engineers' Journal*, 2–12 Gresham Street, London EC2V 7AG.

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Correspondence relating to the distribution and sale of the *Journal* should be addressed to *The Post Office Electrical Engineers' Journal* (Sales), 2–12 Gresham Street, London EC2V 7AG.

Communications

With the exceptions indicated above, all communications should be addressed to the Managing Editor, *The Post Office Electrical Engineers' Journal*, NP 9.3.4, Room S08, River Plate House, Finsbury Circus, London EC2M 7LY.

Model Answer Books

Books of model answers to certain of the City and Guilds of London Institute examinations in telecommunications are published by the Board of Editors. Details of the books available are given at the end of the Supplement to the *Journal*. Copies of the syllabi and question papers are not sold by *The Post Office Electrical Engineers' Journal*, but may be purchased from the Department of Technology, City and Guilds of London Institute, 76 Portland Place, London W1N 4AA.

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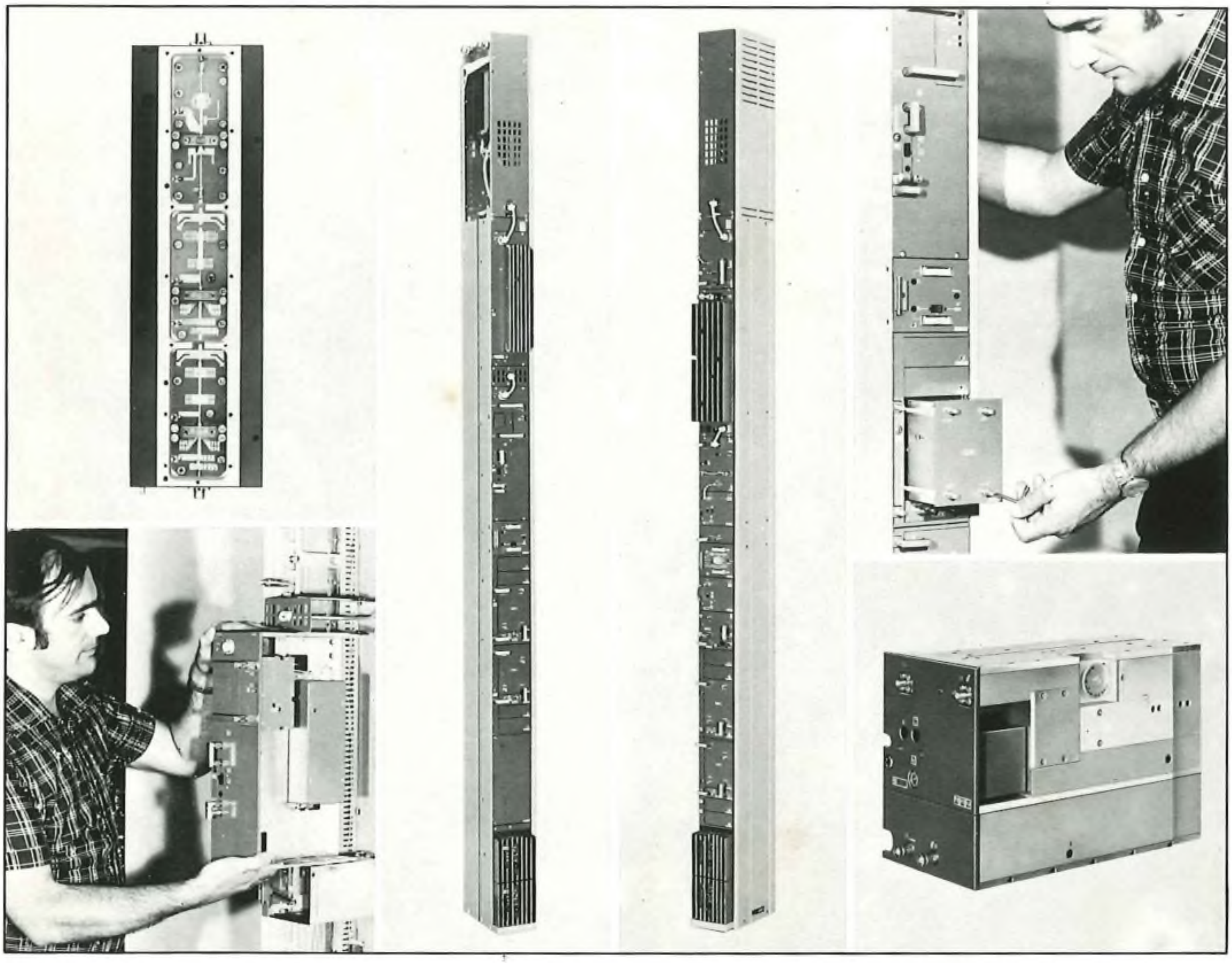

