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THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

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Ninety-Seven Years of Engineers-in-Chief

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The course of telecommunication developments in the British Post Office is traced during the time since the Engineering Department was formed in 1870, a period during which 16 Engineers-in-Chief have, in turn, been at the head of the Department.

INTRODUCTION

THE first Engineer-in-Chief to the General Post Office was Mr. R. S. Culley, and the announcement of his appointment is contained in the Post Office Circular of the 7 February 1870. Prior to the 5 February 1870, when by virtue of the Telegraph Act of 1863 the Post Office took over the whole of the public telegraph services operating within the British Isles, these services were in the hands of a number of private companies. Under the private companies the development of the services had been sporadic and unco-ordinated, although it must be acknowledged that the companies had frequently been hampered by reason of local opposition as regards the provision of wayleaves. The largest and oldest of the telegraph companies was the Electric Telegraph and International Company, usually known by its earlier name of Electric Telegraph Company. Cooke and Wheatstone, the installation of whose five-needle telegraph system between Paddington and Slough in 1837 had demonstrated the potentialities of the electric telegraph, were associated with the formation of this company a few years later. Culley joined the company in 1846 following an introduction to Cooke in the previous year, and rose to be its Engineer-in-Chief. Most of the technical staff of the five private companies concerned came over to the Post Office, and there followed a period of intense activity during which the company services were reorganized, expanded and integrated.

The Electric Telegraph Company owned the largest of the London telegraph offices. It was situated in Telegraph Street, Moorgate Street, and to this office the central London services of the other telegraph companies were transferred. This building also provided the first location of the Engineer-in-Chief's office. However, in 1873 the office was transferred to a newly erected building in St. Martin's-le-Grand, where it remained for many years.

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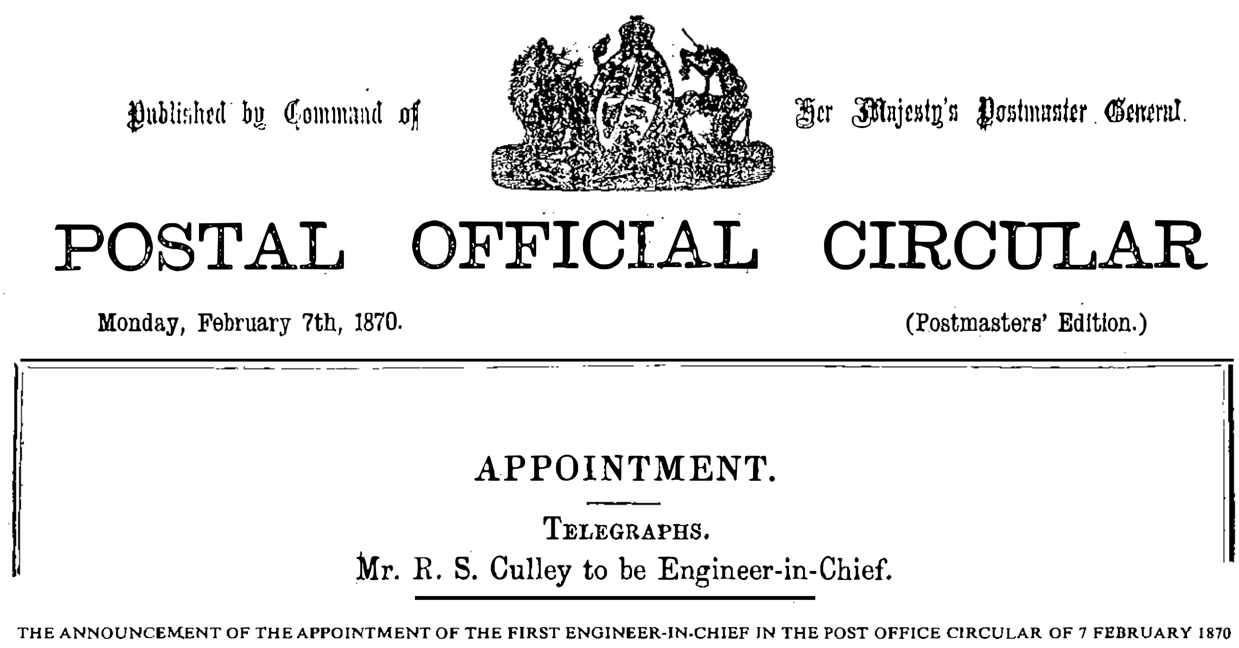
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POSTAL OFFICIAL CIRCULAR

Monday, February 7th, 1870. (Postmasters' Edition.)

APPOINTMENT.

TELEGRAPHS.

Mr. R. S. Culley to be Engineer-in-Chief.

THE ANNOUNCEMENT OF THE APPOINTMENT OF THE FIRST ENGINEER-IN-CHIEF IN THE POST OFFICE CIRCULAR OF 7 FEBRUARY 1870

Engineers-in-Chief to the General Post Office 1870–1967

R. S. CULLEY	1870–1878
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SIR ALBERT MUMFORD, K.B.E., B.Sc.(Eng.), F.Q.M.C., F.I.E.E.	1960–1965
D. A. BARRON, C.B.E., M.Sc., F.I.E.E.	1965–1967

The new building was called G.P.O. (West) and was intended as the main administrative headquarters of the Post Office. Owing to the expansion of telegraph business following the transfer to the Post Office, the accommodation at Telegraph Street had become excessively congested, and accommodation originally intended for the transaction of postal business was made available in G.P.O. (West). All the telegraph circuits emanating from central London were transferred to the new building, which later became almost exclusively devoted to telegraphs and was known as C.T.●. (Central Telegraph Office).

At this time the Engineer-in-Chief's Department was responsible for all technical matters concerned with the development, provision and maintenance of the public telegraph services in the British Isles. The plant included three submarine telegraph cables between the mainland and Ireland, one to the Isle of Man, one to the Channel Islands, and one to the Isle of Wight. There was also a cable ship, *Monarch* (500 tons), which was replaced by a second *Monarch* (1,121 tons) in 1883, this vessel being the first specially-built cable ship. The Post Office did not, however, take over the submarine telegraph cables to the Continent in 1870; these were not acquired until 1889 when the concessions to the operating companies concerned expired. At this time a second cable ship, *Lady Carmichael,* later renamed *Alert,* was also taken over.

The staff of the Engineer-in-Chief's office in 1873 consisted of the Engineer-in-Chief, his assistant, the Electrician and Submarine Superintendent, 17 clerks, 14 shorthand writers and 4 messengers. All reports and minutes had to be written out in longhand, as typewriters did not begin to come into use in business offices until the 1880s. The permanent field staff amounted to 590, in the charge of seven superintendent engineers whose districts covered the British Isles. Construction gangs, employed for the most part on the erection of overhead routes, were manned by temporary staff engaged as required. The majority of the technical staff had come over from the telegraph companies, as likewise had the operating staff. The greater part of the staff had served with the Electric Telegraph Company, and, in fact, the first five Engineers-in-Chief had all originally served with this company.

It is clear that any account relating to the Engineers-in-Chief of the General Post Office must inevitably be linked to the history of telecommunication. However, for the present purpose it is intended to do no more, nor would space permit, than give a broad outline of the general course of the developments during the period covered so as to bring them into relationship with the responsibilities and contributions of the Engineer-in-Chief and his Department at the material times.

There exists a considerable volume of literature in the form of books, articles and learned papers recording the history of telecommunication in the United Kingdom over the last 150 years. Of particular interest in the present context is the Jubilee Presidential Address[1] delivered by Brigadier Sir Lionel H. Harris in 1956 before the Institution of Post Office Electrical Engineers, and the Jubilee number of *The Post Office Electrical Engineers' Journal* of October 1956.[2] Other references are given at the end of the article.[3-8]

In passing in review over the period concerned, a period which covers almost a century of unparalleled progress and the terms of office of 16 Engineers-in-Chief, it will be convenient to recognize four eras, the first lasting up to about the close of the 19th century, when the public-message telegraph service had passed its zenith and was beginning to lose traffic to the expanding telephone services, and when Marconi's experiments in wireless telegraphy were about to come to spectacular fruition. The second period can conveniently be regarded as extending beyond the end of the First World War to include the subsequent post-war reconstruction period. This period was something of a transitional phase during which the Post Office took over the telephone services operated by the National Telephone Company, adding greatly to the responsibilities of the Engineer-in-Chief. It was also a period when developments in long-distance telephone transmission and radio were injecting a need for a more scientific approach to telecommunication problems, and the practice of telecommunication was becoming less of an art and more of a science. The third period may similarly be conveniently regarded as reaching beyond the Second World War and covering the subsequent post-war period. This was essentially a consolidating period when the preceding discoveries and developments in the field of radio and line transmission and in automatic telephone switching were exploited and further developed, and the foundations were laid for the modern electronic age which, for the present purpose, may be deemed to have begun to take its present shape during and shortly after the end of the Second World War, thus ushering in the fourth or modern era.

Each of the four periods indicated correspond approximately to the terms of office of four Engineers-in-Chief.

1870–1902

The Engineers-in-Chief during the period 1870–1902 were Mr. R. S. Culley (1870–1878), Mr. E. Graves (1878–1892), Sir William Preece (1892–1899) and Mr. J. Hookey (1899–1902)

In 1870 the electric telegraph, as a practical system of communication, had been in existence for barely 30 years, and hand-operated systems such as the morse-sounder, single-needle and Wheatstone ABC systems prevailed. About this time, however, machine telegraph systems were coming into use, mainly with a view to increasing the traffic capacity of the lines. It was a time of prolific invention in the telegraph field, and many were the devices and systems tried with a view to improving the efficiency and reliability of the telegraph circuits. The first paper to be read before the Society of Telegraph Engineers (forerunner of the Institution of Electrical Engineers) was given in 1871 by Mr. Culley, one of the founder members, on the subject of "Automatic Telegraphy."

Mr. Graves, the second Engineer-in-Chief, holds the distinction of being the youngest to occupy the office, being appointed when he was 44. He was principally regarded as having great administrative ability and financial acumen, which was of considerable value in the arbitration proceedings which ensued during the period 1874–78 with the railway companies to determine the compensation to which they were entitled upon the take-over of the telegraph services. Graves was not, apparently, of very robust health, and died in office at the age of 58, having been Engineer-in-Chief for 14 years, the longest term of office of any holder of the appointment. The following delightful description, which seems worth repeating, was penned at the time in reference to his early days, by his redoubtable successor Mr. W. H. Preece (later Sir William).

"He was a light-haired, thin delicate-looking youth, who dressed very eccentrically, appearing in London with a soft felt slouched hat, a long waterproof down to his heels, and sometimes, owing to weak eyes, wearing green spectacles."

Amongst the various activities with which he was associated it is topical to note that he was a member of the Channel Tunnel Defence Committee.

When the Post Office took over the telegraph service the average cost of an inland message was around 2 shillings for 20 words. This was immediately reduced to 1 shilling, with a notable increase in traffic. In 1885 the sixpenny telegram was introduced, and the traffic, which at the transfer was under 7 million telegrams per annum and in 1885 had grown to 30 million per annum, immediately increased by two thirds to an annual rate of 50 million. This must have put some strain on the telegraph resources of the Post Office, both as regards the equipment and lines as well as regards the operating and technical staff. Although a rapid expansion of the network was urgently necessary, the fact that the system was so well able to withstand the initial strain was in no small measure due to the technical improvements which had been introduced as a result of the constant effort, experiments and trials undertaken by the technical staff.

Sir William Preece, who at this time held the post of Assistant Engineer-in-Chief and Electrician (in these days the term electrician was used for one skilled in electrical science, cf. mathematician) and was a leading figure in the telegraph world, was a tireless experimenter and had much to do with the technical advances made in the British telegraph service. The regard in which he was held may be judged by the fact that he was President of the Society of Telegraph Engineers in 1880, Mr. Graves, his chief, not achieving this honour until 1888. It was about this time that Oliver Heaviside published the results of his classical mathematical researches into electromagnetic propagation, giving the now well-known formula for the distortionless line. Preece was not alone in failing to appreciate the significance of Heaviside's work, which was very much ahead of its time and was at first not understood by such eminent scientists as Lord Rayleigh and Lord Kelvin. Nevertheless, possibly because of the great influence he wielded in the commercial world, his initial scepticism was probably more generally reported, and led Heaviside to feel that his ideas were being unjustly opposed by Preece. In this connexion it must be remembered that, at this time, the science of electrical engineering was still in its infancy, a.c. theory had not yet been developed, and, for example, the running of alternators and transformers in parallel for power distribution was only first successfully adopted in 1888. However, within a few years Heaviside's work had been accepted by the leading academicians, principally due to the efforts of Sir Oliver Lodge, and by 1892, when Sir William succeeded Mr. Graves and adopted the style of Engineer-in-Chief and Electrician, he was writing in most optimistic terms of "the revolution in long-distance speaking through submarine cables to which the beneficial influence of mutual induction could lead."

That Sir William Preece was a man of many parts cannot be doubted. He was the author of innumerable papers and articles, an indefatigable lecturer, and co-author of standard textbooks on telegraphy and telephony. In 1898 he was elected President of the Institution of Civil Engineers, of which he had become an Associate in 1859. Amongst other things, he fostered the extension of electric lighting and claimed to be largely instrumental in introducing block signalling on the railways. In 1884 he commenced a long series of experiments with a view to establishing communication without connecting wires, which were ultimately successful in providing links to off-shore islands.

In an address delivered in 1892 on "40 years in Telegraphy" Sir William referred to the encouragement and assistance it had been the policy of successive Engineers-in-Chief to give to inventors with a view to furthering the development of telegraphy, and stated that the art of telegraphy had been advanced by the British Post Office more rapidly than by any private undertaking, and that even American inventors were looking to the Post Office for help in developing their inventions.

This claim that the Post Office had been a source of encouragement and asistance to inventors was, so far as Sir William himself was concerned, to receive a degree of justification which even he could not have foreseen, for within 3 years he was welcoming the young Marconi and giving him valuable help in his early experiments whereby Marconi was able to demonstrate the practicability of his proposals for establishing communication by means of electromagnetic radiation. The accounts of these early experiments make interesting reading, and we learn that on the occasion of Marconi's first visit to the Post Office they were conducted on the table of the Chief's private secretary, and were terminated in the afternoon upon the arrival in the room of the coachman to take the Chief back in his private brougham to his residence in Wimbledon.

These were the days when the inland telegraph service had reached its zenith, with a volume of traffic exceeding 90 million messages per annum. Great changes were, however, looming. In 1877 Sir William himself had brought from America, and demonstrated to the British Association, the first pair of Bell telephones to reach these shores, and the potentialities of the system in relation to the Postmaster General's telegraph monopoly were so far realized that in 1880 a High Court ruling was obtained to the effect that a telephone was a telegraph within the meaning of the Telegraph Acts.

Although by this ruling the Postmaster General became the licensing authority for telephone operating companies, the Post Office did not for a time take a very active part in telephone development, which proceeded through the hands of various companies. In 1892, dissatisfaction with the way the service was being developed, and realization that a satisfactory national trunk service required a single developing authority, led to the Post Office being required to take over the whole of the trunk services—the Post Office was now definitely in the telephone business.

In 1899 Mr. W. H. Preece, as he still was, retired on reaching the age limit of 65, his knighthood being conferred shortly afterwards. It was a time when the telegraph service, for which he had done so much, was beginning to feel the effects of competition from the telephone service, and the era of its supremacy as a means of communication was drawing to a close. One cannot but feel some affection for this man who brought lustre and prestige to the appointment of Engineer-in-Chief to the General Post Office, an appointment but for the untimely death of his predecessor, whose age was the same as his own, he might never have held. He took pride in the fact that he had, as he put it, studied at the feet of Michael Faraday, and in his style of "Electrician," which he retained to the end. He was a Fellow of the Royal Society, and President of the Society of Telegraph Engineers in 1880 and again in 1893 after it had been re-named the Institution of Electrical Engineers. During his time the Engineer-in-Chief's office establishment consisted of an Assistant Engineer-in-Chief, a Principal Technical Officer, a Submarine Superintendent, and a Superintendent of Electrical Lighting, together with 26 officers of other grades. The field staff consisted of about 1,000 established officers and a temporary force varying up to around 2,000 strong.

The next Engineer-in-Chief, J. Hookey, was in his 60th year when he assumed office. Although he had claimed respect for his contribution to telegraphy and was credited with a phenomenal memory, he had been, as were most of his contemporaries, very much overshadowed by his distinguished senior. Following a breakdown in health he retired in 1902.

We can, however, thank him for giving us a glimpse of the Engineer-in-Chief's private office as it was in his day.

in 1898 to investigate the methods adopted in providing telephones in large cities. As a further result of this visit it was decided to adopt the central-battery exchange system in place of the existing magneto system, and within a few years the Post Office had opened City and Central Exchanges with a total capacity of 32,000 subscribers' lines. In 1905 an agreement was concluded between the Post Office and the National Telephone Company covering the conditions under which the Post Office would take over the company's system on 1 January 1912. After the transfer there followed a period of intensive activity, during which an inventory and valuation of the whole of the company's plant was carried out with a view to establishing the purchase price. At the time of the transfer some 7,000 engineering staff were taken over, bringing the total engineering staff of the Post Office up to some 16,000. A somewhat difficult period followed since, as a natural result of the anticipated take-over, the services of the National Telephone Company had tended to run down and had not been developed and expanded as they might otherwise have been. After a time of re-organization, rationalization, and provision for expansion,

J. HOOKEY IN HIS PRIVATE OFFICE

1902–1922

The Engineers-in-Chief during the period 1902–1922 were Sir John Gavey (1902–1907), Major W. A. J. O'Meara (1907–1912), Sir William Slingo (1912–1919) and Sir William Noble (1919–1922)

The early part of this period was noteworthy for the rapid expansion in the use of lead-covered paper-insulated cables, which had been introduced during the 1890s. A number of long-distance telegraph cables radiating from London were laid, and, in agreement with the National Telephone Company, the Post Office prepared and completed an underground cable network to serve the telephone exchanges in the London area. This enabled the mass of wires and aerial cables which had festooned the streets of central London, and the enormous roof standards which had surmounted the telephone exchanges, to be dispensed with. As a preliminary to this work, Mr. Gavey, as he then was, had visited the U.S.A.

the Post Office was poised for development of the telephone service when these plans, along with many others, had to be abandoned with the outbreak of war in August 1914.

On the technical side, arising from Heaviside's mathematical researches, Pupin and Campbell in the U.S.A. had, around 1900, developed the theory of adding inductance to telephone circuits, by means of iron-cored inductance coils installed at regular intervals along their length, with a view to reducing the losses due to the self capacitance of the circuits; soon after this, experiments in "loading" cable circuits with inductance were commenced in the British Post Office. In 1910 the first fully-loaded telephone cable of importance in Great Britain was laid between Manchester and Liverpool. About this time, with the aid of improved measuring techniques, a more scientific approach could be made to the nature of speech, and the steady-state theory of telephone transmission was formalized.

About this time also, the Post Office became actively concerned in the operation of radio services with the taking over of the ship-to-shore services previously operated by the Marconi Company in association with Lloyds.

The next epoch-making event was the invention of the thermionic valve which, in the hands of the radio and telephone engineer, was to become not only a most powerful tool in expanding the range, efficiency, and quality of the telegraph and telephone services but also to serve as a means of extending the frontiers of the knowledge of the physical processes and phenomena concerned. The practice of telecommunication was now moving from a time when it had had many of the attributes of an art to become more firmly based on scientific and mathematical methods, and the need for a more formal approach to the design and development problems involved was early recognized. At first, in order to satisfy this need, steps were taken to permit the rapid advancement of those of the staff who could, by means of special competitive examinations, demonstrate that they possessed the necessary educational attainments. Also, a limited number of special appointments were made from candidates nominated by the universities; but under Major O'Meara the engineer grades were re-organized, and open and limited competitions for entry to the newly-created Assistant Engineer (now Executive Engineer) grade were introduced.

Sir William Slingo, who entered the Post Office service as a Telegraphist, was a versatile man who was noteworthy for the enthusiasm with which he took up technical training, founding a school for the teaching of telephony and telegraphy and kindred subjects which, when he relinquished his position as Principal, had 850 students. He was for a time head of the Electrical Department at East London College, and was co-author of a textbook on electrical engineering. He had associations with the foundation of the City and Guilds of London Institute, and was instrumental in establishing the close relationship which ensued between it and the Post Office. He was Engineer-in-Chief throughout the exceptionally difficult period of the First World War, when, despite the heavy war-time requirements for special services, 13,000 out of a total engineering force of 25,000 men were released, principally to be engaged in the Army Signals services. There had always been a close liaison between the Post Office and the Army Signals services, and three future Engineers-in-Chief were to give especially distinguished war-time services, while for a fourth, just old enough to enter the fray, it was to serve as his introduction to the mysteries of the signalling art.

Although since 1900 a start had been made with the loading of telephone cables, the long-distance services were still very much dependent on heavy overhead routes, which, despite the improved constructional standards, were still vulnerable to storm damage. In 1916, a blizzard, which swept across the country from the Bristol Channel to the North Sea over an area about 100 miles wide, practically demolished the overhead system, bringing down some 41,000 poles and entailing a cost for repairs of some £600,000. The new London–Birmingham–Liverpool cable, only just completed, provided for a time the sole means of communication between London and the North; the urgent need for the establishment of a network of long-distance cables to cover the country was amply demonstrated, and became one of the first major tasks of the post-war period.

Upon the conclusion of the war, public interest was focussed on the shortcomings of the telephone service. Apart from the depletion of the staff and the diversion of much effort to the meeting of military requirements, the Post Office, at the outbreak of the war, had barely assimilated the telephone services of the National Telephone Company, which, as already explained, had been allowed to run down. This, coupled with the effects of the war period itself, led to public criticism of the service in the Press and Parliamentary Committees, and it fell to Sir William Noble, who had now become the Engineer-in-Chief, to meet and rebut the attacks on his Department; this he did with considerable skill. Sir William Noble was Engineer-in-Chief for 3 years only, leaving the service to become a director of the General Electric Company and Managing Director of the Telephone Works, Coventry, which positions he held for many years.

Sir John Gavey, who was elected President of the Institution of Electrical Engineers in 1905, is perhaps to be especially remembered for sponsoring the formation of the Institution of Post Office Electrical Engineers, which was formally constituted in 1906 and whose activities have been of the greatest benefit to all concerned in fostering the progress and development of telecommunication. Major O'Meara was originally associated with the Post Office when attached to the K Company of the Royal Engineers, which had been employed in the south of England on the construction and operation of Post Office Telegraph Services. He returned after a distinguished military career to be Engineer-in-Chief, and is perhaps to be chiefly remembered for reorganizing the engineering grades, resulting in increased recognition and an improved status. He was also closely concerned in drafting the first comprehensive volume of Engineering Regulations, considered to be something of a model of its kind. His probable gifts in this direction can perhaps be gauged by the fact that, after leaving the post of Engineer-in-Chief for other fields of activity, he qualified as a barrister.

1922–1951

The Engineers-in-Chief during the period 1922–1951 were Col. Sir Thomas F. Purves (1922–1932), Col. Sir George Lee (1932–1939), Col. Sir Stanley Angwin (1939–1946) and Sir Archibald J. Gill (1946–1951)

By the commencement of this era questions of electrical theory and electromagnetic propagation had finally passed out of the area of conjecture and opinion, and the combined work of the illustrious mathematical physicists, scientists, and experimental practitioners of earlier eras had provided solid foundations for the design and building of the modern technological edifice. The previous early recognition in the Post Office of the great importance of sound technological training on the part of those who were to provide the spearhead in the advance of telecommunication was to ensure that men of great ability and character were to hand to lead the Engineering Department forward, and to give it a prestige and recognition previously unequalled. The principle that no doors were barred to young men who, by ability and sheer hard work, could prove their merit and earn the reward of a responsible part in the development of telecommunication had already provided a nucleus of gifted engineers before 1914. By 1920, however, a considerable leeway had to be made up, both from the ranks of those whose education and careers had been disrupted by the war and those who had escaped the worst of its excesses. During these years, somewhere in the recesses of the Civil Service Commissioner's Offices in Burlington Gardens, lists were periodically being prepared which contained a high proportion of names that were ultimately to become highly respected, some outstandingly so, throughout the telecommunication world.

It would be impossible, if not invidious, to attempt in the present context anything which purported to give more than the barest indication of the momentous events which marked this phase of telecommunication history. As already indicated, at the outset of the period there was a pressing need in the United Kingdom to give direction and momentum to the development of the telephone service after the uncertainties and dislocations of the previous two decades. This took two main forms. The first of these was the expansion and development of the underground trunk telephone network. Thanks to the previous advances in transmission theory and in methods of its practical application, the whole system of cables and repeater stations could now be designed, specified, manufactured, and installed to meet predetermined overall standards of performance. The other major aspect of the development was the establishment of standards of transmission, construction and performance in respect of the instruments, local cables and exchange switching equipment, coupled with the adoption of radical changes in the switching systems themselves.

Originally, essays into the field of automatic switching were little more than exercises in ingenuity with a view to finding if there was anything in it. It was some time before it was realized that it offered, in fact, the only practical way of dealing with switching in a highly-developed intercommunication system. The problem first became imperative of solution in large densely-populated urban areas with numerous telephone exchanges within relatively short distances of one another, and to meet this case special problems had to be solved. In the United Kingdom the problem of London and other large cities was solved by the introduction of the "director" system, an early exercise in the design of logic circuits; a momentous decision was thus made which allowed standardization throughout the country on the basis of the Strowger two-motion switch, and which determined the pattern of automatic switching equipment in Great Britain for 40 years. This far-reaching decision was made under the forceful leadership of Sir Thomas Fortune Purves, who himself had once been responsible for an ambitious manual telegraph switching system in the Central Telegraph Office, catering for over 1,000 morse circuits.

This also was a period of great activity in the development of radio communications, with a substantial expansion in the range and extent of ship-to-shore communications and direction-finding services. Long-wave telegraph services were introduced, culminating in the construction of the Rugby high-powered station, then the most powerful in the world, with its impressive battery of transmitting valves, and giving world-wide coverage. This station's design and construction entailed novel problems in fields covering the whole range of engineering—civil, structural, mechanical, electrical and radio—its 12 820-foot masts and aerial system offering to countless travellers by road and rail a spectacular reminder of the latest man-made wonder. It is perhaps fitting that this impressive monument to telecommunication progress should have been completed during the office of the first of the four Engineers-in-Chief for the period under review, and that his three immediate successors were the senior engineers having direct responsibility for its famed success.

This period also saw the introduction of short-wave radio-telegraph services and the beginning of transatlantic telephony, and also the large-scale exploitation of carrier telephony. Great advances were also made in respect of frequency control and frequency standards. The expansion of broadcasting services brought new responsibilities to the Engineer-in-Chief, while other accretions were the responsibility for the maintenance of the large motor-transport fleet operated by the Post Office, the Post Office tube railway, opened in 1927, and the Factories Department, originally started for the manufacture and repair of telegraph equipment but whose field of activities had been enlarged to cover various aspects of telephone work.

With these brief references to some of the landmarks of the period, and leaving the reader to fill in the many omissions, we come to 1939. Once more the resources of the Engineer-in-Chief's Department, as of the whole country, had to be given over to the prosecution of war. Although the maintenance of efficient telecommunication services for civilian use was very necessary for the purposes of government, the general war effort, and the sustaining of morale, there was also a heavy additional requirement for specialized services for defence and to meet the needs of the armed services. The importance of telecommunications (or signals to use the military term) to the armed services had never been underrated. Just as from its earliest days land-line telegraphy was of great interest to the Army, so from its inception was radio of great interest to the Navy. Like two of his predecessors in office—Col. Sir Thomas Purves, O.B.E., and Col. Sir George Lee, O.B.E., M.C.—Col. Sir Stanley Angwin, K.B.E., D.S.O., M.C., T.D., who was now Engineer-in-Chief, had given highly distinguished service in the First World War. This coupled with his interest in the Territorial Service, dating from before the First World War, had earned considerable respect in high circles for his wise counsels in Service matters and prepared the way for valuable co-operation between civilian and service personnel, both at Headquarters and in the field, in almost every conceivable facet of the operational exploitation of telecommunication techniques and services. This was a time when the body of expertise, which between the wars had been built up through the various technical branches of the Engineer-in-Chief's office and disseminated through its training organization and technical literature to the field staff, was to prove of outstanding importance, while the facilities for research and experiment established in its various laboratories, covering all aspects of telecommunication, was likewise to be of the utmost value.

Amongst the many members of the personnel of the Engineering Department who left to serve as officers or men in the Armed Forces there was again one future Engineer-in-Chief, Brigadier Sir Lionel H. Harris, K.B.E., T.D., who gave highly distinguished service and who, as already mentioned, had acquired Signals experience in the First World War and had maintained his interest through the Territorial Army.

Towards the end of the war the Post Office cable ships *Monarch* (III), and *Alert* (II) were both, unhappily, sunk after surviving many vicissitudes, leaving in service only two recent additions to the fleet, *Iris* and *Ariel*. The large

British cable ship *Faraday*, built for Siemens Bros., Ltd., was also sunk, but a new large cable ship *Monarch* (IV), 8,056 tons gross, designed for operations in deep water, was built for the Post Office and completed in 1946. This ship represented a considerable advance on any previous cable ship in respect of the scientific equipment and electrically-operated cable machinery. The extreme novelty and superb design and performance of the latter equipment was very much the product of the brilliant mind of Sir Archibald Gill. This was the ship which some 10 years later was the only one then capable of undertaking the task of laying the first transatlantic telephone cable.

Throughout this period the loss of telegraph traffic to the telephone service, which had been arrested during the First World War, continued. While at first it was the more lucrative short-distance traffic which had been primarily affected, the growth and improvement of the trunk telephone services now began to have its effect on the longer-distance traffic. A resurgence during the Second World War, when the message rate increased from 30 to 60 million telegrams per annum was succeeded by the resumption of a rapid decline. A quiet technical revolution had, nevertheless, been going on. The older forms of telegraphy had been completely replaced in the inland service by the telephone and the teleprinter, and most circuits over a score or so miles in length were carried on multi-circuit voice-frequency systems with great economies and much improved performance. A plan for completely automatic office-to-office switching to avoid the intermediate handling of teleprinter messages, largely inspired by Brigadier Sir Lionel Harris but suspended during the war, was brought into effect, and with the technical costs reduced to a relatively small proportion of the total operating costs there was little more the engineer could do to improve the economics of the service. At the same time, a subscriber-operated teleprinter-message service (telex), which had begun before the war, was reorganized and expanded as an aid to business efficiency.

In this brief review it has been impossible to mention many different facets of the development: improvement in materials, components, procedures, construction, circuit designs, signalling methods and the widespread introduction of automatic telephone exchanges, all of which enabled telecommunication to advance on a broad front.

At the outbreak of the Second World War a scheme for Regionalization, already under trial, was fully implemented, and from this time a considerable degree of devolution to regional staffs of standardized work and procedures, previously controlled in some detail from the Engineer-in-Chief's office (now to be known as the Engineering Department), was undertaken. This left the Engineering Department freer to devote its energies to long-term developments and planning, although all of the more specialized services, including the long-distance services, still largely remained under Headquarters' control.

During the war earlier signs of new uses for electronic devices multiplied, and the first stirrings of the electronic revolution became clearly evident. Logic-type circuits, based mainly on hard and soft valves, metal rectifiers and crystal diodes, began to appear in a number of commercial and military applications, such as the classical time-division multiplex systems of telegraphy, and privacy, prediction and digital-computing equipments. As yet these solutions could not generally compete in terms of size, cost, reliability, and power consumption with electromechanical alternatives for such purposes as telephone switching, although early trials gave promising results. A reversal of this situation had to await the arrival of some new electronic device. This was, however, soon to follow with the appearance around 1948—near the end of the period under review—of the first transistors.

The four Engineers-in-Chief of this period, all men of stature, and eminent engineers, can, therefore, be said to have presided over the Engineering Department when a bridge was being built from the older forms of telecommunication, not only towards a world-wide highly sophisticated means of "instant" communication, but to a whole new technological civilization in whose development, insofar as "electronics" has a major role to play, the progress achieved in telecommunication techniques has been a decisive factor. It was a time when the size, scope and range of the telecommunication services grew and multiplied enormously, with a corresponding growth in the responsibilities both Departmental and extra-Departmental of the Engineer-in-Chief. The visible manifestations of the latter responsibilities, always an important function of the office, took the form of membership of the Council and the Presidency of the Institution of Electrical Engineers, membership or chairmanship of such advisory or controlling bodies as the Royal Institution, the Radio Research Board, International Telecommunication Conferences, Broadcasting and Television Conferences and Committees, to name but a few of these activities. Noteworthy in this respect was a tour undertaken by Sir Stanley Angwin with Lord Reith in 1945, involving flying 44,000 miles and visits to all the Commonwealth Administrations to review and discuss the organization and operation of the radio and cable telecommunication facilities provided by Cable and Wireless, Ltd. The general administrative changes which followed included the setting up of a new Government-owned company of which Sir Stanley became the first Chairman on vacating the post of Engineer-in-Chief in 1946. This bare statement of a very arduous and momentous task, undertaken at the end of a period of exceptional difficulty, perhaps provides a fitting close to this brief description of a memorable era during which the Engineering Department had grown and prospered under a succession of really great leaders.

1951–1967

The Engineers-in-Chief during the period 1951–1967 were Sir Gordon Radley (1951–1954), Brigadier Sir Lionel H. Harris (1954–1960), Sir Albert Mumford (1960–1965) and Mr. D. A. Barron (1965–1967)

The events of this, the latest, phase are still too near to have passed into history and cannot, therefore, yet be viewed in proper perspective. The pace with which new developments have, in fact, followed one another and with which new devices have appeared, and the extent of the ever-widening scope of the techniques embraced in telecommunication, are such that any attempt to summarize and give balanced descriptions of them within the space available would be merely to invite criticisms of omission and inadequacy. The immense range and diversity of current work is patent from the most casual inspection of contemporary technical literature, and, for the present purpose, little more than passing references to some of the more outstanding landmarks must suffice.

Most spectacular of the achievements in the early part of the period was the successful establishment of trans-oceanic submarine-cable telephony, which, in the first flush of acceptance of Heaviside's work, Sir William Preece had daringly forecast in 1893 in terms which it would now be unfair to quote. From the development and laying of the first submerged telephone repeater in the Irish Sea in 1943, research work was continued, either at, or under, the direction of the Post Office Research Station, on all aspects of the problem, and further repeaters were laid in waters round the British coast. Not the least value of this work was that it enabled the Post Office later to enter on more or less equal terms with the American Telephone and Telegraph Company and Bell Laboratories, with their very great resources, into a joint project with them and the Canadian Overseas Telecommunication Corporation, to unite Great Britain with Canada and the United States via a repeatered submarine telephone-cable system. This project, which was soon to be followed by even more advanced British-designed systems, was, as is well known, successfully completed in 1956, by which time Sir Gordon Radley, whose courageous and decisive leadership had contributed so much to its flawless success, had moved on to yet higher responsibilities as Director General of the Post Office.

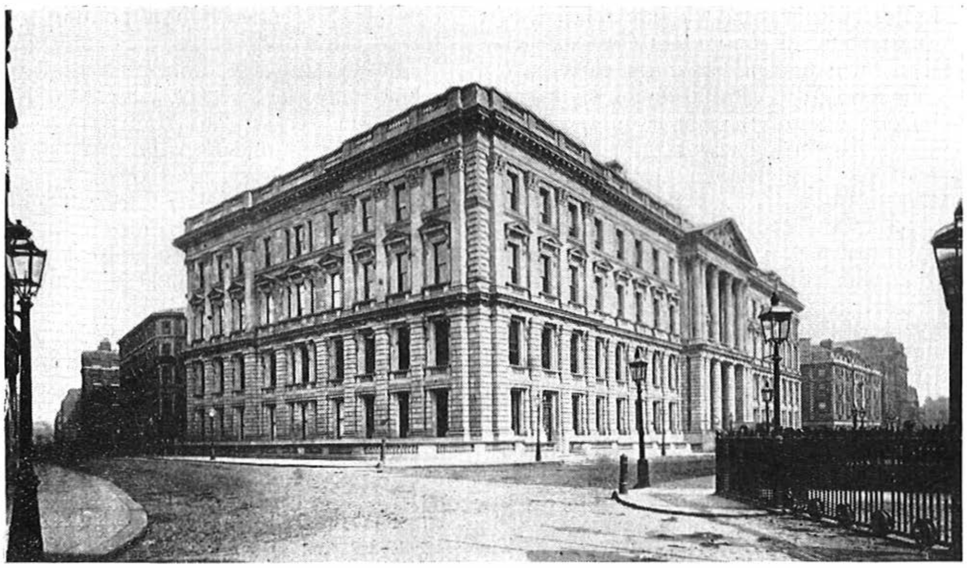
Coincident with these developments, others were proceeding in every branch of telecommunication. Early during Brigadier Sir Lionel Harris's term of office a Joint Electronic Research Committee (representing the Post Office, Associated Electrical Industries, Ltd., the Automatic Telephone and Electric Co., Ltd., Ericsson Telephones, Ltd., the General Electric Co., Ltd., and Standard Telephones & Cables, Ltd.) was set up under his direction to direct and co-ordinate the development of electronic telephone-exchange equipment, which highly complex enterprise is now coming to fruition with the introduction of developed electronic telephone exchanges.

On the radio side, amongst a number of other developments, July 1962 was to witness the first transmission of television across the Atlantic via TELSTAR to the satellite-communication ground station at Goonhilly Downs. Another radio development, spurred on by demands for more television links and greatly increased numbers of telephone trunk circuits, was in connexion with broad-band point-to-point systems which, spurning coaxial tubes, took wings (or should one say dishes) to appear as line-of-sight microwave systems. The radio engineers were again the instigators of a striking monument to progress, and when the Post Office Tower for microwave systems was erected in London during Sir Albert Mumford's tenure of office one wonders how far it served to remind him of his own pioneering days on the first coaxial-cable system.

Soon after the Second World War early steps towards mechanization of the trunk service, together with the rapid extension of the provision of automatic telephone exchanges, paved the way towards the ultimate goal of universal subscriber-to-subscriber dialling. The facility of subscriber trunk dialling (S.T.D.) was first offered to the public in Great Britain near the end of 1958, and since then it has been extended over the network with amazing rapidity, so transforming the public's approach to, and use of, the telephone trunk service as to necessitate a considerable expansion and reorganization of the trunk system and associated trunk-switching facilities. The success of these developments, the technical aspects of which had to a large extent been under the direction of Mr. Barron himself, was to be a notable feature of the scene during his own term of office as Engineer-in-Chief.

During the period under review the public telegraph service further contracted. The reasons for this were not entirely technical since, although the previous use for

Brig. Sir Lionel Harris. Sir Archibald Gill. Mr. D. A. Barron. Sir Gordon Radley. Sir Albert Mumford.
THE LAST FIVE ENGINEERS-IN-CHIEF ON THE OCCASION OF THE RETIREMENT OF THEIR SECRETARY



THE G.P.O. (WEST), SHOWING THE GROUND FLOOR (SOUTH WING) IN WHICH THE E.-in-C.'s OFFICE WAS LOCATED

social purposes of the service could be largely met by means of the telephone, there still existed a need for a rapid means of exchange of written messages and information for business purposes. High operating and delivery costs had rendered the public service uneconomic for these purposes except over the longest distances, and this need has now been met by the fully-automatic telex service with outlets to many foreign countries, a large proportion of calls to which may be dialled direct by the telex subscriber. In fact, the number of international telex calls exceeds that of international telephone calls, and while comparisons are not strictly possible it might gladden the hearts of the old telegraph stalwarts to know that the volume of telegraph traffic circulating over the telex network has grown in size to something of the order of more than twice that carried by the inland public telegraph service in its heyday.

The foregoing brief résumé offers only the barest indication of the activities of the Engineering Department during the past 25 or so years. These activities have, amongst other things, also included advances in line-transmission techniques, new signalling systems, new telephone instruments and cordless switchboards, new designs of cables, advances in postal mechanization, the introduction of data-transmission services, the exploitation of new devices and the use of computers for design, and so on.

Not to be forgotten during these years of great expansion and vast changes are the activities of the field staff who have been called on to engineer many modifications and re-arrangements in the system, to assimilate new techniques, streamline procedures and processes, and to cope with the needs for vocational training, especially heavy in times of changing requirements.

The Engineers-in-Chief during this latest period all entered the Service between the World Wars and were, therefore, essentially men of the times, who had played a major part in those earlier developments mentioned in the previous section and which prepared the ground for the great changes which were still to come. They were all brilliant engineers and highly qualified in their chosen profession: Sir Gordon, with his inspiring capacity for work, tremendous output and rapid mastery of almost any subject to which he cared to turn his attention; Sir Lionel with his gift of seeing through with clarity to the essentials of a matter which to lesser minds appeared to lie in a fog of uncertainties and contradictions; Sir Albert with his refreshing zest for tackling intricate problems, and inexhaustible energy and good humour; and Mr. Barron with his acute perception of men, their places in the scheme of things, and his incisive power of judgment.

During the last two decades when the Engineering Department has been going from strength to strength, and fostering a growing stream of brilliant and influential engineers and scientists, it has changed out of all recognition from the early days when the whole of the staff of the Engineer-in-Chief's office could be accommodated in a single wing, that bordering on Newgate Street, of the ground floor of G.P.O. (West), the last remains of which are currently in course of being razed to the ground.

Of the "Chiefs," who, throughout 97 years, have led the Engineering Department through times of both extreme difficulty and great progress, it can be said they were first and foremost great engineers, devoted to their calling—something the importance of which those, who in one way or another have been actively involved in the building and operating of telecommunication services, are perhaps better than any able to appreciate.

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The Pole-Erection Unit

R. J. HUNT†

U.D.C. 621.315.66.005:658.5.

As a result of a work study most Telephone Areas are being equipped with one or more pole-erection units. This article briefly describes the pole-erection unit and the reasons for its introduction. The training of operators, typical working procedures, and the organization and control of the unit's work are also described.

INTRODUCTION

In the past, various forms of mechanical assistance for pole-erection work have been tried by the British Post Office to a limited extent. The aids ranged from a tractor-mounted pole-hole borer, which still left the men to erect the pole, to a fully mechanized unit such as the line-construction vehicle, of which three have been in use on a trial basis for 3 years.

A work study of these machines in operation was conducted during 1964, and the results indicated that financial savings of the order of 10 per cent could be expected from the introduction of total mechanization of poling work.

In addition to this, considerable savings are to be expected from the streamlining of the remainder of the overhead work which becomes possible when the poling content is removed. The number of men in each working party can be reduced, and smaller vehicles can be used, with resultant direct financial savings and an increase in the efficiency of working. Estimates of these savings have been made, but reliable figures will not be obtained until the new methods have become established and further work study has been conducted.

†Mr. Hunt is now with the Ministry of Public Building and Works but was formerly in the External Plant and Protection Branch, Engineering Department.

[1]Ward, W. C. A Line-Construction Vehicle. *P.O.E.E.J.*, Vol. 55, p. 226, Jan. 1963.

Most Telephone Areas will be equipped with these specialist machines to deal solely with poling work; a total of 100 have been purchased, and their allocation to Telephone Areas has been made on the basis of the number of poles erected annually. The majority of Areas have at least one machine and some have up to four.

PRINCIPAL FEATURES OF UNIT

Comparison With Line-Construction Vehicle

The line-construction vehicle[1] was designed as a multi-purpose vehicle, and was equipped to carry out such operations as underground cabling, moleploughing, and overhead wiring and cabling work as well as pole erection. These extra features are not required in the present application, and the pole-erection unit is intended to be used at this stage for the erection and recovery of poles and the provision of stays.

The main differences between the pole-erection unit and the line-construction vehicle are that the winch is smaller and mounted on the end of the jib, a personnel bucket for the jib is not provided, and a heavier chassis and different body are provided to increase the pole-carrying capacity.

Dimensions and Capacities of Pole-Erection Unit

The machines are of two types, the King "Tel-E-Lect" (Fig. 1) and the Simon "Polecat" (Fig. 2), and differ in some details although they are broadly similar in function. All pole-erection units will be painted yellow. A brief specification of the main features of the machines is given below; figures for the Polecat, if they differ from those for the Tel-E-Lect, are given in brackets. When

FIG. 1—GENERAL VIEW OF KING TEL-E-LECT MACHINE

FIG. 2—GENERAL VIEW OF SIMON POLECAT MACHINE

the vehicle is carrying poles these may project beyond the dimensions given for the overall length and height.