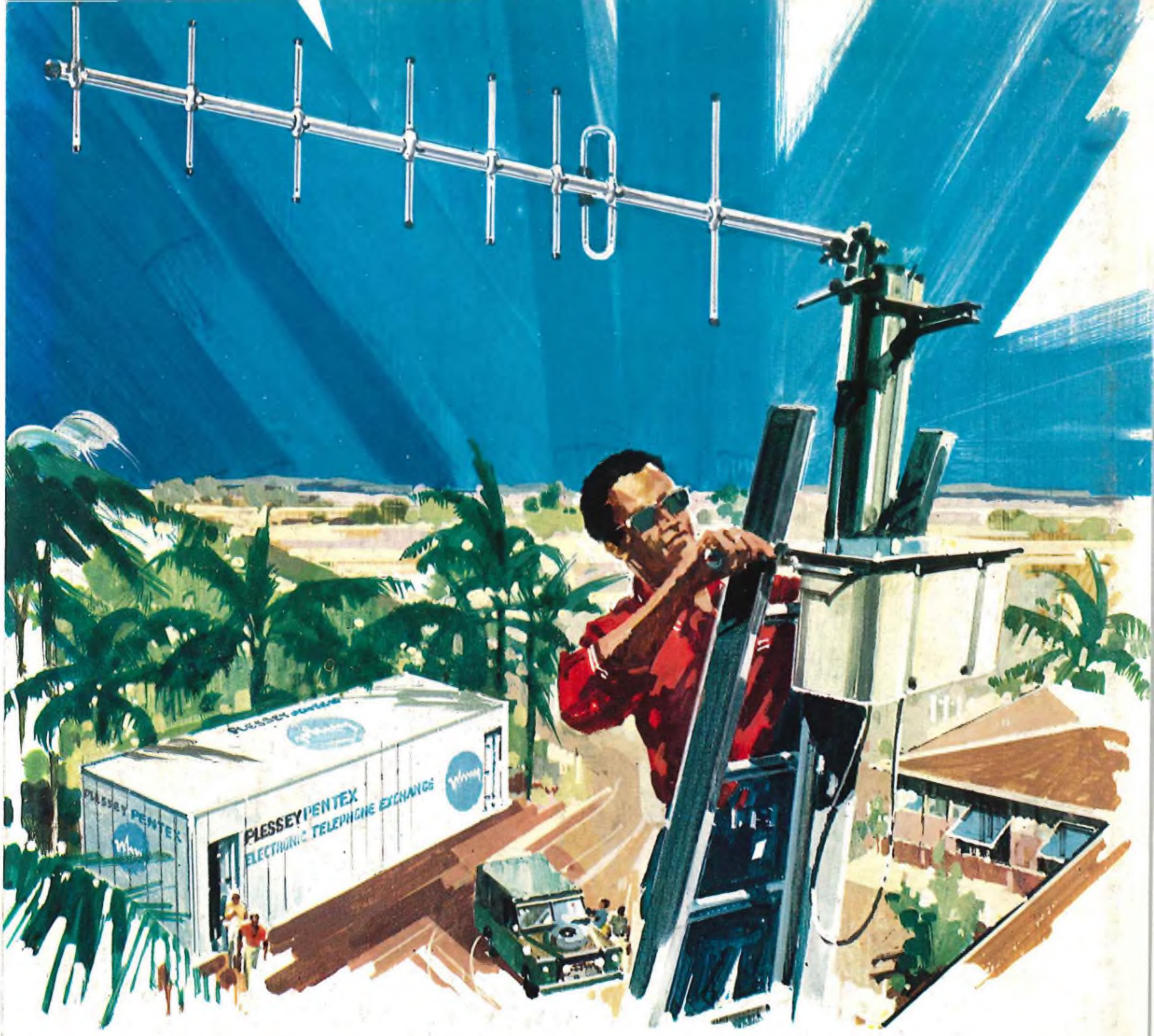

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