Overall length (unladen): 21 ft.

Overall width with stabilizer jacks retracted: 8 ft (8 ft 6 in.).

Overall height (unladen): 12 ft.

Gross moving weight: 11 tons 2 cwt.

Pole-carrying capacity: 30 cwt. This represents approximately nine poles of assorted sizes in common use.

Lifting capacity: 1 ton at a radius of 6 ft (4–10 ft), and 8 cwt at the maximum radius of 24 ft 6 in. (22 ft 6 in.).

Auger size: 12 in. diameter, but others could be fitted.

Maximum depth of boring: 6 ft 6 in. This can be increased in 1 ft steps to 11 ft 6 in. by repositioning the auger down its driving shaft.

Reach of jib for boring: 14–22 ft (13 ft 6 in.–21 ft).

Maximum size pole which can be erected or recovered: approximately 50 ft, subject to weight limitations.

Ancillary equipment: hydraulic backfill tamper and pole-recovery jack.

TRAINING OF OPERATORS

The pole-erection unit operators must become skilled specialists in order to make maximum use of the machine's capabilities and to avoid causing expensive damage due to misoperation. They are, therefore, selected for their mechanical aptitude combined with a good basic knowledge of overhead work, and receive specialist training in the operation and day-to-day maintenance of the machine. The training consists of an intensive 1-week course at the Home Counties Regional Training Centre, and covers basic manipulation of the machine, detection of buried underground services plant, a limited amount of actual pole-erection work, and day-to-day maintenance. A minimum period of 3 weeks is then spent with a working party experienced in using the pole-erection unit in the field to gain a broader appreciation of the problems likely to be encountered.

Experience has shown that, due to the unusually heavy and uneven wheel loadings, driving the pole-erection unit over bad ground conditions requires specialist training, and this is also being arranged.

USING THE POLE-ERECTION UNIT

Detection of Underground Services Plant

The size, power and speed of operation of the soil auger are such that it is essential to make every effort to ensure that there is no underground plant present which it might damage, and local-authorities' records must always be consulted before boring operations are undertaken.

The possibility of developing a special detector for underground plant has been considered, but, for the time being, the best existing equipment for the purpose, the Locator No. 1A, is being used. The Locator No. 1A is basically a transistor radio-frequency transmitter and detector set, which combines the functions of a metal detector and track locator. The basic way in which it is used by pole-erection unit operators is to position the detector over the proposed pole position and to carry the transmitter in a circle around the detector. The two parts of the instrument are kept in alignment during this operation, and if the transmitter passes over metallic services plant, which also runs past the proposed pole position, a signal is heard in the detector headphone; Fig. 3 shows the instrument being used in this way. Obviously, great care must be exercised in checking the proposed pole site.

In addition to metallic services plant there are, unfortunately, a considerable number of empty earthenware pipes, plastics and asbestos-cement pipes, buried brick structures, etc., for which there is no means of detection.

The presence of manhole covers, stopcocks, reinstatement scars, etc., on the surface and their layout in relation to the roads and any adjacent houses, etc., can often provide an indication of the positions of underground services plant, and in some instances it will be obvious from this information that it would not be safe to bore.

FIG. 3—LOCATOR No. 1A BEING USED TO CHECK A PROPOSED POLE POSITION

In the absence of any positive indication from the Locator No. 1A, or of any deduced information such as that described above, it is assumed that the position is safe for boring, unless there is some other doubt which warrants the excavation of a pilot hole by manual means.

Pole Erection

In a straightforward case of erecting a pole the sequence of operations is as follows.

(*i*) Team puts on safety helmets, positions the vehicle, sets out road signs, etc., and engages the power take-off to drive the hydraulic system.

(*ii*) The proposed pole position is checked for the presence of buried services.

(*iii*) The stabilizing jacks are lowered, and, using the jib as a crane, the pole is unloaded from the vehicle and set down on the ground on a pole horse for dressing.

(*iv*) The auger is released from its rest position on the side of the jib, and is lowered into the working position. The pole hole is bored and the auger is restored to its rest position.

(*v*) Using the jib as a crane, the pole is picked up at a point about one-third of its height from the top and is raised into a vertical position by winching it in to the tip of the jib.

(*vi*) The pole is manoeuvred into the pole hole by rotation, extension, elevation and depression of the jib, as necessary, and the jib is used to hold it vertical during backfilling (see Fig. 4).

(*vii*) The hydraulic backfill tamper is connected to the hydraulic-accessory points, and is used to backfill around the pole.

(*viii*) The vehicle is finally restored to road trim.

This sequence of operations can take as little as 20 minutes under ideal conditions. In practice, five to nine poles are usually erected by one pole-erection unit in one day.

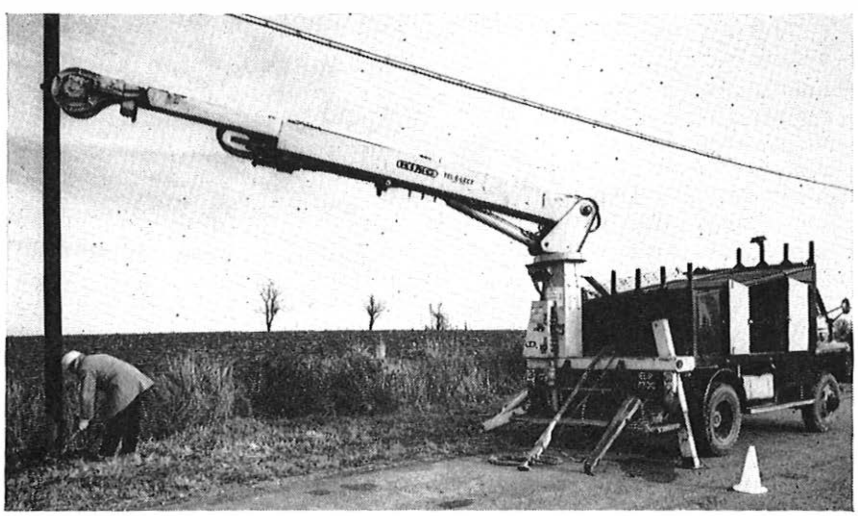


FIG. 4—POLE BEING HELD IN POSITION DURING BACKFILLING

Pole Recovery

For pole recovery the machine is set up as shown in Fig. 5, using similar techniques to those described above. The hydraulic jack is connected to the hydraulic-accessory points, the grip on the pole being obtained by fixing a chain around the pole and engaging it in a fork at the top of the jack ram. The pole is then jacked out, the winch rope, holding the top of the pole, being kept just sufficiently tight to steady the pole as the butt comes out of the ground. The pole is then lowered to the ground, ready for any stripping that may be necessary before loading it on to the vehicle.

The pole is under complete control all the time, and this ensures a high degree of safety compared with manual methods.

FIG. 5—MACHINE SET UP TO RECOVER A POLE

Staying

A new type of stay anchorage[2] has been introduced to replace the existing stayblock method, thus speeding up this part of the overhead-construction process to match the speed of the pole-erection unit for poling.

A screw-in stay anchor is installed by the pole-erection unit in line with the proposed line of the stay wire. The anchor is driven in by an adaptor, which is virtually a long box-spanner fastened to the auger driving shaft in place of the auger itself. The adaptor passes over the stay-anchor rod and engages on a square boss just in front of the anchor plate (see Fig. 6).

The installation of a screw-in stay anchor takes only a matter of minutes, and the holding power that can be obtained is adequate for over 95 per cent of staying situations encountered. In the few instances where heavier staying is required two or more separate stays are fitted, each with its own anchor.

A new method of terminating stays using helical wrap-on stay grips is being introduced in conjunction with the screw-in stay anchor, and this will further speed up the staying operation.

[2]LUND, A. E. Stay Anchorages. *P.O.E.E.J.*, Vol. 59, p. 53, Apr. 1966.

ORGANIZATION AND CONTROL OF POLING WORK

Initially the pole-erection unit in a Telephone Area will work to a "poling control," in the major-works control or in the installation control; this is another matter that will be reviewed when mechanized poling has become established.

The function of the poling control is to receive all requests for poling work from advice notes,* from extracts from estimates for development work, and for maintenance and renewal work. The work is then programmed and issued to the pole-erection unit party in an order which is determined on such considerations as priority, grouping of work in a geographical area, and reduction of travelling. As an aid to this programming, each poling control is equipped with a large-scale map of the Telephone Area on which the positions of works are indicated to provide an initial visual guide. It is expected that the pole-erection units will erect practically all the poles, the exceptions being where the site is either inaccessible, such as in a back garden, or is very remote.

FIG. 6—SCREW-IN STAY ANCHOR AND ADAPTOR BEING STARTED INTO THE GROUND

*Advice note: a document issued by the Sales Division of a Telephone Manager's office and which constitutes the authority for carrying out certain installation or other work.

Ratchet Relay No. 2

F. HAYTHORNTHWAITE†

U.D.C. 621.318.56

A mechanism incorporating two ratchet relays has been developed; it enables spring-sets to be operated when the two cam assemblies are stepped to predetermined positions relative to each other. The mechanism has particular application in circuits such as those associated with coin-boxes in which it is necessary to allocate time against prepaid money.

INTRODUCTION

THE mechanism known as the Ratchet Relay No. 1[1] has been used successfully in numerous exchanges throughout the country for a number of years, performing a variety of functions. The facilities offered by this relay have been extended by the design of a new device,[2] known as the Ratchet Relay No. 2.

Basically, the new device consists of two ratchet-relay mechanisms, mounted side-by-side on a common frame and using a single spindle for the cam assemblies. The two mechanisms are functionally independent but operationally interdependent, and by the use of interrupter springs and specially cut cams each mechanism will, after use, return to a normal or "home" position. In order to provide specific contact operations when the two cam assemblies are disposed to each other by pre-determined angular amounts, a spring-set is fitted to one cam assembly and an auxiliary cam is fitted to the other. This cam has the risers formed on its flank rather than, as is more usual, on the periphery. By suitable positioning, the contact springs can be arranged to be actuated in the home position or whenever the two mechanisms have made the same number of steps from the home position. These springs are known as the "coincidence" springs, and the positions where they are actuated as the "coincidence" positions. By suitably cutting the auxiliary cam a second contact closes when one mechanism is a predetermined number of steps in advance of the other. These contact springs are known as the "sector" contact springs and the positions where they are actuated as the "sector" positions. The coincidence and sector springs comprise a single 3-position change-over contact unit.

Fig. 1 shows a general view of the complete mechanism, and Fig. 2 a view of the underside of the mechanism.

DESIGN DETAILS

The relay is arranged to mount on 3,000-type relay-set plates and occupies three relay drillings. For maintenance reasons the relay is arranged to divide into two parts: one, the mechanism itself, i.e. magnets, cams, etc.; the other, a mounting bracket which carries the spring-sets, etc. This latter part is secured to the relay-set plate by means of resilient mountings, the purpose of which is to restrict vibration caused by magnet operations from passing via the mounting plate to any relay contacts situated nearby. Also associated with this part is the jack into which the mechanism plug can be fitted. This arrangement allows all the spring-sets to be permanently wired, and, at the same time, permits the mechanism to be removed for maintenance purposes. The association of the two parts is by two captive screws, secured to the spring-set mounting and fitting into tapped holes in the mechanism frame. Fig. 3 shows the parts separated.

The frame of the mechanism is of "U" section; midway between the limbs two supporting brackets are secured to the frame, and the magnet assemblies are located between these supports and the outer limbs. Below the magnet coils, the armature knife-edge bracket is situated; as this bridges the space between the supporting bracket and the outer limb of the frame, a rigid mounting is achieved. Fitted to the underside of the knife-edge bracket is the armature-restoring spring and the interrupter spring-set; the tags of the latter, together with the coil terminations, are soldered to a small 4-way plug which forms part of the rear cheek of the coil itself. From the above description it will be seen that removal of the mechanism is a simple operation.

Towards the front of the mechanism, and extending over the full

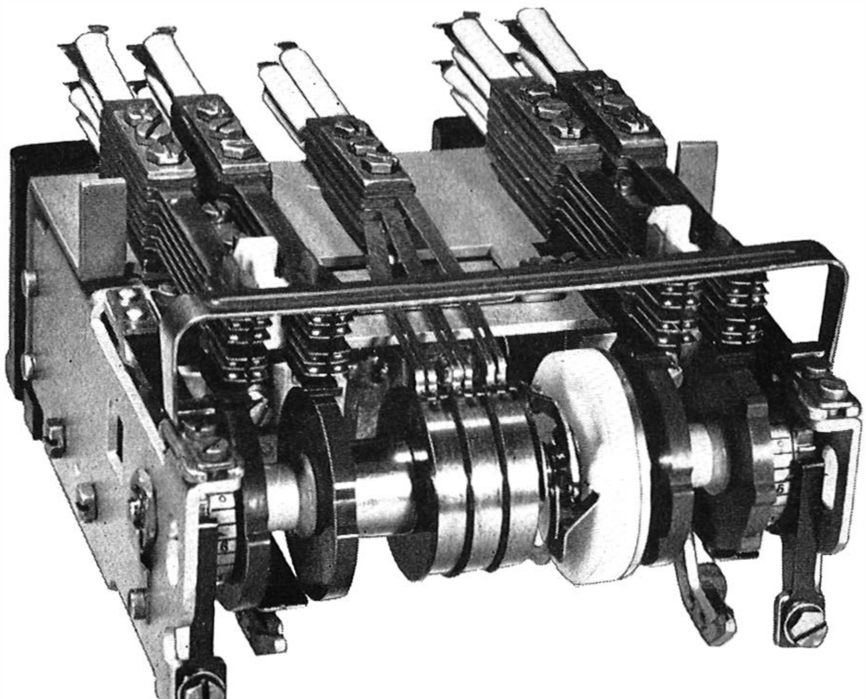


FIG. 1—RATCHET RELAY No. 2

†Telephone Exchange Standards and Maintenance Branch, Engineering Department.

[1]MANNING, D. J. Ratchet Relay No. 1. *P.O.E.E.J.*, Vol. 53, p. 154, Oct. 1960.

[2]British Patent Applications. No. 32883/64 and 48390/64.

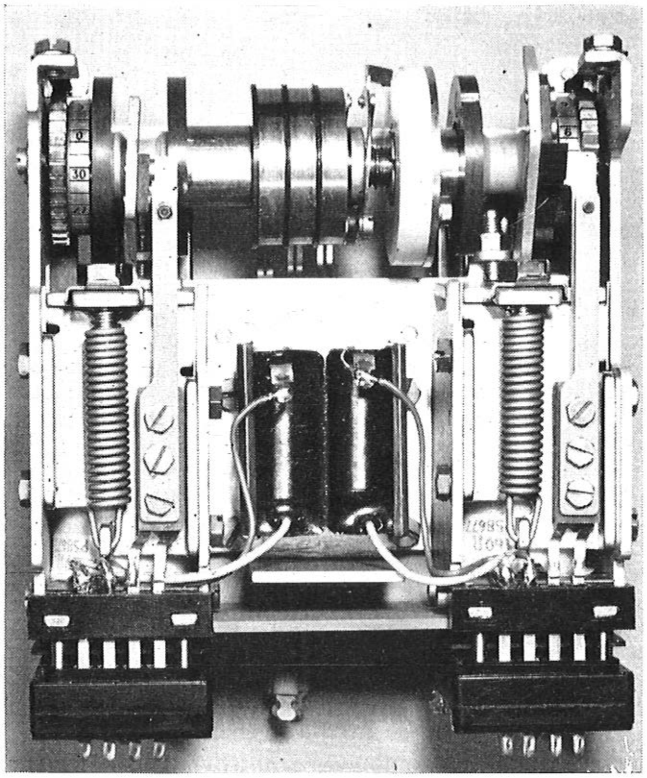


FIG. 2—UNDERSIDE OF MECHANISM

width of the frame, is located the spindle on which the two cam assemblies A and B rotate. Screwed bushes are provided at each end of the spindle to permit lateral adjustment of the cams, and to limit end-play to a minimum—a requirement necessary for the satisfactory functioning of the coincidence contact springs fitted to one cam assembly. The cam assembly shown on the left in Fig. 4, assembly A, consists of a ratchet wheel mounted concentrically on a brass tube on which two cams, known as the N and S cams, collector disks and contact springs are clamped. Cam assembly B is similar in construction, but carries an additional cam for the purpose of actuating the contact springs on assembly A.

Considerable variations of spring-set operation can be obtained by the use of different cams in the N and S cam positions and also by varying the number of teeth on the ratchet wheel. If, for example, the mechanism has a 36-tooth ratchet wheel, it is possible to use cams to actuate the springs on any step or series of steps between 0–36. Should the circuit require fewer steps than 36, additional home positions can be provided, equally spaced round the periphery of the cams. Provision is made for each mechanism to self-drive home, if required, by using interrupter springs in series with the magnet coil and under the control of a break contact actuated by the N cam. By this means each part of the mechanism will always return to a set position, e.g. position 0, after use.

The springs of the coincidence spring-set are secured to the collector disks by screws that establish the electrical connexion between each spring and its collector. This method of assembly allows individual springs to be replaced during maintenance; also, from the manufacturer's point of view, the spring-set can be assembled as a complete self-contained unit, fully adjusted and ready to assemble on the cam hub.

The ratchet wheel, cams and collectors are clamped to the hub, in specific positions relative to each other, and, to enable this to be done quickly and accurately, a datum hole is provided in each item. After being loosely assembled, a rod is passed through the datum holes and the assembly is then clamped rigidly, in a special fixture, by means of a circular nut screwed on the hub. The second cam assembly is aligned in the same way, but, in this instance, the auxiliary cam can be independently adjusted within a narrow range, to cater for any slight variations in the position of the operating tongue of the lever spring of the coincidence contact-unit. The auxiliary cam is fixed to the assembly by means of two screws that pass through elongated holes in a metal disk. By loosening these screws, the cam itself can be rotated sufficiently to obtain the correct position of the tongue of the lever spring on the cam riser. As the cam form is produced on the flank rather than the edge, it follows that the coincidence lever-spring is moved to and fro in a direction parallel to the spindle.

The coincidence spring-set is special in two respects: firstly, it rotates with the cam assembly, and, secondly, it is arranged to have a mid-way position, when all springs are disconnected from each other. This 3-stage function necessitates a greater movement of the lever spring, to provide adequate contact gaps. The height of the risers on the auxiliary cam determines the movement of the lever spring, and the angular position of the risers determines the step when the springs operate and release.

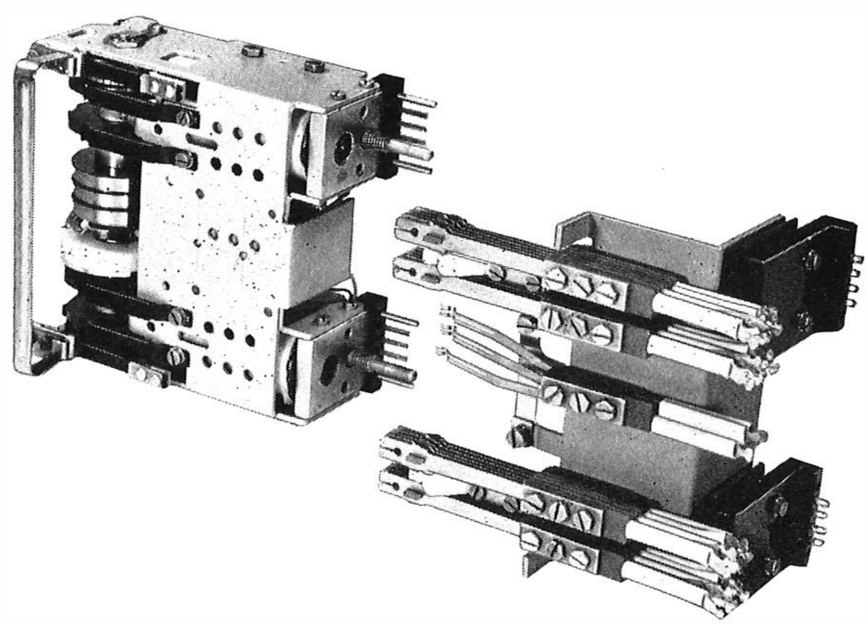
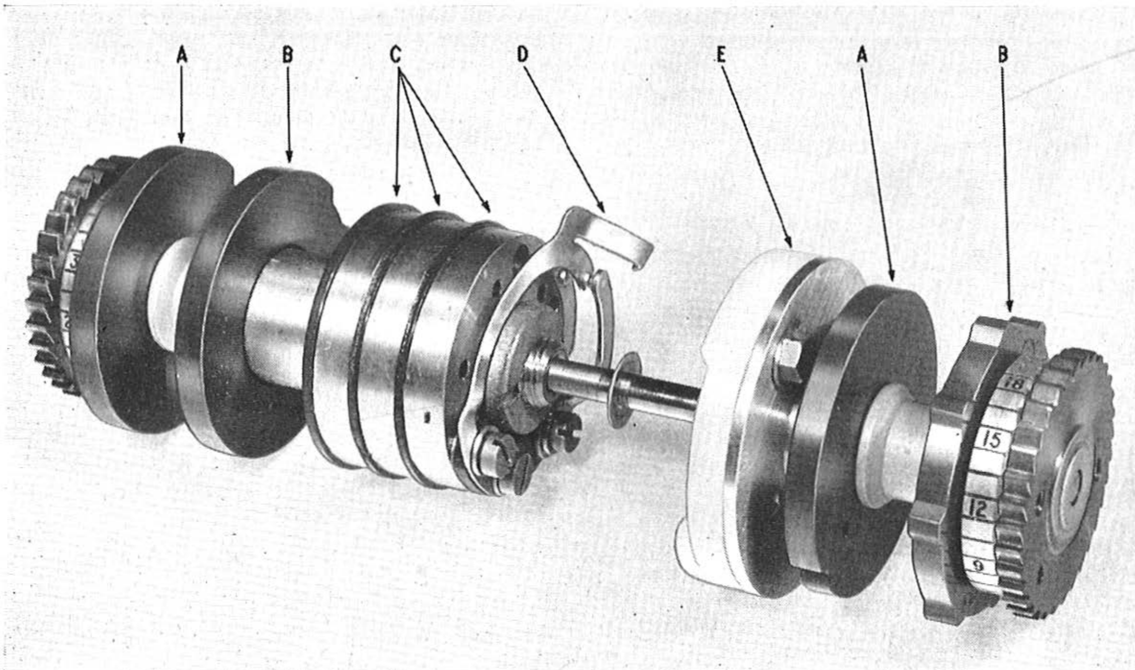


FIG. 3—THE TWO PARTS OF THE MECHANISM SEPARATED



A—N cam. B—S cam. C—Collector disks. D—Coincidence springs. E—Auxiliary cam.

FIG. 4—CAM ASSEMBLIES A AND B

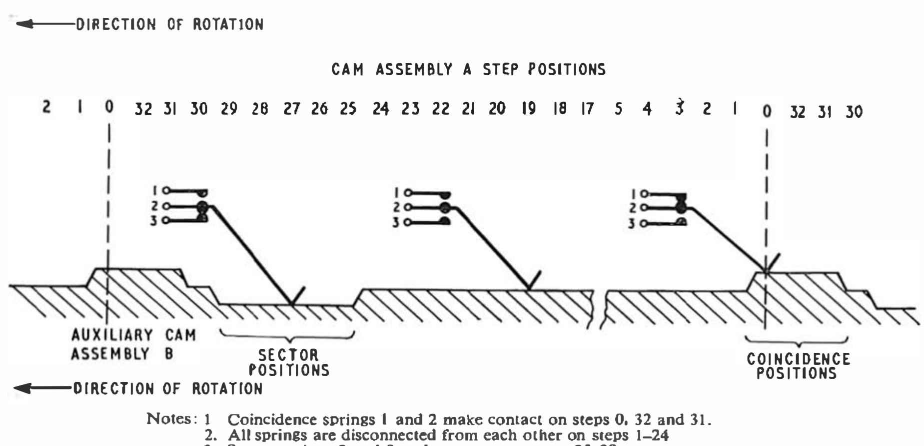
Fig. 5 shows in schematic form the functions of the springs in three positions. Each mechanism has a number wheel attached to the ratchet wheel, engraved according to the number of teeth on the ratchet wheel. The tip of the detent has been specially shaped so that it serves as a pointer, in addition to its normal purpose.

The springs operated by the N and S cams are similar in form to those used on the Ratchet Relay No. 1, but have been redesigned at the tag end to ease fitting to the mounting plate, and lengthened to facilitate the termination of the wiring. The contact ends of the springs have been modified by adding a second tongue to each make and break spring. This additional tongue, together with the new form of tag, allows the spring-sets to be fitted to either side of the buffer block, thereby avoiding the necessity to stock left-hand and right-hand spring-set assemblies for each contact action. This change has advantages to both manufacturer and the user, particularly from a replacement aspect and because of the reduction in the different types of spring-set to be stocked.

Provision is made to extend the connexions from the coincidence springs to tags at the rear; this is achieved by the use of brushes which bear on the collector disks. The individual brushes are formed to a "V" shape where they bear on the disks, to provide high contact pressure; they are split for a short distance along their length to give a twin contact. The brushes are formed into a spring-set, the bottom clamping plate of which is shaped so that it can pivot about its mid-point. This permits the contact force of the brushes on the collector disks to be readily adjustable. Measurement of the contact force has been simplified by extending the brush forward of the "V" to give an access point for a measuring gauge.

ELECTRICAL PERFORMANCE

The mechanism is required to step to 30 ms pulses at a frequency of 20 pulses/second and to be capable of a self-drive speed of 33 steps/second. These requirements could not be met with any of the existing magnet coils used on the Ratchet Relay No. 1, so a new coil of 160 ohms was developed, which enabled the conditions to be met with adverse adjustments over a voltage range of 46–52 volts. Life tests carried out on prototype



Notes: 1 Coincidence springs 1 and 2 make contact on steps 0, 32 and 31.
2. All springs are disconnected from each other on steps 1–24
3. Sector springs 2 and 3 make contact on steps 25–29

FIG. 5—DIAGRAM SHOWING POSSIBLE SPRING POSITIONS WHEN CAM ASSEMBLY B REMAINS ON STEP 0

samples indicate that a life of 50 million steps can be expected, without failure or need for re-adjustment, with the mechanism in adverse adjustment. These tests included stepping under pulses of the correct speed and ratio, and also self-drive stepping, the former being the more onerous condition to be met in practice. At the termination of the tests, the mechanisms still met the requirements.

OPERATION OF COMPLETE MECHANISM

In order to describe the operation of the mechanism, it will be assumed that it is used in a circuit where time is to be allotted after payment has been made. As stated previously the mechanism can be considered as two separate parts, referred to as assembly A and assembly B, respectively. Assembly A will be activated by the insertion of coins in a suitable collecting box, each coin creating a pulse or pulses according to its value. Assembly B will respond to pulses which indicate the completion of a specific period of time.

Both parts of the mechanism will be on position 0, the home position, when brought into use. On receipt of the first coin pulse, assembly A will rotate one step, causing the coincidence springs 1 and 2 (Fig. 5) to disconnect the pay-tone signal applied by these springs to the caller. The insertion of further coins will cause the mechanism to step once for each unit of money. As each unit of time elapses a pulse is sent to assembly B, causing this mechanism to rotate one step for each pulse. When both assembly A and assembly B have made the same number of steps, the coincidence contacts re-make and re-apply the pay-tone to the line. Should further coins be inserted, the above operations will be repeated as often as necessary. The caller may anticipate that the call will be of fairly long duration and, to avoid interruptions, may insert a number of coins; provision is made for this possibility, up to an ultimate maximum of 29 money units. In order to limit credit storage to this value, arrangements are made so that any coin inserted after the 24th unit has been credited closes the payment slots in the collecting box after the coin has been accepted. The maximum credit units, therefore, depend on the unit value of the last coin inserted, and will vary between 25 and 29. As time is used, the coin slots become "unlocked" when the credit falls to 24 units.

These operations are made possible by shaping the auxiliary cam to actuate the sector springs 2 and 3 (Fig. 5) on steps 25–29 of assembly A and connect the circuit to operate the coin-slot locking mechanism in the collecting box. On termination of a call, both parts of the mechanism return to their home positions under the action of the interrupter contacts.

From the above it will be seen that the mechanism as a whole does not restrict in any way the duration of a call, and in no way does it depend on the number of teeth on the ratchet wheel. It is flexible in so far as the "time" allowed for a unit charge can be varied to cater for the fastest metering rates now envisaged, without any change to the mechanism itself.

CONCLUSIONS

This article describes a mechanism with which it is possible to allocate periods of time against prepaid money, and its use in the telecommunications field. The principles involved enable this type of mechanism to be used in other fields where it is desired to measure one quantity against another, providing that the measurement of each quantity can be converted into electrical pulses.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the help given by colleagues in the E.-in-C.'s Office in compiling this article, and also to the General Electric Co., Ltd., who have developed the mechanism for the Post Office under the British Telephone Technical Development Committee procedure.

Book Reviews

"Electron Tubes." R. G. Kloeffler, Professor Emeritus of Electrical Engineering. John Wiley and Sons, Ltd. viii+262 pp. 202 ill. 45s.

The appearance of yet another book devoted to the basic characteristics and associated circuits of the transistor would be regarded by many electronic engineers as superfluous. How much more so, therefore, is the publication of a new elementary textbook devoted to the receiving-type thermionic valve?

The path followed is conventional. After opening with a very brief discussion of electron emission, the common electrode configurations are considered, occupying about the first half of the book. The remainder is an examination of simple amplifier circuits and power supplies, except for the last chapter which returns to devices with a seemingly random selection, including X-ray tubes and cathode-ray tubes.

The book has some claim to distinction based on its generous use of graphical methods. It might on this account commend itself to the student who must perforce embrace the thermionic valve for its historical interest as a member of the family of active devices, or who is perhaps associated with the fifty million or so valves still manufactured in the the United Kingdom every year.

Even with question of its justification set aside, however, it is not easy to muster confidence in this volume, due to the many mistakes so easily discerned, ranging from simple confusion between deg. C and deg. K to the erroneous assertion that contact e.m.f.s do not matter, not to mention the diagram of a frame grid which never existed.

Altogether an odd product of the U.S.A., 1966.

F.H.R.

"Physical Principles of Magnetism." F. Brailsford. D. Van Nostrand Co., Ltd. x+274 pp. 153 ill. Cloth 60s., paperback 30s.

Although Professor Brailsford is an engineer, his book will be more easily intelligible to physicists then to engineers. It truly covers the ground described in its title and shirks nothing in giving adequate accounts of modern theories of magnetism, including the diamagnetic, paramagnetic, ferromagnetic, ferrimagnetic and antiferromagnetic varieties. It is well balanced, and room has been found for a surprising amount of useful background. The final chapter on technological aspects of magnetism attempts to survey the whole range of materials now available; but the technical problems of these materials cannot, in so short a space, be adequately related to the theory given in the rest of the book.

The units are intended to be M.K.S., but C.G.S. units have intruded occasionally.

The diagrams, the references, and the index are good, and the book does credit to the printer and publisher as well as to the author.

A.C.L.

Joint Loading of Local-Line Cables

K. G. T. BISHOP, C.Eng., A.M.I.E.R.E., and H. E. ROBINSON†

U.D.C. 621.395.743:621.372.221:621.315.2

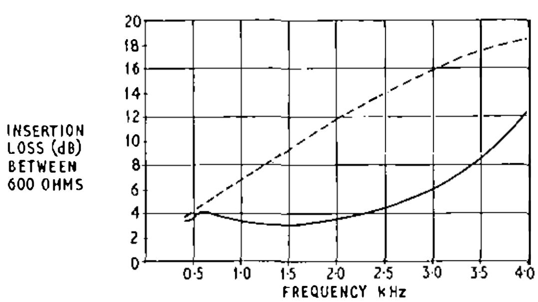
The change from open-wire to covered conductors in the local-line network has necessitated the loading of some subscribers' circuits in rural areas. The factors involved and the techniques employed are described.

INTRODUCTION

IN rural exchange areas long overhead routes have been for many years a feature of the local-line network. The conductors of these routes had low attenuation, of the order of 0·25 dB per mile, which met the transmission requirements of lines to subscribers located many miles from the exchange. With normal development the number of open wires on a route grows, and eventually the circuits are diverted to cables, either aerial or underground. Nowadays it is planning practice to provide cables along a route initially, and the familar open-wire routes will, in time, disappear.[1]

The change-over to cables, with their higher resistance and attenuation, has produced both signalling and transmission difficulties in the provision of exchange lines to subscribers in remote areas. Difficulties with transmission occur more frequently than with signalling, as the following example illustrates. The d.c. resistance of 11·3 miles of 20 lb/mile cable is 1,000 ohms, but the transmission equivalent resistance (T.E.R.) is 1,490 ohms. A line of this length, connected to an automatic exchange with a signalling and transmission limit of 1,000 ohms, would be just within the signalling limit, but the transmission performance would be 490 ohms T.E.R. outside the limit. Experimental work has been carried out on the development of a 2-wire amplifier to reduce the transmission losses of local lines, but adequate stability is difficult to obtain. The most promising method of reducing loss so far has been to introduce inductive loading into the cable pairs. If the signalling limit is also exceeded, as may occur with longer lines, signalling units can be fitted in automatic exchanges to effectively increase the limit to 2,000 ohms.

The loading of cable pairs with inductance is not a new technique. It has been the practice of the Post Office to load trunk and junction cables for the past 60 years, but the use of loading on long routes of subscribers' cable in rural areas is a departure from the normal method of local-line provision. Improvements in magnetic-core materials, leading to a reduction in the size of the individual loading coils, has helped to make this possible. Up to 39 small coils of 88 mH inductance can be inserted in the joints of small-size cables without resorting to unduly large jointing sleeves. These small coils, as used in joints, are called "unicoils."



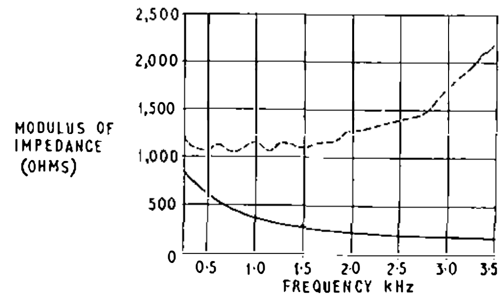
- - - - - Non-loaded pair
——— Pair loaded with 88 mH at 1,500 yd intervals

FIG. 1—INSERTION-LOSS/FREQUENCY CHARACTERISTICS OF NON-LOADED AND LOADED 20 lb/mile POLYTHENE-INSULATED TWIN CABLE PAIRS

Fig. 1 shows the reduction in insertion loss and in loss/frequency distortion following the loading of 7 miles of 20 lb/mile polythene-insulated twin cable.

PRACTICAL CONSIDERATIONS

One of the results of adding inductance to a cable pair is to increase its characteristic impedance. The impedance/frequency characteristics of loaded and non-loaded 20 lb/mile polythene-insulated cable pairs are shown in Fig. 2, from which it can be seen that the modulus is approximately doubled by loading. This has a degrading effect upon both the cable crosstalk and the sidetone performance of the telephone.



- - - - - Pair loaded with 88 mH at 1,500 yd intervals
——— Non-loaded pair

FIG. 2—IMPEDANCE/FREQUENCY CHARACTERISTICS OF TYPICAL 20 lb/mile POLYTHENE-INSULATED TWIN CABLE PAIRS

Crosstalk

For lines terminated in their characteristic impedance near-end crosstalk, resulting from capacitive couplings and measured in millionths of the disturbing signal, is proportional to the modulus of the impedance of the lines. At audio frequencies crosstalk between cable pairs is almost entirely due to capacitive rather than magnetic couplings, so that, providing the former remains unchanged, doubling the modulus doubles the crosstalk in millionths. When expressed as crosstalk attenuation the degradation amounts to 6 dB.

From a field study it is estimated that the near-end crosstalk attenuation between adjacent pairs in twin cable at audio frequencies is 94 dB with a standard deviation of 10 dB. 99·5 per cent of adjacent pairs will have a value better than 70 dB, the remainder having values down to 64 dB. Speech signals do not usually

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exceed a mean value of −10 dBm, so that in the worse cases the disturbing speech signals in an adjacent pair of a loaded cable will not exceed −74 dBm, a level at which they will not be audible. Even if the level is raised with loaded cable the risk of crosstalk being disturbing is negligible. The exact 6 dB difference between the crosstalk attenuation of non-loaded and loaded lines does not apply in practice, because loaded lines are not terminated with their characteristic impedance, as explained below.

Sidetone

If the sidetone between the telephone transmitter and receiver is excessive, the talker tends to speak more quietly, thus producing an apparent increase in the transmission loss to the distant listener, and, if room noise is present, the received speech signals will be masked. The sidetone performance is mostly influenced by the impedance of the line. The balance network in the Telephone No. 706[2] has been designed so that, in conjunction with the regulator, satisfactory sidetone performance is obtained when the telephone is connected to unloaded cable. With loaded cables having twice the line impedance, the sidetone performance is worsened. The match between the loaded line and the telephone can be improved by connecting a simple resistor-capacitor network across the telephone terminals. In practice, this has not been found necessary with the schemes carried out so far because the sidetone has not reached a level disturbing to the user, and any sidetone impairment has been more than offset by the reduction in line loss due to loading.

Loading-Coil Spacing

It is the practice to space 88 mH loading coils at 2,000 yd intervals in trunk-type quad cable having a mutual pair capacitance of 0·066 μF/mile: 20 lb/mile conductors with this loading have an attenuation of 0·37 dB/mile and a characteristic impedance of 1,110 ohms. For the sake of uniformity it is desirable that loaded trunk and local circuits should have similar secondary characteristics. To achieve this, and because the mutual pair capacitance of polythene-insulated twin cable is of the order of 0·085 μF/mile, it is necessary to space the 88 mH coils at 1,500 yd intervals with a 750 yd section at the exchange end of the route.

To maintain a uniform frequency response the length of each loading-coil section is arranged to be within ±30 yd of the length of adjacent sections as well as being within the same tolerance of the average section length. Ideally, the end section at the telephone should be an exact half-section, but as this is unlikely to occur in practice some compromise is necessary. End sections between 375 yd and 1,500 yd are permitted, but those less than 375 yd are built-out with capacitors to an equivalent half-section. Some relaxation is allowed, when an existing cable is being loaded, to restrict the making of additional joints to a minimum, but, if adjacent sections differ by more than 45 yd, the shorter length is built-out with capacitors.

Types of Unicoil

Two types of core are used in the current manufacture of 88 mH unicoils: ferrite pot-cores with an air gap, and toroidal cores in which there is no air gap. The unicoils using either type of core are encased in cylindrical metal cases of the same dimensions, 1·125 in. diameter × 1·0 in. long. The cases provide mechanical protection and effective electrical screening of the coils. Measurements have shown that the d.c. feed in a local telephone circuit can reduce by as much as 3 per cent the inductance of toroidal-core unicoils in which there is no air gap. The current has a negligible effect on the inductance of unicoils with air-gapped ferrite cores, so these have been used exclusively for local-cable loading.

INSTALLATION

When handling unicoils every precaution is taken to avoid subjecting them to mechanical shock, as damage to the cores is almost certain to result in a change of inductance.

The unicoils are mounted in plastic holders for fitting in the cable joint. One holder is used for up to 10 unicoils; when the number is between 11 and 20 a second holder is laid alongside the first. A triform cradle is used if 21 to 39 unicoils are to be installed. This cradle consists of an assembly for mounting three holders side by side and is shown in Fig. 3.

The plastic holders are scored circumferentially 2½ in. from one end, so that whether used singly or in the triform cradle, the overall length can be easily reduced

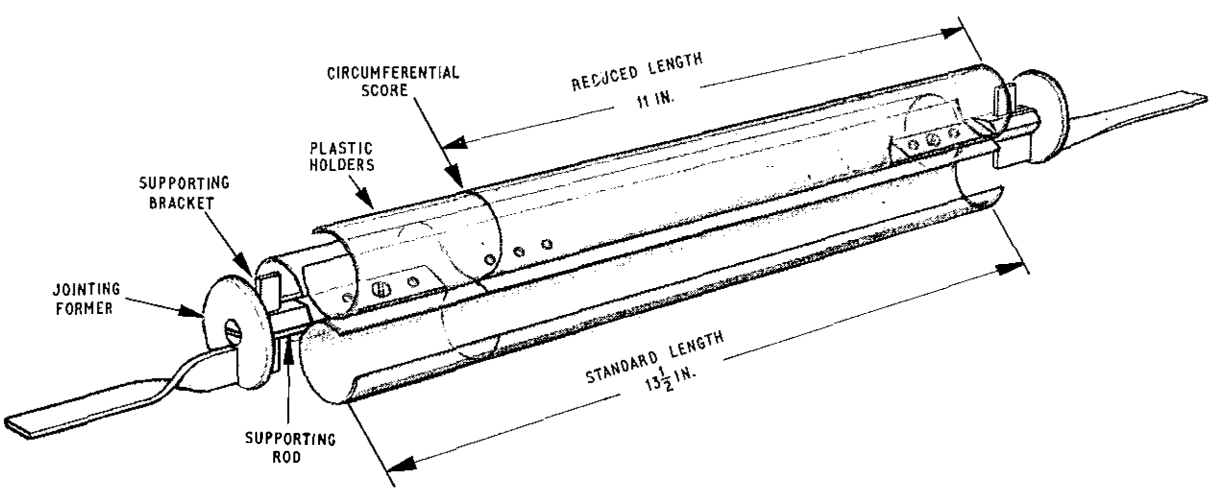

FIG. 3—CRADLE USED FOR MOUNTING THREE UNICOIL HOLDERS

on site. This avoids having a joint longer than is necessary to accommodate the ultimate number of unicoils. The plastic holders are made of non-plasticized PVC of 0·040 in. thickness, cut into strips 13½ in. long × 2½ in. wide. Each strip is formed to a cylindrical shape by inserting it in a metal tube with an internal diameter of 1 in. The tube and its PVC insert are then placed in boiling water long enough for the PVC to soften and mould to the shape of the tube wall. After cooling, the PVC retains its moulded shape and is flexible enough to facilitate the insertion and removal of unicoils and to hold them firmly in position. Locked-in stresses are present to some degree in the holders because of the forming process, and care must be taken if heat is subsequently applied, for example in plumbing the sleeve, to ensure that the temperature within the joint does not reach the softening point of the PVC.

The cradle is secured in position in the jointing gap by binding the cable supporting brackets to the ends of the cable sheath using a suitable binding strip or clip (Fig. 4). The unicoils are inserted in the holders with their ends abutting and with their lead-out tails arranged so that the red-white and white wires are laid to one side of the joint and all the red-black and black wires are laid to the opposite side. The unicoils are numbered from the exchange side of the joint, commencing at any one of the three rows of coils and continuing in sequence along each of the adjacent rows in turn. The red-white and white

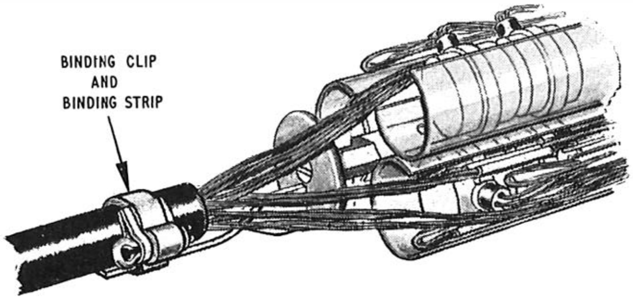

FIG. 4—METHOD OF SECURING CRADLE IN POSITION

wires of each unicoil are jointed to the A-wires and B-wires of the cable pairs from the exchange, and the red-black and black wires to the A-wires and B-wires of the cable pair on the subscribers' side of the joint in the order described. The full length of the unicoil tails should be maintained, no matter where the unicoil is located in the cradle, the surplus wire of the tails being laid alongside the row coils to the right or to the left of the lead-out bushes. The PVC insulation of the tail-cable wires and the polythene insulation of the cable conductors are stripped for about 1 in., and the wire joint is made by twisting the tail wires, which consist of seven 0·0076 in. copper strands, to form an open helix around, and in line with, the cable conductor. The connexion is then soldered and insulated, using a polythene sleeve in the conventional manner.

The completed joint is tied and enclosed in a polythene sleeve, and is sealed to the cable sheath by means of expanding plugs. For in-line joints a moulded polythene sleeve[3] (coded Sleeve, Polythene, Screwed) may be

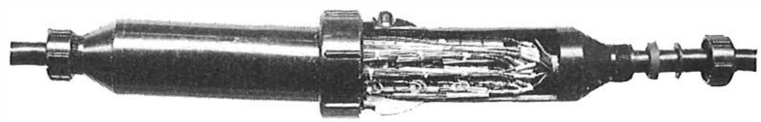

FIG. 5—JOINT CONTAINING UNICOILS ENCLOSED BY MOULDED POLYTHENE SLEEVE

used (Fig. 5). This type of sleeve is by design divided at its centre, and is particularly useful for making loading-coil joints in small or congested jointing chambers.

CONCLUSIONS

A number of loading schemes have been satisfactorily carried out on local cables with route lengths of 7–12 miles. Objective transmission performance tests corrected for feeding-current effect were made on exchange lines using 20 lb/mile conductors: the tests showed that loading improved the sending and receiving transmission performance by approximately 50 per cent. This is equivalent in terms of transmission equivalent resistance to reducing the loss of a 20 lb/mile conductor from 1,800 ohms to 1,000 ohms T.E.R.

It is expected that loading will be confined to 20 lb/mile conductors because, apart from the need to use a heavy-weight cable to meet signalling limits, the percentage reduction in transmission loss is less with the smaller gauges. The attenuation of 20 lb/mile conductors is reduced by 75 per cent by loading, but for 10 lb/mile and 6½ lb/mile conductors the reduction is only 66 per cent and 54 per cent, respectively. Furthermore, the 1,000 ohm signalling limit of automatic exchanges restricts 10 lb/mile and 6½ lb/mile conductors to route lengths of 5·7 and 3·7 miles, respectively, unless the signalling units mentioned earlier are used.

Loading has proved to be a simple and effective way of reducing the line loss of the small number of long local-cable routes that present transmission difficulties.

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Computer Simulation of a Character-Recognition Machine

Part 2—Information Recoding and Character Recognition

E. S. DEUTSCH, B.Sc.†

U.D.C. 681.327.12:371.693.4

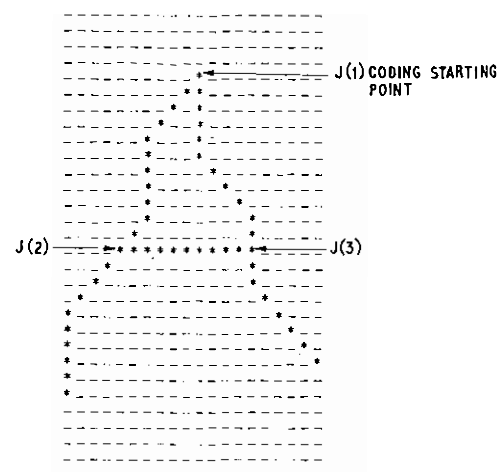
This article describes the simulation, on a computer, of a machine that will recognize handwritten and printed alpha-numeric characters. Part 1 described methods of coding, smoothing, standardizing and thinning a character. Part 2 describes the final two stages: information recoding and character recognition.

INTRODUCTION

PART 1 of this paper was concerned with the pre-processing stages of an input character, i.e. coding, smoothing, standardizing and thinning. Further laboratory investigation of these techniques is to be carried out, but this part of the article describes the last two stages intended to be used: recoding and recognition.

Having undergone the thinning process, the input character is coded in the form of a string of element vectors (indicating directions of steps of traverse along points on the pattern) and node points. Coding commences from the uppermost matrix element on the character pattern, but should this present a dichotomy, e.g. if the upper part of the character is a horizontal line, then coding starts from the top-left-most element. Further, if the coding starting point is a node then preference in the coding of branches in the following order of directions is made: 1, 8, 6, and 7.

Fig. 12 shows a "thinned" letter A. The position of the coding starting point is the uppermost element on the



J(n) indicates node points, the value of n indicating the order of their occurrence during coding.

FIG. 12—THINNED LETTER A

pattern, as shown, and as it is a node, coding in direction 6 takes place first. Thus, coding the letter A in accordance with the rules developed in Part 1 yields the chain code

J(1)66667777766J(2)666677777 |
J(1)77777888877J(3)7788888 | J(2)111111111 | J(3)e.

Vertical strokes are included in the chain to indicate the end of each feature of the character, and the entry "e" at the end indicates the termination of the character chain. The method of coding employed differs from that of Freeman* in that node points are introduced into the chain. The recognition technique Freeman then uses is one of cross-correlation between the input-character chain and chains stored in the computer, and, accordingly, the input pattern is classified as belonging to the class of the stored chain giving the maximum correlation output function. It is not intended to use this method; it should be noted that the stored chains, as well as the input chain, can have any number of elements in them, and the storage of different chains may become a problem if large-scale storage is required. In addition, the more elements there are in a chain, the longer the recognition process will take. It is therefore proposed to recode the chain and thereby reduce the number of elements (without loss of information), so as to obtain a very short chain code. It is found that chain recoding not only reduces the storage requirements per chain but also offers a simple and short way of overall chain storage. In the ensuing discussion on recoding, the character A in Fig. 12 will be used as an example.

RECODING

Consider the chain code of the first encoded feature (the left-hand slanted limb) of the character A:

J(1)66667777766J(2)666677777.

This feature may be regarded, on inspection of either Fig. 12 or the above chain, as a slanted line which, on using the starting point as the origin, falls into the third quadrant and bears in the general direction of $5\pi/4$. By counting the number of consecutive vector-elements 6 and 7 and ignoring node entries, the angular orientation ϕ of this feature can easily be determined. The angle ϕ is compared with a predetermined fixed angle θ (at present $\theta = \pi/18$), and the whole feature is recoded in accordance with the following rules.

(*i*) For $3\pi/2 - \theta > \phi > \pi + \theta$, recode chain in direction $5\pi/4$.

(*ii*) For $\pi + \theta > \phi > \pi$, recode chain in direction π.

(*iii*) For $3\pi/2 > \phi > 3\pi/2 - \theta$, recode chain in direction $\pi/2$.

Fig. 13 illustrates the three possible forms of recoding a chain falling into the third quadrant. It is obvious that the same recoding would have resulted had the order of the groups of consecutive identical elements been interchanged. The actual method of recoding will be dealt with later, but first the general case is considered.

It should be remembered that the eight possible vector directions are at $\pi/4$ to each other, and, in the ensuing discussion on recoding, consideration is made only of sets of feature chains whose groups of consecutive identical

†Post Office Research Station.

*A Technique for the Classification and Recognition of Geometric Patterns. Proceedings of the Third International Congress on Cybernetics. Namur, Belgium, Sept. 1961.

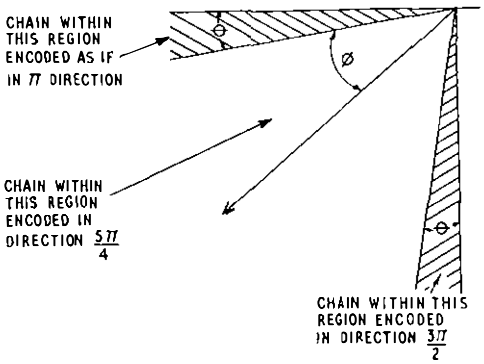


FIG. 13—THREE POSSIBLE FORMS OF RECODING A CHAIN IN THE THIRD QUADRANT

elements have vectors at $\pi/4$ to each other and, at the same time, comprise elements of the same value as those in the one-before-last group within the future chain. Each group of consecutive identical elements is termed a subchain. Thus, subchains of the following forms will be considered:

11112211 . . . ,
11888111188 . . . ,
6667776666777 . . . ,

or, more generally,

$e_i\ e_i\ e_i\ e_{i+1}\ e_{i+1}\ c_i\ e_i \ldots$

or

$e_{i-1}\ e_i\ e_i\ e_i\ e_{i-1}\ c_{i-1} \ldots,$

where e_i is the element in direction i ($i = 1$-8).

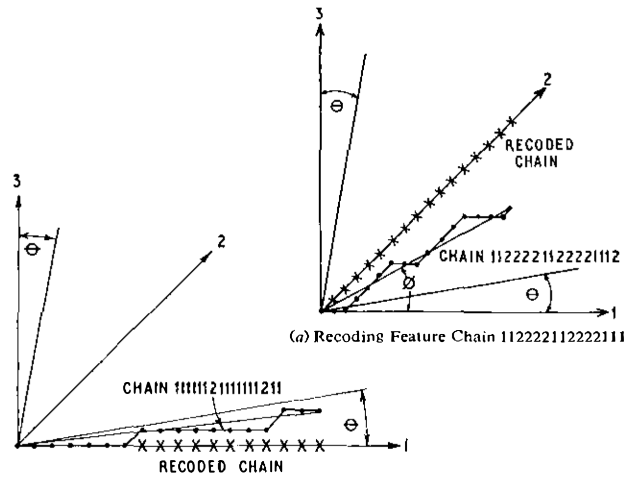
Recoding takes place only if there is a minimum of three consecutive subchains of the form just stated, in which case two subchains consist of identical elements. Recoding a particular subchain combination ceases as soon as vector elements are encountered different from those in either subchain considered. These vector elements can, however, combine with other compatible subchains within the feature chain and effect further recoding. Each given subchain can combine with two different subchains at $\pi/4$ to it. As the order of appearance of the individual subchains within a particular subchain combination is immaterial (simple vector addition), there are only eight different possible subchain combinations: these are given in Table 1.

The next part of the recoding process consists, as stated above, of comparing the angular orientation, ϕ, of the feature chain, with a predetermined angle θ. If the inclination ϕ to both horizontal and vertical axes is greater than θ the feature chain is recoded so that its new direction of orientation is either $\pi/4$, $3\pi/4$, $5\pi/4$, or $7\pi/4$, depending into which quadrant the feature chain extends. If, however, ϕ is less than θ the branch is recoded so as to have an angular disposition of either 0, $\pi/2$, π, or $3\pi/2$, the choice again depending upon how close the branch falls to either the positive or negative x or y axes.

As an example, consider the feature chain 1122221122221112 shown in Fig. 14(*a*). There are altogether six subchains, and, within them, seven vector elements have the value 1 and nine have the value 2. Two sides of a triangle can be drawn: one side of length seven units in direction 1, and the other side of length nine in direction 2. The third side can then be drawn, and its angular orientation gives the value of ϕ. This value can be calculated very simply ($\phi = \tan^{-1} 9\sqrt{2}/(7 + 9\sqrt{2})$), and it will be seen that it is greater than θ ($\theta = \pi/18$). The chain would consequently be recoded as if it was in direction $\pi/4$ or in vector direction 2. Using a similar approach, chain 1111112111111211, shown in Fig. 14(*b*), for which ϕ is less than θ, would be recoded in vector direction 1.

TABLE 1
Possible Subchain Combinations

Subchain Comprising Vectors of Value		Combines with a Subchain Comprising Vectors of Value
1	←→	2
2	←→	3
3	←→	4
4	←→	5
5	←→	6
6	←→	7
7	←→	8
8	←→	1



(*a*) Recoding Feature Chain 1122221122221112

(*b*) Recoding Feature Chain 1111112111111211

FIG. 14—RECODING OF FEATURE CHAINS TO TAKE ACCOUNT OF ANGULAR ORIENTATION

It should be noted that all eight possible subchain combinations consist of a subchain of even-valued elements followed by a subchain of odd-valued elements, or vice versa. Transformation into directions 0, $\pi/2$, π, or $3\pi/2$, involves, as the case may be, the replacement of each element in the even-valued subchain by the value of the odd elements in the subsequent subchain. The reverse is done for transformations into directions $\pi/4$, $3\pi/4$, $5\pi/4$, and $7\pi/4$. Thus, for the chain 1122221122221112, shown in Fig. 14(*a*), for which ϕ is greater than θ, all odd-valued elements in the subchains are replaced by the value of the even elements to yield a new chain 2222222222222222, whereas the chain 1111112111111211, shown in Fig. 14(*b*), is recoded to 1111111111111111. These recoded chains are shown in Fig. 14(*a*) and (*b*), respectively. Note that there has been a change in feature size, an effect that will be discussed later.

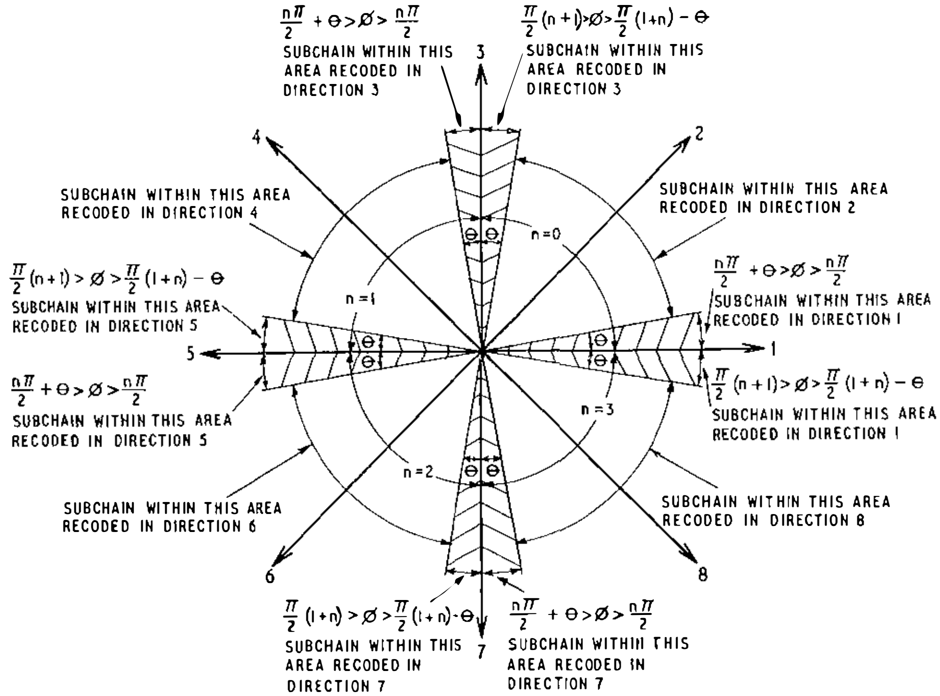


FIG. 15—POSSIBLE RECODING DIRECTION

Fig. 15 and Table 2 summarize the possible recoding directions. Referring to Table 2, it should be noted that for each subchain combination there are only two entries for the final recoding directions. This is to be expected, because each allowable subchain combination can give

TABLE 2

Possible Recoding Directions

Subchain Combination of Angle ϕ	Reading Directions for ϕ and θ Relations: $\pi/2(1+n) > \phi > \pi/2(1+n)-\theta$	$\pi n/2 + \theta > \phi > \pi n/2$	Neither	n
1⇄2	—	1	2	0
2⇄3	3	—	2	
3⇄4	—	3	4	1
4⇄5	5	—	4	
5⇄6	—	5	6	2
6⇄7	7	—	6	
7⇄8	—	7	8	3
8⇄1	1	—	8	

an angular variation of only $\pi/4$, irrespective of the number of elements in the individual subchain. Accordingly, the initial character A (Fig. 12) is recoded as

J(1)66666666666J(2)666666666J(1)88888888888J(3)
8888888J(2)111111111J(3)e.

If the character A is now reconstructed on the basis of the information content of the new, recoded, chain it will be slightly different in shape and some features will have been altered in size, as shown clearly in Fig. 16. The fact that the, now curtailed, horizontal stroke of the A reaches the right-hand limb as well is manifested by the J(3) entries in the chain, and the stroke may, therefore,

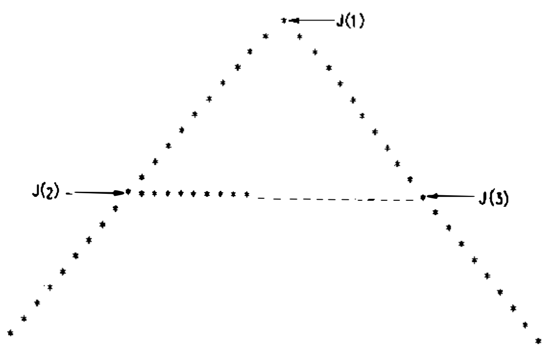


FIG. 16—CHARACTER A RECONSTRUCTED ON BASIS OF INFORMATION CONTENT OF RECORDED CHAIN

be imagined to extend to the point J(3) in the figure. This general effect is of no consequence as it is the feature orientation that is of importance. For this reason the size of the recoded chain can be reduced further. This reduction involves the construction of a new chain consisting of only one element of each group of consecutive identical elements, and the nodes, all in the previous order. Accordingly, the final chain code for the initial input character A is

J(1)6J(2)6J(1)8J(3)8J(2)1J(3)e.

Generally, recoding of subchains in accordance with Fig. 15 takes place only if there is a minimum of three consecutive subchains. It is hoped that recoding by means of the stated subchain combinations alone will be sufficient, in every case, for the final chain to present feature orientations and nodes only.

Using a letter A as an example, the various stages of chain coding—subchain transformation, recoding and reduction—have been shown. The resultant information now presents features and nodes only. It is worth comparing the length of the initial chain of character A with that of the chain finally developed. If the comparison be assessed on the basis of the number of entries in the chain then there has been a reduction of almost 80 per cent in the amount of data to be handled for recognition purposes.

RECOGNITION

All the processes described hitherto are considered to be transformation operations on the input character, and, as a final result, all similar features are reduced to one and the same entry in the final chain code describing the character, i.e. there is a single entry in the chain for numerous feature orientations of any length. It is thought that, as a result of this reduction, it will be possible to predict, to a fair degree of accuracy, all the final possible shapes of a transformed input character, and hence be possible to recognize it. There will be more than one final chain code per class of a particular character, especially if hand-printed characters are being considered, but it is thought that the number of these, by virtue of the manipulations described, is limited. Further, in view of this and the shortness of the final chain code, the problem of computer storage of chains is reduced. It will be shown that if there are, say, n possible chain codes per class of character, not all the n chains have to be stored individually. The stored chains are regarded as templates, and recognition is effected by comparing the final chain code of the input character with those stored in the computer.

The above will now be illustrated with reference to a number 7. This character has been chosen purposely because of the particular arrangement of some of its features and also because of its relative simplicity in shape. Fig. 17 shows all the final possible feature directions of a

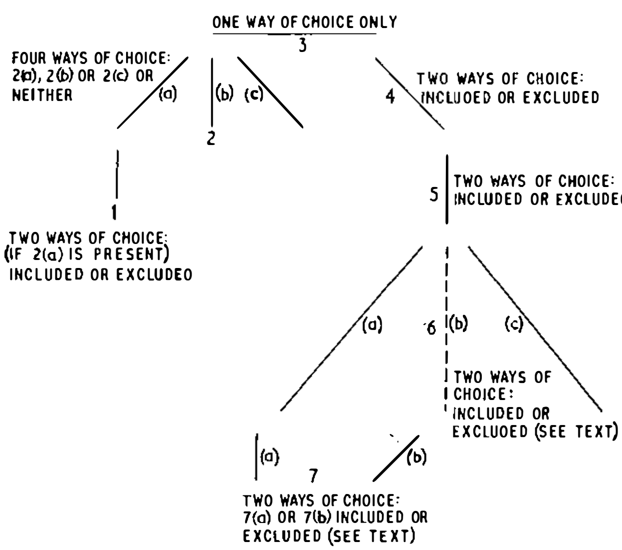


FIG. 17—POSSIBLE WAYS IN WHICH A FEATURE DIRECTION CAN APPEAR IN A CHAIN OF A CHARACTER 7

transformed erect character 7 (with the exception of feature 6(c)). Not all the features shown need necessarily appear in every input 7, and the figure clearly indicates this, but they constitute features the combination of some of which yield a character 7.

Fig. 17 also shows the number of ways a given feature direction can appear in the chain. Feature 2 can be coded in four different ways: either as a feature in direction 6 (feature 2(a)), as a feature in direction 7 (feature 2(b)), or as a feature in direction 8 (feature 2(c)), or not at all, if it is not present in the input 7. Feature 3 can be coded in one way only (for an erect number 7) as it must be present in every input 7. Feature 6 can be coded or chosen in two different ways: either as a feature in direction 6 (feature 6(a)), or not at all. Feature 6(c), appearing anomalous, is included in the list for reasons that will be discussed later; its presence can, therefore, be ignored for the moment. Feature 6(b) (dotted line) is not an additional feature within the list because, if it were present, it would be no different from feature 5 which is already included in the list; there are, therefore, only two ways of selecting feature 6. Feature 7 can be chosen in two different ways only: if feature 6(a) exists then feature 7(a) can either exist or not exist in the input 7. If feature 6(b) exists—not as a separate feature but as feature 5—then feature 7(b) can also either exist or not exist. But it should be noted that features 7(a) and 7(b) cannot coexist after pre-processing.

At this point it might be worthwhile to digress for a moment and refer to the previous discussion on subchain recoding. Features 5, 6(a) and 7(a) constitute a subchain combination which would be finally recoded in the chain code describing the input 7—had these features been present in it—as a single feature: either 6(a) or 5. Thus, the three features 5, 6(a) and 7(a) cannot all appear consecutively in the final chain code. They still have to be included in the list as they can combine individually with other features.

Multiplying together all the possible ways of choosing the individual features, it is found that the total number of feature combinations is 128. This is not the number of feature combinations yielding a character 7, as it includes, for example, a combination of features including features 5, 6(a) and 7(a) which cannot coexist, as was pointed out above. It also includes meaningless feature combinations such as features 3 and 1 only, and 3 and 2 only. Whatever the number of feature combinations yielding a character 7 is, the individual combinations are not stored separately: it is possible, by means of logic operations, to construct a simple computer routine to act as a thesaurus which would include all these combinations, and it would then be "consulted" for recognition purposes. Great care must be taken in the construction of the routine so that there are no ambiguities between feature combinations of different classes. The feature flow diagram of the character 7 is given in Fig. 18, the encircled figure representing chain entries. The computer tries to recognize the input-character chain by determining whether the order and the value of the entries in the chain combine so as to form a path "through" the feature flow diagram. The maze is arranged (not shown in Fig. 18) so as to prohibit combinations of the type mentioned above. The feature combinations of the next class is consulted should the particular chain not fit the maze in question. If a complete path has been found (this includes the symbol "e" at the end of the chain) the character is recognized to belong to the class of characters represented by the feature-combinations list.

The recognition of rotated or tilted characters will now be dealt with. At present, input characters rotated not more than $\pi/4$ in either direction will be considered. In order to be able to recognize these, a further manipulation of the feature combinations already in the computer is

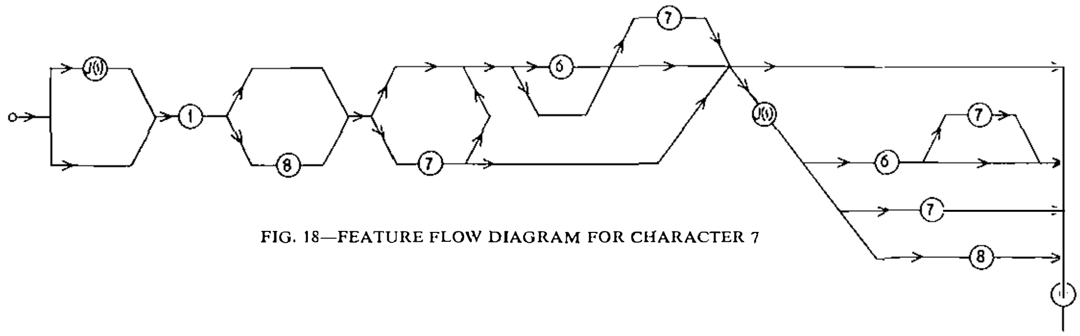


FIG. 18—FEATURE FLOW DIAGRAM FOR CHARACTER 7

required. The method of manipulating these is introduced by considering a simple case. The configuration shown in Fig. 19(*a*) would, after recoding and reduction, yield the final chain code

87J(1)7J(1)1c

The position of the chain-coding starting point on the figure should be noted. Fig. 19(*b*) depicts Fig. 19(*a*)

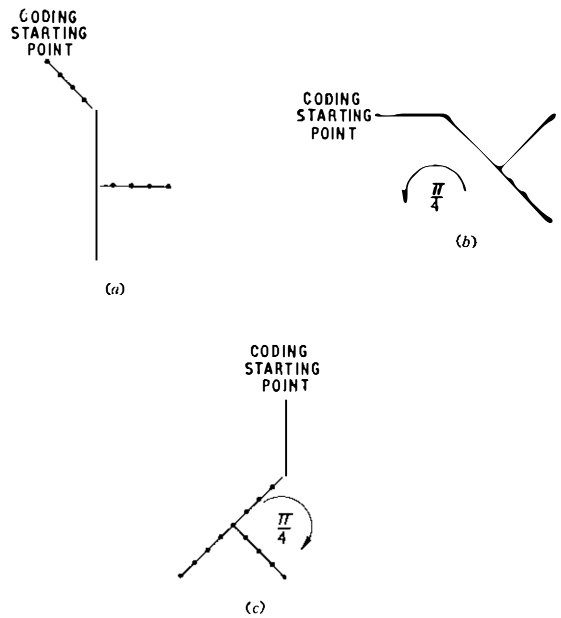


FIG. 19—CONFIGURATION ROTATED CLOCKWISE AND ANTI-CLOCKWISE

rotated by $\pi/4$ in an anti-clockwise direction. With the starting point the same point as on the pattern of Fig. 19(*a*) the rotated curve will be coded as

18J(1)8J(1)2c.

The chain code of the rotated curve could have been derived directly from the first chain code by simply adding 1 to every element vector in the first chain, as explained in Part 1 of this article. By subtracting 1 from each vector element in the first chain, a $\pi/4$ clockwise rotation of Fig. 19(*a*) is effected. The rotated figure is shown in Fig. 19(*c*), and its final chain code would be

76J(1)6J(1)8e.

In all three curves in Fig. 19 the coding starting point is the same point on the pattern, because it is always the top-left-most position on the curve. But consider now the chain shown in Fig. 20(*a*), for which, as will be shown below, this observation concerning the starting point is not valid. Referring to the remarks made at the beginning

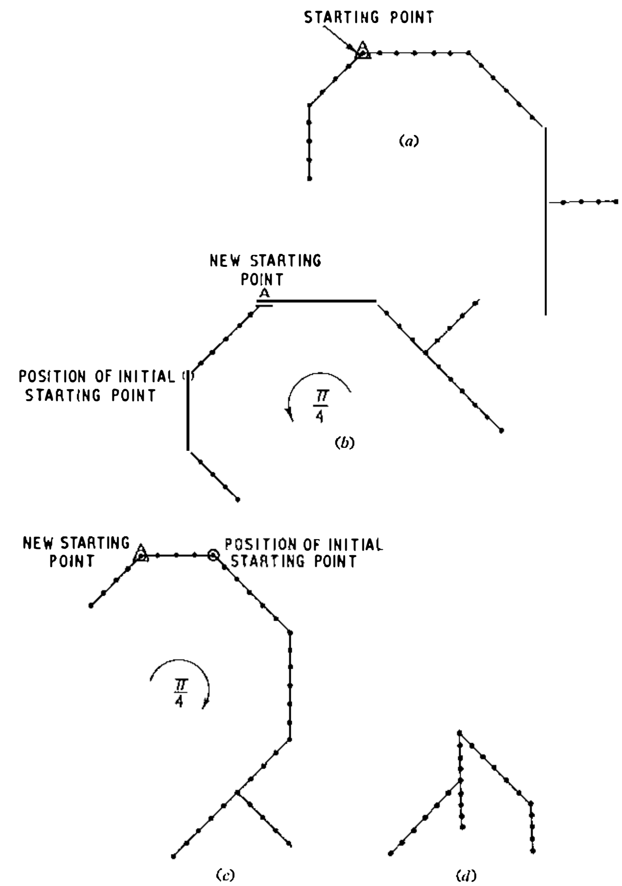


FIG. 20—CONFIGURATION REQUIRING NEW CODING STARTING POINT WHEN TILTED

of this article concerning the position of the coding starting point and the priority of coding a particular feature if the starting point is a node, Fig. 20(*a*) would be finally encoded as

J(1)187J(2)7J(1)67J(2)1e.

Fig. 20 (*b*) shows Fig 20(*a*) rotated $\pi/4$ clockwise. This rotated curve will be encoded (with the coding starting point at the top-left-most position on the curve) as

J(1)18J(2)8J(1)678J(2)2e.

The above chain has been derived directly from Fig. 20(*b*) and not by adding 1 to every vector element in the chain representing Fig. 20(*a*). Had this been done, a chain different from the one just derived would be obtained, viz

J(1)218J(2)8J(1)78J(2)2e.

By adding 1 to each element in the chain representing Fig. 20(*a*), the initial coding starting point has also been rotated by $\pi/4$, and is, therefore, no longer the top-leftmost point on the rotated curve. This will be borne out if the curve is redrawn on the basis of the appropriate chain. The second chain has been derived directly from Fig. 20(*b*) with the coding starting point in the correct position and is, therefore, the correct one. Generally, as in this case, where rotation causes the initial coding point to be displaced, a further manipulation of the original chain is required before adding or subtracting 1, so that this point is in the correct position. In the case of Fig 20(*d*), as for the curves of Fig. 19, such a manipulation is not required.

Physically, the desired effect is accomplished by allowing the initial starting point to remain stationary in the plane and rotating the curve only. In terms of chain manipulation this implies that the element vector following the first entry, J(1), in the original chain is rotated by $4\pi/4$ (i.e. 4 is added to its value) and reinserted into the chain immediately after the second J(1) entry. This causes the recoding starting point to be shifted one feature along the pattern. Adding 1 to every vector element in the new chain effects a $\pi/4$ anti-clockwise rotation, causing the starting point to return to its original position. Applying the first step to the chain representing Fig. 20(*a*), the chain

J(1)87J(2)7J(1)567J(2)1e

is obtained, and adding 1 to every vector element in this chain to effect a $\pi/4$ anti-clockwise rotation yields the chain

J(1)18J(2)8J(1)678J(2)2e,

which is identical with the chain derived directly from Fig. 20(*b*).

Conversly, when a $\pi/4$ clockwise rotation is to be effected, 4 is subtracted from the value of the first vector element following the second J(1) entry in the chain. This element is reinserted in the chain immediately after the first J(1) entry. Applying the first step to the chain of Fig. 20(*a*) yields the chain

J(1)2187J(2)7J(1)7J(2)1e,

and on subtracting 1 the chain

J(1)1876J(2)6J(1)6J(2)8e

is obtained. This chain is identical with the one that would have been derived directly from Fig. 20(*c*).

So far it has been assumed that the starting point was a node point, and thus the first entry in the original chain was always a J(1). Should this, however, not be the case, then, prior to proceeding as above, an artificial junction point entry, J(0), is made in the chain. It is treated in the same manner as any other node entry. Thus, assuming that the orignal configuration had been that of Fig. 19(*b*), the chain code

18J(1)8J(1)2

would have the junction point J(0) inserted at the beginning of the chain and also before the second J(1) entry, yielding the chain

J(0)18J(0)J(1)2.

Also, if the new starting point was already entered as a junction point, the chain has to be rearranged again before making the above changes (the exact method of treatment is not covered in this article). As a result, however, the number of node entries in the final chain is reduced by 1, as expected, and the order of appearance of the features is changed so that the priority of encoding feature directions is still maintained.

Thus, using the techniques just described, tilted characters can be recognized. The feature combinations developed for an erect character are rearranged and recoded accordingly, and a new set of templates, or a maze, pertaining to tilted characters is derived. Recognition is then carried out as above. The lists of feature combinations, derived by the computer, replace those of the erect characters, and a separate set of templates of tilted characters does not have to be stored separately. The original set of combinations can be rederived by rotating the set of tilted feature combinations in the opposite sense.

Referring again to Fig. 17, it is pointed out that feature 6(*c*) is included only when a feature-combination list of a clockwise-rotated character 7 is generated by the computer. Instructions in the computer ensure that feature 6(*a*) in its rotated form is not included in the list. Features 7(*a*) and 7(*b*) in their rotated form can then combine with features 6(*b*) and 6(*c*), respectively, also in their rotated form.

Finally, it should be noted that, in view of subchain-combination recoding, on effecting a $\pi/4$ rotation either way about the vertical, the sector bounded by the limits of ϕ, where $\pi - \theta > \phi > \theta$, is in fact covered. By considering the possible subchain combinations that could yield the features shown in Fig. 17, in conjunction with Fig. 15, this is immediately apparent.

CONCLUSION

Preliminary investigations using printed and hand-printed numerals have proved successful, but it is felt that, in view of the limited number of samples processed, figures of performance could be misleading. Publication of these is therefore reserved for a later date.

ACKNOWLEDGEMENTS

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Semiconductor Device Developments: Integrated Circuits

Part 2—Standard Logic Circuits

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U.D.C. 621.38.049.75:621.374.3

In the first part of this article the main types of integrated circuits were described, and it was stated that the semiconductor integrated circuit was likely to provide the cheapest form of construction for circuits which are required in large quantities. Part 2 is an introduction to the logic circuits of this type that are currently available as standard items from the manufacturers. Some of the basic logical operations are defined, and a brief description of the different types of logic ranges that can be obtained to perform these operations is given.

INTRODUCTION

COMPLEX logic systems can be built up using only a few basic logical operations, and large numbers of the logic circuits providing these operations are required in the construction of, for example, high-speed digital computers. It was seen in Part 1 that this is just the sort of application for which semiconductor integrated circuits are most suited, and most of the manufacturers are now producing one or more ranges of such circuits. Before describing these ranges in more detail some of the basic logical operations which can be provided are defined, together with some of the terms in general use. There is as yet no standard nomenclature in use for integrated circuits, and the current terminology is largely a confusing mixture of trade names and initials. In most instances the terminology adopted in this article is that which is in general use in the literature.

LOGICAL OPERATIONS

In logical operations on binary digits the signal has one of two values only: these are normally designated as 0 and 1. If the logic element has no memory its output signal is completely determined by the combination of signals present at its inputs, and several standard logical operations of this type have been defined.[1] In the AND operation the output signal represents 1 only when all the input signals represent 1, and in the OR operation the output signal represents 1 when any one or more of the input signals represents 1. The appropriate output signals for all possible combinations of two input signals are thus as shown in Table 1. The operation of negation changes a 0 to a 1 and vice versa, and is equivalent to NOT, since if a signal is not 0 it must be 1. The NOT-AND, or NAND, operation and the NOR operation are also shown in Fig. 10, and are equivalent to the AND and OR, respectively,

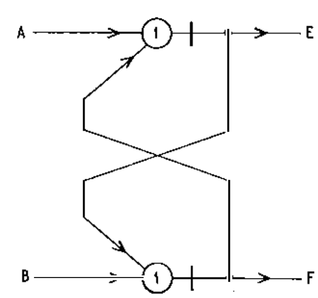

FIG. 10 -BISTABLE CIRCUIT

followed by a negator. Although only two inputs, A and B, are shown in Table 1, these operations can be extended to any number of inputs.

The other two operations shown in the table are defined for two inputs only: in the EQUIVALENCE operation the output signal represents 1 only when both the input signals are alike, and in the NON-EQUIVALENCE operation the output signal represents 1 only when the input signals differ from each other. The latter is often called the EXCLUSIVE-OR operation, whilst the OR operation above may be called the INCLUSIVE-OR. Logic elements which provide the above or similar operations are generally known as "gates" and the terms AND gate, NOR gate, etc., are in common use. Tables giving every possible combination of the input and output signals completely specify the logical operation of the circuit and are generally known as truth tables.

Very few logical operations are required to give a comprehensive range of building blocks for more complex circuits (it is in fact possible to construct the logic sections of a computer using NOR circuits only), but certain combinations of the basic operations occur frequently in

TABLE 1
Simple Logical Operations

Inputs		Output For					
A	B	AND Operation	OR Operation	NAND Operation	NOR Operation	Equivalence Operation	Non-Equivalence Operation
0	0	0	0	1	1	1	0
0	1	0	1	1	0	0	1
1	0	0	1	1	0	0	1
1	1	1	1	0	0	1	0

†Post Office Research Station.

TABLE 2
Truth Table for Half-Adder

Inputs		Outputs	
A	B	Sum	Carry
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

carrying out arithmetical operations on binary digits, and these could be combined in single, more complex, logic elements. For example, a half-adder has two outputs and two inputs and provides the operation required for adding two binary digits. If the signals applied to the inputs represent the two binary digits to be added, one output signal represents the sum and the other the carry. The operation is defined by the truth table of Table 2, and, by comparing this with Table 1, it is seen that the operation could be provided by a NON-EQUIVALENCE element and an AND element having their inputs in common. The next stage in complexity would be a full-adder providing the operation shown in Table 3. This is a similar binary addition operation but it is performed on three input signals, two of which represent the digits to be added and the third the carry digit from the previous stage.

So far as is known there are as yet no standard definitions for logical operations which involve memory, and the terms given below are those which are widely used in the literature. The memory generally takes the form of a bistable circuit, and it is unfortunate that in United States terminology this is called a flip-flop, whilst in United Kingdom terminology it is a toggle, and the term flip-flop is used for a monostable circuit. A basic bistable circuit can be made by cross-connecting the outputs of two NOR gates back to the inputs, as shown in Fig. 10. By considering the definition of a NOR gate given in Table 1 it will be seen that, if there is a 0 signal on the A input and a 1 signal on the B input, output F will be a 0 signal and output E will be a 1 signal. If the B signal now goes to 0 the outputs remain unchanged. Similarly, if input A is now made 1, output E goes to 0

TABLE 3
Truth Table for Full-Adder

Inputs			Outputs	
A	B	Carry	Sum	Carry
0	0	0	0	0
0	0	1	1	0
0	1	0	1	0
0	1	1	0	1
1	0	0	1	0
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

and F goes to 1, and if both inputs are again made 0 the output remains unchanged. The circuit thus remembers which input was the last to have a 1 signal applied to it. If 1 input signals are applied to both inputs at the same time both outputs will go to the 0 state, but if the inputs are then removed simultaneously the outputs are logically indeterminate and will be determined by the relative electrical properties of the two gates used. The presence of simultaneous 1 signals on each input should, therefore, not be permitted if there is any possibility of them being removed together. By considering all the possible values of the input signals, together with all the possible values of the output signals, a truth table can be drawn up to describe the complete operation of the circuit. This is shown in an abbreviated form in Table 4, in which E_0 and F_0 refer to the previous values of the outputs E and F.

TABLE 4
Abbreviated Truth Table for Basic Bistable Circuit

A	B	E	F
0	0	E_0	F_0
0	1	1	0
1	0	0	1
1	1	(0) Not normally allowed	(0)

In the simple case of two cross-connected gates any changes in the output signals occur as soon as the input signals are changed, the only delay being that inherent in the gates themselves. In many applications, synchronous working is required, and most integrated bistable circuits are designed so that the output only takes up the state determined by the inputs after receipt of a trigger, or clock, pulse on a separate lead. A circuit of this type, which provides a similar operation to that of the basic bistable circuit of Fig. 10, would have the truth table of Table 5. This is generally known as R-S (Reset-Set)

TABLE 5
Truth Table for Synchronous R-S Operation

Inputs		Outputs	
R	S	Q_{t+1}	$\overline{Q}_{t+1}$
0	0	Q_t	$\overline{Q}_t$
0	1	1	0
1	0	0	1
1	1	Indeterminate	

operation, and, in the table, Q_t represents the value of the output signal before the clock pulse and Q_{t+1} its value after the clock pulse. The two outputs will always be complementary, so there is no need to include both outputs in the table, and the condition of simultaneous 1 signals at the inputs must not be allowed to occur as the output after the clock pulse will be indeterminate. (It should be noted that the symbol $\overline{Q}$ in Table 5 means "not Q".)

TABLE 6
Truth Table for Synchronous J-K Operation

J	K	Q_{t+1}
0	0	Q_t
0	1	0
1	0	1
1	1	$\bar{Q}_t$

Synchronous J-K operation may be defined by the truth table of Table 6,[2] and is the same as R-S operation except that the outputs for simultaneous 1 input signals are now defined and change state on receipt of the clock pulse. Synchronous T operation may be defined by the truth table of Table 7; the circuit has a single input, and the outputs change state whenever the input signal is a logical 1. This is equivalent to J-K operation with the J and K inputs strapped together. Any of the above operations can be used to provide counter circuits or multi-stage shift registers, and, whilst other types of operation can be defined and are occasionally met, R-S and J-K operation are the two most often provided in integrated logic ranges.

TABLE 7
Truth Table for Synchronous T Operation

T	Q_{t+1}
0	Q_t
1	$\bar{Q}_t$

INTEGRATED LOGIC UNITS

Each logic range consists of a number of compatible logic elements which are generally derived from the same basic circuit configuration, and, in spite of the large number of units in some ranges, most of them provide either one of the logical operations given above or a simple combination of these operations. The large numbers arise from differences in such things as the number of inputs provided, the number of logical elements in a package, the output driving capability, etc. Several factors affect the choice of units to be included in a logic range; the packaging cost, for example, is an appreciable proportion of the cost of a finished unit and, hence, the greater the number of logical operations that can be included in a single package the smaller will be the cost per operation. On the other hand, if the operation provided is too specialized it will not be required in large numbers. A compromise is to provide in one package a number of independent operations which the user can interconnect as required, but the extent to which this can be done is seriously limited by the number of leads on the package. If two gates are included in a 14-lead package a maximum of 5 inputs can be provided on each; with three gates the limit is 3 inputs, and with four gates only 2 inputs can be provided. Units of this type are included in most logic ranges and there is little, if any, difference in price between them. A few units may contain internally-connected gates, and perhaps the most common arrangement is one which is equivalent to two 2-input AND gates followed by an OR or a NOR gate. Most so-called EXCLUSIVE-OR units are actually of this type, and require both true and complementary values of the input signals in order to perform the NON-EQUIVALENCE operation. Each logic range also includes at least one unit containing gates having a high output driving capability for use with capacitive loads.

Bistable circuits are generally designed for synchronous working, and there are two main types. In one, the clock pulse is capacitively coupled and the outputs change state on the transition (generally the negative-going edge) of the clock pulse. In the other, two bistable circuits are connected to work on the master-slave principle, in which the master provides temporary storage and the slave provides the outputs. On receipt of the clock pulse the information at the inputs is transferred to the master whilst the slave is inhibited, then at the end of the clock pulse the information is transferred from the master to the slave whilst the inputs to the master are inhibited. Additional gating is often included at the inputs to these circuits, and it is then generally possible to use an R-S circuit as a J-K circuit by suitably connecting the outputs to the inputs, there being little logical significance in which type of unit is provided in the range. Some units are available which contain two J-K circuits in one package, but the facilities are soon limited by the number of leads available.

With the possible addition of a single-shot monostable circuit, most ranges have so far provided mainly variations on the units above. A few complex units, such as decade counters and shift registers, have recently been introduced into some logic ranges, and an 8-stage shift register may be taken as an example to indicate the complexity of some of these units. The register consists of eight master-slave bistable stages, and the complete circuit, which is constructed in a single chip of silicon, is equivalent to about 160 discrete components.

LOGIC CIRCUITS

When a logic circuit is constructed from discrete components all the components are accessible for test purposes, and, in order to guarantee the performance of the complete circuit, each component can be individually specified and tested. An integrated logic circuit is obtained sealed in a package and is only accessible via the leads provided. Although an equivalent circuit is given, the component values are often not stated and, even if they were, it would not normally be possible to check them all. The circuit is specified as a complete unit in terms of the voltages and currents at the input and output terminals, and what goes on inside the package is largely irrelevant except insofar as it affects the input and output characteristics. The operations of integrated logic circuits are normally described in terms of voltage levels, and it is a necessary feature of such circuits that they should have two stable states which can be used to represent the 0 and 1 conditions of binary logic. It is convenient to refer to the state which results in the more positive output voltage as the "high" state and that which results in the more negative output voltage as the "low" state, and this nomenclature is adopted in this article.

General Properties of a Logic Gate

One type of logic circuit that is widely used in both discrete and integrated form is diode-transistor logic (d.t.l.), and an example of a logic gate of this type is given

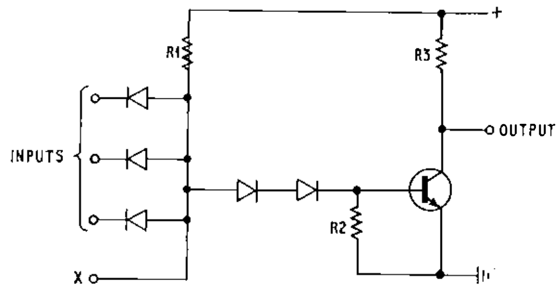

FIG. 11—DIODE-TRANSISTOR LOGIC

in Fig. 11. The number of inputs to the circuit is called the "fan-in," and the gate shown has an extender lead, X, to which additional diodes or groups of diodes can be connected to increase the fan-in. The "fan-out" is a measure of the output driving capability, and represents the number of unit input loads which can be connected to the output. The operation of the circuit has been described previously,[3] and is such that, when the voltage on all the inputs corresponds to that of the high state, the input diodes are non-conducting and the transistor saturates giving a low-state output. If any one input is taken to the low state, the input diode conducts and the voltage across the two level-shifting diodes is insufficient to allow current to flow into the base of the transistor. The transistor is thus turned off and the output changes to the high state.

If the high-state voltage level is chosen to represent a logical 1 signal, the truth table for the circuit is the same as that given for the NAND operation in Table 1. Conversely, if the low-voltage level is chosen to represent a logical 1 signal, the truth table is the same as that given for the NOR operation. The circuit can, therefore, be regarded as either a NAND gate or a NOR gate, depending on the logic convention adopted. The two possibilities are usually referred to as positive logic and negative logic, respectively, but, unfortunately, there is no general agreement on this, and on some data sheets the terms are used with the opposite meaning. In this article, positive logic is used throughout and refers to the case where the high-state voltage level is chosen to represent a logical 1: the circuit of Fig. 11, for example, would be described as a NAND gate.

When the gate of Fig. 11 is used in a logic system the output and inputs will generally be connected to other logic elements, and, in order to maintain flexibility in the interconnexion arrangements, it is desirable that the input characteristics and the output characteristics should be similar for all the units to be interconnected. To achieve this the circuits of the more complex logic elements in a range are generally developed from that of the simplest gate element. The properties of this "basic gate" enable useful comparisons to be made between the properties of the different logic ranges.

One of the most important properties of a logic circuit, and also one of the most difficult to specify, is its noise immunity. A value of d.c. noise margin is quoted for most logic ranges, and the meaning of this can be seen from the simplified transfer characteristic of Fig. 12, in which the solid curve shows a typical plot of the output voltage against the input voltage for a circuit such as the logic gate of Fig. 11. If all inputs except one are left open-circuit, or at the high-state voltage level, and the voltage at this input is increased from zero the output starts off high, passes through a fairly sharp transition region and then remains low. The characteristics of individual circuits may vary somewhat owing to production tolerances, load conditions, etc., and an envelope curve such as that indicated by the dotted lines could be drawn so that it includes all the characteristics likely to be obtained under a given set of conditions. The limits of the logic levels at the output of any unit are, therefore, as indicated by V_H and V_L on the output-voltage axis. In the absence of noise these voltages also represent the limits of the input voltage to the next stage, and they can be replotted on the input-voltage axis to give the two shaded areas, which define the normal operating voltages of the system. It can be seen from Fig. 12, however, that even if the output voltage of one stage is at its maximum low level the input to the following stage could be increased by a further amount V_A without affecting the subsequent output level, and, similarly, a minimum high-level output could be decreased by an amount V_B. The voltages V_A and V_B thus give a measure of the voltage noise which could be picked up on any, or all, output-to-input interconnexions in a logic system without causing errors, and the smaller value (generally V_A) is termed the d.c. noise margin.

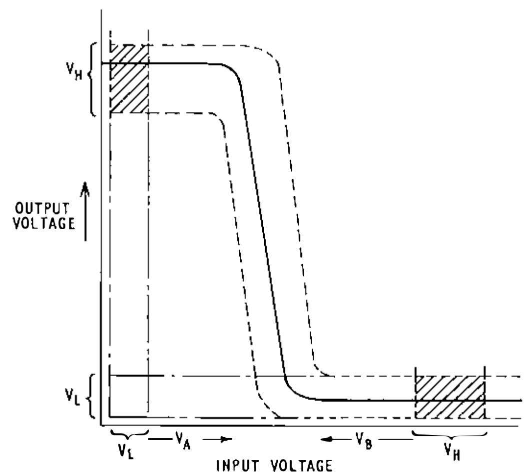

FIG. 12—TYPICAL VOLTAGE-TRANSFER CHARACTERISTIC

Although in practice the situation is not quite so simple as that indicated in Fig. 12, and it is often difficult to interpret some of the values of noise immunity which are quoted, the general principle remains as above. Negative-going noise voltages on a low-state input and positive-going noise on a high-state input will not produce errors in the logic and do not normally present a problem. In practice, impulsive noise will be the main concern, but this is difficult to specify and, in general, the d.c. noise margin gives the worst case for noise introduced on the interconnexions. The value of the d.c. noise margin gives a useful comparison between the noise immunity of different logic ranges, but it is not the only factor involved, and it should be remembered that noise signals may be picked up at other points in the system and also that the impedance levels are of great importance. A circuit with a high level of voltage noise margin may also have a high impedance and be more susceptible to interference than a low-impedance circuit having a lower noise margin.

The speed with which logical operations can be carried out by a circuit depends on the amount by which the signal is delayed in passing through the circuit. This is termed the propagation delay, and is the time between corresponding points on the input and output waveforms. Where the signal is inverted in passing through the circuit, as, for example, in the circuit of Fig. 11, it is easier to consider the delay over two similar stages and to take half of this as the average propagation delay per stage. The delay will increase with capacitive loading.

Direct-Coupled Transistor Logic

Direct-coupled transistor logic (d.c.t.l.) has the basic gate circuit shown in Fig. 13, and was one of the first circuits to be considered for construction in integrated form because of its simplicity. The circuit consists mainly of

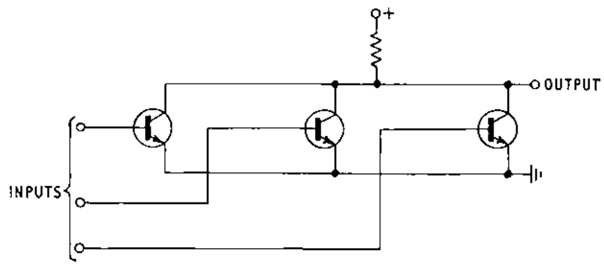

FIG. 13—DIRECT-COUPLED TRANSISTOR LOGIC

transistors having their collectors directly interconnected, and is hence very suitable for integration since this type of configuration leads to economy in the area of silicon occupied. The operation of the circuit has also been described previously,[3] and is, briefly, such that if any one or more of the three inputs shown on the circuit of Fig. 13 is in the high state the transistor will be turned on and the output will be in the low state. Only if all the inputs are in the low state will all the transistors be turned off and the output be in the high state. The circuit, therefore, provides the operation of a NOR gate to positive logic.

The basic circuit shown is not used in practice because of several disadvantages, one of which is the effect known as "current hogging." This can occur when a gate is fanning out to the inputs of several similar units and the output is in the high state. All the transistors on the inputs which are connected to the output of the driving gate should be conducting, and their base currents are supplied from the resistor of the driving gate. The resulting high-state voltage level at the output will be the base–emitter voltage of the saturated transistors, and, unless these are well matched, the transistors having low base–emitter voltages will "hog" the available current. Close tolerances are required on both the resistor and the transistors in the circuit to ensure that all the transistors in the fan-out gates will be fully saturated. The small voltage differences between the logic levels is another disadvantage of the circuit: the high-state voltage level is the base–emitter voltage of a saturated transistor (about 0·8 volts) and the low-state voltage is the collector–emitter voltage (about 0·2 volts).

By modifying the basic circuit to include a resistor in the base of the transistor the effect of variations in the base–emitter voltages, and hence the current-hogging problem, is reduced and at the same time the high-state output level is increased. This is done in all the practical logic circuits based on d.c.t.l., and two types of logic ranges based on modified d.c.t.l. circuits are described below.

Resistor-Transistor Logic

With semiconductor integrated circuits the term resistor-transistor logic (r.t.l.) has been used to describe

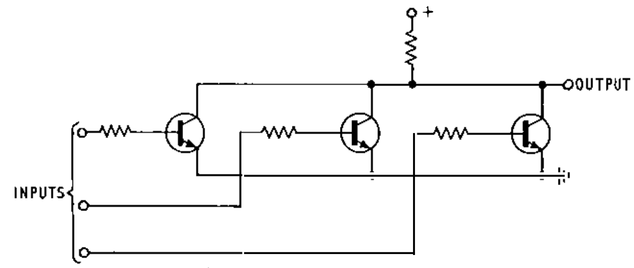

FIG. 14—RESISTOR-TRANSISTOR LOGIC

the modified d.c.t.l. circuit shown in Fig. 14. A logic range based on this circuit was one of the first to become available in integrated form, and has since found widespread use. R.T.L. is one of the faster forms of saturated logic and provides a good compromise between speed and power dissipation. The propagation delay is typically about 12 ns* for a power dissipation of 12 mW, and bistable circuits can be used at counting rates of up to 20 MHz. Low-power circuits are also available, having a dissipation of 2 mW and a delay of about 40 ns. A single power supply of 3 volts is used, and the logic levels are typically 0·2 volts and 1·5 volts. The d.c. noise margin is typically 0·3 volts, but can be less than 0·1 volts under the worst-case conditions. The common collector resistor has a value of about 600 ohms and the circuit thus has a relatively low output impedance in both high and low states. This form of modified d.c.t.l., or variations of it, are available from more than one source, and it is now one of the cheapest logic ranges on the market.

Resistor-Capacitor-Transistor Logic

The term resistor-capacitor-transistor logic (r.c.t.l.) has been used for the modified form of d.c.t.l. which has a circuit similar to that of Fig. 14, but with the addition of a capacitor across each input resistor. This was also one of the earliest forms of integrated logic available and was designed to have a low power dissipation for use in space applications. With a supply of 3 volts the dissipation is 2 mW and the propagation delay is about 150 ns. The circuit has a low d.c. noise margin and the collector resistor is relatively high (5,000 ohms).

Diode-Transistor Logic

Diode-transistor logic (d.t.l.) is probably the most widely available type of integrated logic circuit at the present time, and most manufacturers now make a range of this type. The basic circuit of Fig. 11 is difficult to make in monolithic form, however, and many of the logic ranges use modified versions of this circuit. The difficulties arise from the different characteristics required for the two sets of diodes, and from the close tolerances required on the other elements of the circuit in order to guarantee the fan-out capability. Fast low-storage diodes are required on the inputs to keep the propagation delay to a minimum, whilst the base diodes should have high storage to reduce the turn-off times of the transistor; with present techniques it is difficult to obtain these different characteristics on a single chip. An alternative method of reducing the turn-off time of the transistor

*1 ns = 1 nanosecond = 1×10^{-9} seconds.

is to use a low value for resistor R2, but this diverts current from the transistor when it is turned on, and, since resistor R1 controls both the current available for driving the transistor and also the current into a previous low-state output, there are difficulties in maintaining the fan-out capability of the circuit.

The first d.t.l. range to become available in integrated form had a logic circuit similar to that of Fig. 11, except that a fairly high value for the base resistor (20,000 ohms) was used and this was taken to a separate negative supply. This reduces the turn-off time of the transistor, but the need for a second power supply is a disadvantage for many applications, and alternative ranges are now available which only require a single supply. Some of these have the equivalent circuit of Fig. 11, whilst others have modified circuits. An example of the latter is shown in Fig. 15, and here the first level-shifting diode is replaced by a transistor which has its collector taken to a tap on the input resistor. This transistor cannot saturate, and the

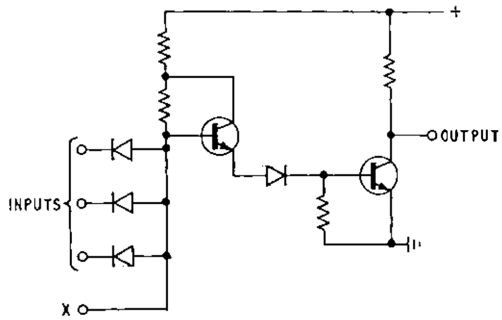

FIG. 15—MODIFIED DIODE-TRANSISTOR LOGIC CIRCUIT

additional gain it introduces enables a higher base current to be used to drive the output transistor, without at the same time increasing the current which flows out of an input in the low state. The tolerances on the circuit elements are eased, and a lower value of resistor can be used between the base and emitter of the output transistor.

General-purpose d.t.l. ranges based on either the straightforward or modified types of circuit are available from several sources. They normally require a single power supply of between 4 and 6 volts, and the logic levels may be typically 0·3 volts and 4·5 volts. The propagation delay is in the range 8 to 40 ns and the corresponding power dissipation is from 20 mW to about 8 mW. Bistable circuits can be used at counting rates of about 10 MHz, and the d.c. noise margin is typically 0·9 volts with a worst-case value of 0·4 volts. The output impedance in the high state is generally fairly high (6,000 ohms); this results in the output signal having a relatively slow rise time, which in turn leads to a marked increase in the propagation delay with capacitive loading, but additional gate units which have either a low-value collector resistor or a "pull-up" transistor (see Transistor-Transistor Logic below) are provided for driving such loads. Very low-power d.t.l. ranges can be obtained in which the logic gate has a dissipation of only 1 mW and the delay is about 100 ns.

Other Diode-Transistor Logic Ranges

Amongst the many varieties of d.t.l. circuits available there are several which have special features of interest. One range, described as a modified form of d.t.l., uses the normally unwanted p–n–p transistor formed when a p–n diode is produced in a p-type substrate, in place of the conventional input diode. Usually the gain of this transistor is made as low as possible, but in this range the small amount of gain obtainable is used to ease the tolerance on the input resistor. The basic gate circuit is shown in Fig. 16, and has little in common with the normal d.t.l. circuit; it has p–n–p transistors at the input, uses

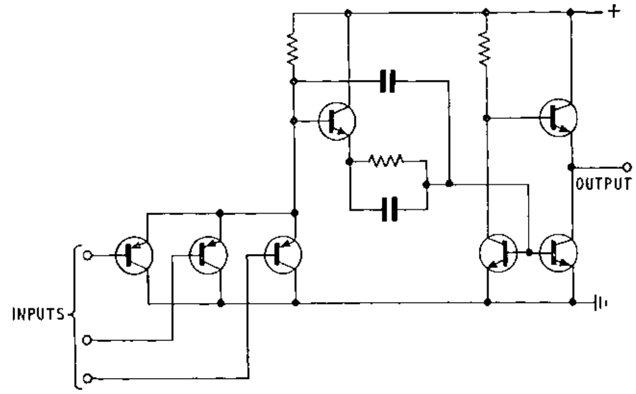

FIG. 16—MODIFIED FORM OF DIODE-TRANSISTOR LOGIC CIRCUIT

more circuit elements, and includes a pull-up transistor in the output. Most units in the range are based on this circuit, which has a delay of about 25 ns, but a fast AND gate having a delay of about 5 ns can also be obtained. This AND gate consists of the input gating transistors of Fig. 7, followed by an emitter follower in which the emitter resistor is taken to a negative supply. Two or three such stages can be cascaded before the logic levels have to be restored by using the basic NAND gate. Power supplies are +3·5 volts and (where required) −3 volts.

The noise margin of the basic d.t.l. circuit of Fig. 11 can be improved by increasing the voltage drop in the base circuit of the transistor, and this could be done, for example, by adding a third diode. In the variable-threshold logic gate shown in Fig. 17 a resistor is used in place of one of the base diodes, and a n–p–n transistor with its emitter taken to a negative supply is used as a constant-current source in place of the base resistor R2 of Fig. 11. The current, and hence the voltage drop across the resistor, depends on the supply voltages, and by varying these it is possible to obtain noise margins of up to 5 volts.

Another form, high-noise-immunity logic, uses a single 12-volt supply and has a Zener diode in place of the base diodes. The noise immunity is, typically, about 4 volts, and all units have a pull-up transistor on the output. Logic levels are typically 1 volt and 11 volts, and inter-

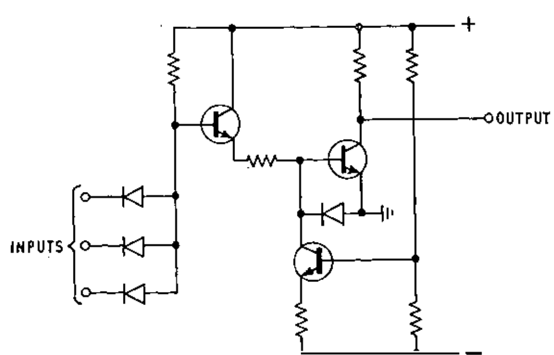

FIG. 17—VARIABLE THRESHOLD LOGIC

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facing units are available which transform between these levels and those used in the normal d.t.l. ranges.

Complementary Transistor Logic

Complementary transistor logic (c.t.l.) is a high-speed logic range which uses the non-inverting AND gate, as shown in Fig. 18. This is similar to the modified d.t.l.

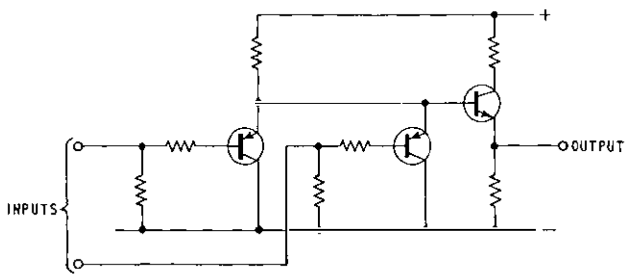

FIG. 18—COMPLEMENTARY TRANSISTOR LOGIC

mentioned above in that p–n–p transistors are used on the inputs, and several of these gates can be cascaded before the logic levels have to be restored. Either NOR gates or level-setting AND gates can be used for restoring the levels; both have n–p–n transistors on their inputs and delays of about 12 ns. The AND gate of Fig. 18 has a delay of about 4 ns and a dissipation of about 40 mW. Two power supplies of +4·5 and −2·0 volts are required, and the logic levels are nominally −0·5 volts and +2·5 volts.

Transistor-Transistor Logic

Transistor-transistor logic (t.t.l. or t^2.l.) is a development from d.t.l. in which the diodes are replaced by a multi-emitter transistor.[4] Almost all t.t.l. units also have a pull-up transistor in the output stage, and this is included in the typical basic circuit shown in Fig. 19.

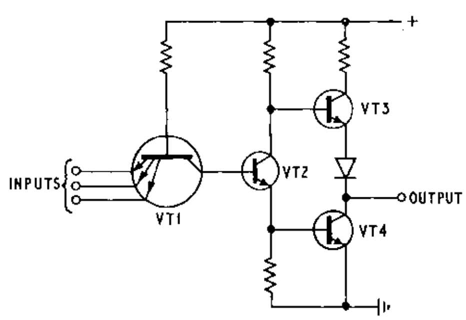

FIG. 19—TRANSISTOR-TRANSISTOR LOGIC

This type of output is used in other logic ranges on certain units which are intended for driving highly capacitive loads, and is often called a "push-pull" or a "totem-pole" output.

The basic gate circuit provides the same logical operation (NAND) as d.t.l. When all the inputs are in the high state, current flows through the base resistor and the base–collector junction of transistor VT1 into the base of transistor VT2. Transistor VT2 saturates, turning pull-up transistor VT3 off and pull-down transistor VT4 on, and thus gives a low-state output. The diode in the output stage ensures that transistor VT3 is turned off when transistor VT4 is turned on; it may, alternatively, be included in the base of transistor VT3 where, in the faster forms of t.t.l., it is often replaced by a transistor. When any one input is in the low state the base current of transistor VT1 is diverted to the base–emitter junction and the transistor saturates providing a low impedance path which enables transistor VT2 to turn off quickly; transistor VT4 is turned off and transistor VT3 turned on, thus giving a high-state output. The low resistance in the collector of the pull-up transistor limits the current surge which can occur on switching.

The multi-emitter transistor is one of the forms of construction that is economical in the area of silicon occupied, and is inherently faster than the diode gate of d.t.l. since the base current is similar in both states and switching only involves a rearrangement of charge in the base. As with d.t.l., both low-power and high-speed ranges are available; typical propagation delays are in the region of 7 to 15 ns and the corresponding power dissipation is from 25 to 10 mW. There is also a very low-power range which has a dissipation of only 1 mW and a delay of about 60 ns. A single power supply of about 5 volts is required, and the logic levels are typically 0·3 volts and 3·5 volts. The worst-case voltage noise margin is generally about the same as, or slightly better than, that for d.t.l., and the circuit has a low output impedance in both the high and low states.

Emitter-Coupled or Current-Mode Logic

With the exception of c.t.l. all the basic gate circuits considered so far use transistors operating in the saturated condition. In emitter-coupled logic (e.c.l.), alternatively known as current-mode logic (c.m.l.), the transistors do not saturate, and this mode of operation enables very fast operating speeds to be obtained because of the absence of delays caused by the removal of stored charge. A basic gate circuit of this type is shown in Fig. 20; a single power supply is used, but, in addition, a bias supply is required for the base of transistor VT4. This bias may be provided internally within each unit, or the range may include a

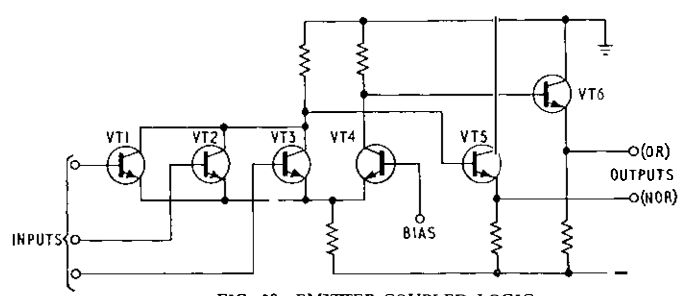

FIG. 20—EMITTER-COUPLED LOGIC

separate bias supply unit which is capable of supplying the bias to several logic units.

With all the inputs in the low state the emitter-follower VT5 will be conducting to give a high-state output. Transistor VT4 will also be conducting, and the output from transistor VT6 will be low. If any one input is taken to the high state, current will flow through the input transistor, resulting in a low-state output from transistor VT5. Because of the common emitter resistor the current through VT4 will be reduced as that through the input transistor increases, resulting in a high-state output from transistor VT6. Emitter-followers are used at each output in order to restore the logic levels, and it is an advantage of e.c.l. that complementary outputs can be obtained from the basic gate: a NOR output from transistor VT5, and an OR output from transistor VT6.

A supply of −5·2 volts is normally used, and the logic levels are nominally −0·75 volts and −1·55 volts with a typical noise margin of 0·3 volts; power dissipation is about 35 mW. The propagation delay is, typically, 6 ns, although faster ranges are now becoming available with typical delays of under 4 ns; bistable circuits can be used at counting rates of over 30 MHz.

CHOICE OF LOGIC RANGE

Most of the earlier logic ranges were designed to work between the full military temperature limits of −55°C to +125°C. During the past 2 years many of these, and also some specially-designed ranges, have become available at reduced prices for use between restricted temperature limits which may be, typically, 0°C to +70°C, or +15°C to +55°C. There is obviously no point in using units tested for a wider temperature range than is necessary since this only increases the cost.

The packages available have been described in Part 1, and many logic ranges can now be obtained in both the flat and the dual in-line type of package. The latter is at present cheaper and is probably the most convenient, except where extreme miniaturization is required; it should be remembered, however, that the long-term reliability of packages, particularly the cheaper plastic varieties, is not yet proven.

In the following general summary of the properties of the main types of logic only those types for which broadly similar ranges are known to be available from more than one manufacturer are given. Whilst it would also be desirable to use a logic range which was available from United Kingdom manufacturers this is not yet always possible. The non-saturated e.c.l. type of logic is the fastest, giving delays of only a few nanoseconds, but it has a low noise immunity and a high power dissipation. Very-high-speed circuits generally introduce problems associated with their interconnexions, and there is no point in using such circuits if the high speed is not essential.

The three main saturated types of logic which are generally available are r.t.l., d.t.l. and t.t.l. Of these r.t.l. has a low voltage noise margin but provides a good compromise between delay and power. The wired-OR* facility can be used, fan-in extender units are available, and units as complex as decade counters can be obtained. D.T.L. is a useful general-purpose type of logic and is available in one form or another from most manufacturers. It is the only type known to be available from more than one United Kingdom manufacturer at the present time. The speed is sufficient for many applications and the circuit has a good voltage noise margin. Most units have a high output impedance when the output is in the high state, but gates having the push-pull type of output are also available. The wired-OR facility can generally be used and the fan-in can easily be increased, but the most complex unit available at present is probably one that contains two master-slave bistable circuits in a single package. T.T.L. is generally faster than d.t.l. and the voltage noise margin is about the same. All units have the push-pull output, giving a low output impedance in both states but also a high current-surge during switching. The wired-OR facility cannot be used and fan-in extenders are not generally available, but many complex logic units can be obtained. T.T.L. is the latest general-purpose type of logic to become available, but already such circuits as decade counters, full-adders and 16-bit scratch-pad memories are on the market.

It is difficult to give comparative prices for the various types of logic because they change so rapidly that they are almost certain to be out of date by the time this article is published. In order to give some idea of the way prices are going, however, some multiple-gate units are now advertised at under £1 (in quantity) and bistable units at under 30s.

*Wired-OR is a term used for the facility of providing the OR operation purely by circuit wiring, e.g. if the outputs of two circuits similar to Fig. 15 are connected together the common output will be low if either circuit has a low output.

CONCLUSIONS

A variety of units providing basic logical operations can now be obtained in the form of semiconductor integrated circuits. These units can be used as the building blocks of complex logic systems and should result in smaller, cheaper and more reliable equipment. Only those logic units which are available as standard items from the manufacturers have been considered, but already some quite complex operations can be obtained and many more are likely to become available as the technology improves.

Much development work is now being done on the large-scale integration of complete sub-systems and on the use of metal-oxide-semiconductor transistors (m.o.s.t.) in integrated circuits. It seems likely that there will be about a tenfold increase in the complexity of the logical operations obtainable in a single package during the next few years.

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U.D.C. 621.317.799:621.395.34:621.395.722

Routiners, originally introduced in automatic telephone exchanges over 30 years ago, have been developed in several stages to give increased flexibility and to provide more facilities. The latest versions use transistors and are fully automatic in operation.

INTRODUCTION

ROUTINERS have been used by the British Post Office for testing automatic telephone-exchange plant since the commencement of large-scale automation in the late 1920s. The broad principles of operation of these early routiners have continued to the present day, but, through the years, many alterations and improvements in design have been adopted and more facilities have been added. The essential elements of a routiner are shown in block form in Fig. 1. The access selectors

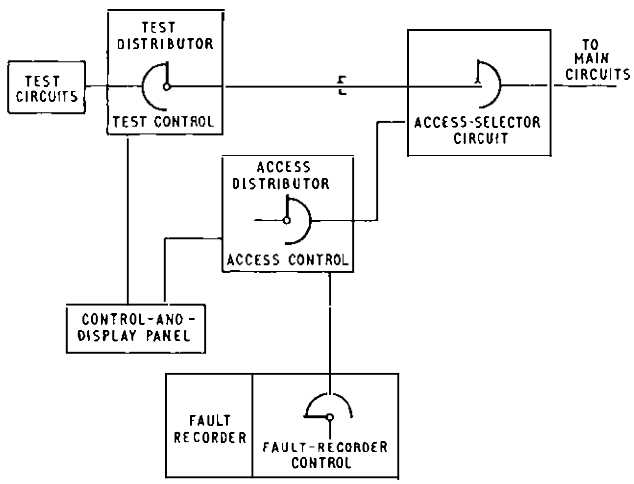

FIG. 1—ESSENTIAL ELEMENTS OF A ROUTINER

are mounted on the rack of the main equipment under test or on a special access rack, the fault recorder and fault-recorder control circuit on a miscellaneous apparatus rack, and the remainder of the equipment on the routiner rack.

PRE-2,000-TYPE ROUTINERS

The earliest routiners were designed individually by the manufacturers; each was built as a single composite rack (see Fig. 2(*a*)) which constituted a large and somewhat specialized item for manufacture.[1] The control circuit, the access selectors and the various test circuits were covered on one diagram, and often used the same test-circuit components for different tests. This arrangement proved somewhat inflexible when it came to modifications, the need for which is apt to arise more frequently on routiners than on most other equipment because of developments, changes and supersessions affecting the equipment under test. An early attempt was, therefore, made to divide the test circuits into separate elements segregated from the control circuit, thereby facilitating test-circuit design and permitting some degree of standardization of circuit elements common to different routiners. However, although these routiners (known as RW type) afforded an improvement in testing, the method of dividing the test circuit into separate elements inter-connected by direct wiring and without uniformity in their general pattern, rendered the documentation of the inter-connecting wiring difficult. This feature became unpopular with both designers and manufacturers, and the design (see Fig. 2(*b*)) was short lived.

2,000-TYPE ROUTINERS

With the advent of the 2,000-type equipment rack, a fresh attempt was made to improve and standardize routiners, and a "2,000-type" version was produced. A suite of 2,000-type routiners is shown in Fig. 2(*c*). This design was a successful compromise, the general features of which have lasted to the present day; it aimed at a simple division of the routiner into two parts, the access-control circuit and the test unit, the latter returning to the earlier practice of combining all test elements into one large circuit. The access-control unit and the test unit are built as self-contained sub-assemblies allowing each access-control unit to be used with any one of a number of different test units to provide the facilities required. Access-control units have also been built to serve two test units on one routiner, testing, for example, two different types of final selector.

Recent versions of the 2,000-type routiner have been equipped for fully-automatic operation. Clock control permits the starting and stopping of routining periods at times pre-set individually for each routiner, and a shared fault-recorder prints, in docket form, a record of each routining period. The printed information includes docket serial number, date, details of items failing on test, and the identity of the first and last item tested during the routining period.[2] Arrangements are being made for these facilities to be extended to many of the earlier designs. Where shortage of rack space prohibits the necessary modifications a simplified method of recording has been employed using a transportable fault-recorder serving only one routiner at a time.[3]

The earlier versions of the 2,000-type routiner were mounted on a 1 ft 6 in. rack (see Fig. 2(*c*)), but some more recent ones have been engineered, without the use of sub-assemblies, on a 2 ft 9 in. rack to accommodate a larger range of tests. Examples of this are register-translator routiners, which require a relatively large number of uniselectors and lamps for digit storage and a number of Yaxley switches for setting translation tests, as shown in Fig. 2(*d*). Thus, although the 2,000-type routiner has been superseded for many purposes, by the RT types described in later paragraphs, a use for it is likely to

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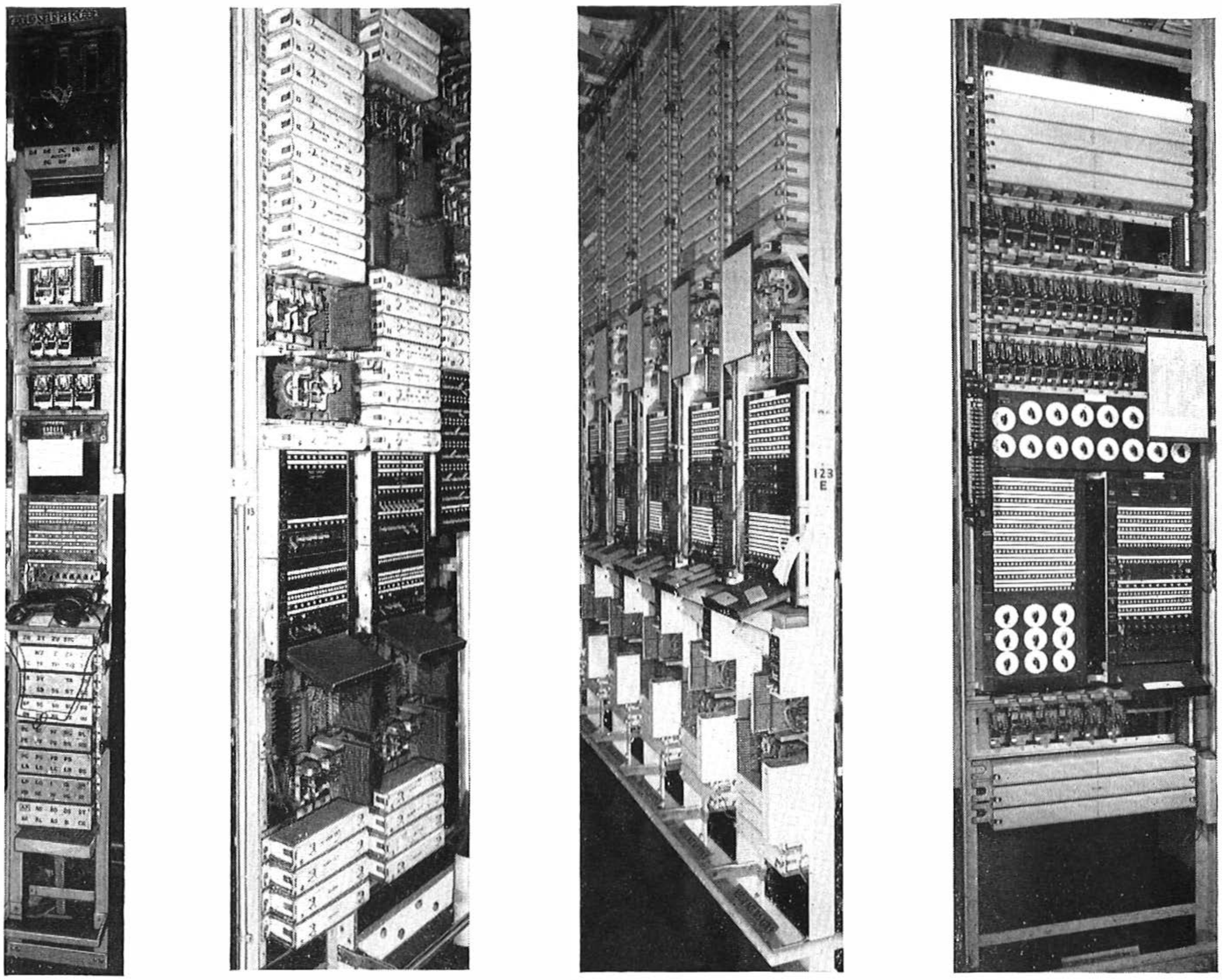

(*a*) Pre-2,000-Type Routiner

(*b*) RW-Type Routiner

(*c*) 2,000-Type Routiners on 1 ft 6 in. Racks

(*d*) 2,000-Type Routiner on 2 ft 9 in. Rack

FIG. 2—PRE-2,000-TYPE AND 2,000-TYPE ROUTINERS

continue when the more standardized design of RT types imposes limitations on the use of available rack space.

RT 1,000-TYPE ROUTINERS

Some 20 years ago a new look was taken at routiner design with a view to combining the advantages of the various earlier types and also to introduce more refined tests. The outcome of this project was the now well-known RT 1,000-type routiner (Fig. 3), which returned to the method of dividing the test circuit into separate elements, i.e. to the elemented type of test circuit.[4] On these routiners the documentation complexities of the earlier elemented type, i.e. the RW type, have been avoided by designing test circuits to have a uniform method of association with the rest of the routiner. The essential features are the adoption of a standard 2,000-type 4 ft 6 in. equipment rack fully wired with the control circuit, the control panel, and shelves to carry 45 test relay-sets and 9 common-test relay-sets. Each test relay-set is designed to set up the conditions necessary for making a small group of related tests. The common-test relay-sets are brought into use in association with test relay-sets when required for basic testing operations such as measurement, counting and timing, suitable calibration limits being set by each test relay-set concerned. These relay-sets, mounted on standard jack-in relay-set mounting plates, are then added to the rack to complete the routiner according to the test program required for the particular type of equipment to be tested.

The RT 1,000-type arrangement offers a number of advantages. Firstly, from the design point of view, when a routiner is required to test a new piece of equipment (which occurs even more frequently with the present rapid development of the telephone switching system) the design engineers have only to deal with the test relay-sets, the common-test relay-sets generally being provided from existing designs. Secondly, the design work is to some extent rationalized in that each test relay-set is self-contained and follows a relatively standardized pattern both for the circuit and the mounting; this results in an economy of effort that is of considerable help when, as often happens, ready-for-service dates are scheduled to

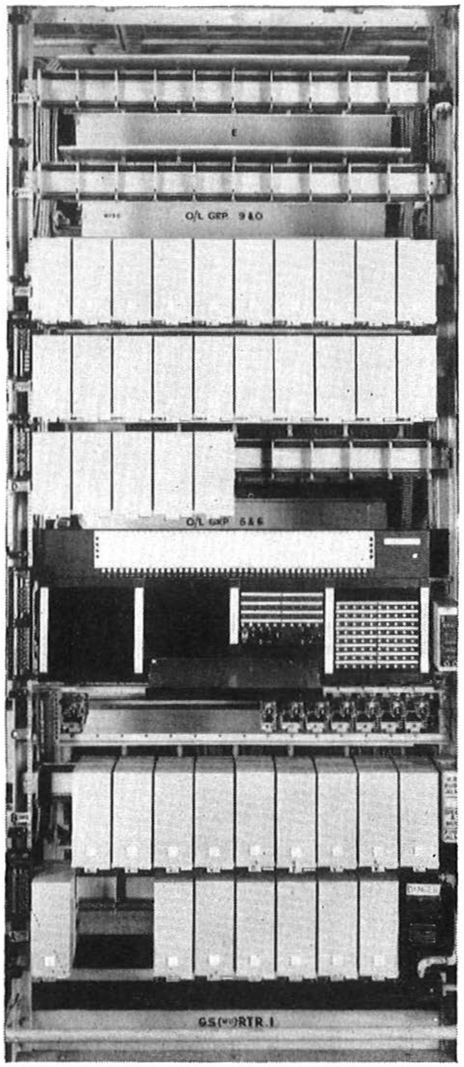

FIG. 3—RT 1,000-TYPE ROUTINER FOR MOTOR-UNISELECTOR GROUP SELECTORS

follow closely the design period. Thirdly, from the point of view of the user, these features are an aid to comprehension, in that all such routiners are to a considerable extent identical; also, the presentation of test relay-set circuits on small individual diagrams is a convenience, since it is usual to require only one for study at a time. Finally, if the main equipment should be superseded by a changed design, it is a straightforward job to modify existing test relay-sets, or to add others, to cover different or additional tests. However, these advantages were not gained without expense, and although the RT 1,000-type, which is equipped for fully-automatic operation, has proved a very useful tool where a large number of refined tests are required, e.g. for a.c. signalling relay-sets, it is unnecessarily elaborate for testing simpler equipment such as group or final selectors. A new version of the design has, therefore, been produced and is known as the RT 5,000-type routiner.

RT 5,000-TYPE ROUTINERS

The RT 5,000-type routiner follows the circuit principles of the RT 1,000-type but occupies only a 2 ft 9 in. rack. The relay-sets are strip-mounted instead of being jacked-in, allowing flexibility in the size of relay-set and leading to economy in the use of rack space. Furthermore, the restrictions imposed on circuit design by working to a limited number of relay-set jack-points and to a fixed arrangement of rack wiring have been eliminated.

The lower half of the RT 5,000-type routiner rack is occupied by the access and test-cycle control circuits, the control panel and the writing desk, which are standard for all applications of the routiner. The remainder of the rack is available for mounting the test and common-test circuits required for a particular application.

The breaking down of a test cycle into self-contained tests or short test-sequences requires rather more rack space than a single large and complex test circuit, but maximum space has been made available for the test circuits by removing the fault-label information from the control panel to the surface of the writing desk. As well as giving greater reliability, the use of transistor circuits, operating from the exchange 50-volt supply, instead of valve circuits requiring a power pack, results in further economy in the use of rack space.

The RT 5,000-type routiner is equipped for fully-automatic operation.

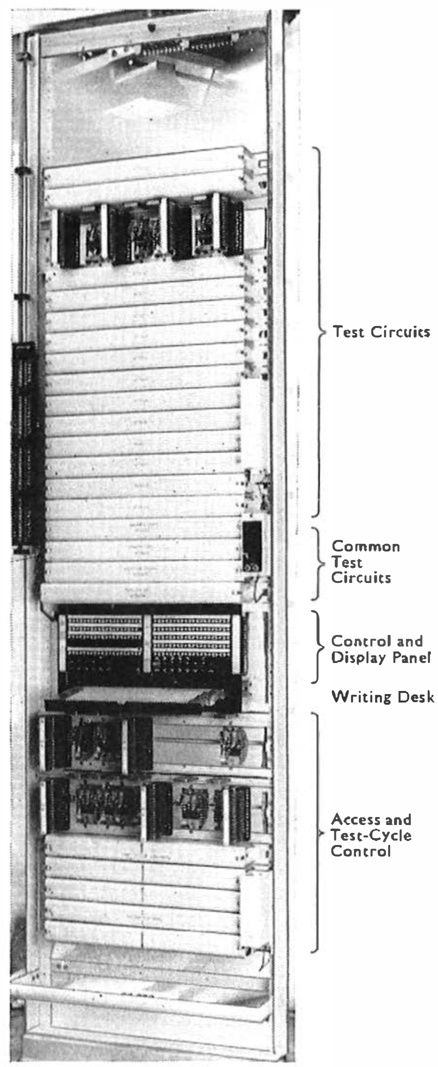

FIG. 4—RT 5,000-TYPE ROUTINER FOR 4,000-TYPE 11-AND-OVER P.B.X. FINAL SELECTORS

11-and-over P.B.X. Final-Selector Routiner

An RT 5,000-type routiner has been designed for testing 4,000-type 11-and-over P.B.X. final selectors; this is illustrated in Fig. 4. The facilities required called for more refined tests than hitherto applied to final selectors; in particular, transmission-bridge tests, timing tests, a comprehensive test of P.B.X. level-to-level hunting, and automatic detection of supervisory tones. The well-tried circuit techniques employed in the RT 1,000-type routiner have been used, and, with the redesign of the common-test circuits to use transistors instead of valves, a high degree of reliability is expected.

Automatic testing of every level of the final selector to check the P.B.X. facilities requires the provision of a strapping field on the routiner so that the level-to-level hunting sequence peculiar to each final-selector multiple can be built into the routiner on initial installation and subsequently altered as the level allocations change during the life of the exchange. It is expected that, with automatic fault-recording, much of the routining will be done at night. A night busying-service is then in operation on some subscribers' lines, but, to enable normal daytime facilities to be tested, the routiner-access circuits cause these lines to be restored to normal during the routine test.

CONCLUSIONS

Routiners have developed in several stages from relatively simple individual designs to standardized types with elemented circuits affording flexibility in application, and providing auxiliary facilities such as fault recording and automatic starting and stopping. The latest version, the RT 5,000-type routiner, has the same access capacity as, but half the testing capacity of, the earlier RT 1,000-type routiner while retaining testing techniques which have proved satisfactory over the last 10 years. The first examples of these routiners (for 4,000-type 11-and-over P.B.X. final selectors) are now coming into use.

ACKNOWLEDGEMENTS

Acknowledgement is due to the General Electric Co., Ltd., who co-operated with the Post Office in the design of the RT 5,000-type routiner, and for the photograph of that routiner (Fig. 4).

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Conference on Plastics in Telecommunication Cables, London, April 1967

U.D.C. 621.315.2:678.5

A CONFERENCE on "Plastics in Telecommunication Cables," organized by the Plastics Institute, was held at the Institution of Electrical Engineers, Savoy Place, London, on 11–12 April 1967. Over 300 delegates attended, approximately 70 from overseas. The opening address was given by Mr. J. H. H. Merriman, Senior Director of Engineering, Post Office Engineering Department, who outlined the advantages that had already accrued from the use of plastics in British Post Office cables and indicated the areas requiring additional development if plastics were to make further inroads into the field of wire insulation. Foamed polyolefins, if they could be produced economically in uniform radial sections of about 0·005 in. and below, could find an additional outlet for plastics of about 3,000 tons per annum in the Post Office trunk, junction and local cable network.

The Conference program was divided broadly into four sections: properties of polymers; extrusion and processing; design requirements, service experience and field failures; testing and analysis.

In the properties-of-polymers section, the thread running through most of the papers was that polythene as a simple material had virtually reached the limit of development, and that co-polymerization, blending and chemical modifications were all being examined as methods of extending the spectrum of available materials. Points of interest were that polypropylene can now be prepared with lower dielectric loss in the microwave region than any other plastic, and that this low loss probably extends through the sub-millimetre to the infra-red region of the spectrum. Polythene can be co-polymerized with acrylic acid to produce polymers naturally adhesive to metals, with vinyl acetate, ethyl acrylate and isobutyl acrylate to improve flexibility, stress-crack resistance or ability to hold conductive quantities of carbon black. Chlorination of both low-density and high-density polythene yield self-extinguishing materials of value as alternatives to PVC for flame-resistant cables. Foaming polythene to produce 25–50 per cent voids can be achieved by three distinct methods for insulating wires, i.e. the Japanese solvent process, and extrusion coating with gas injection or chemical blowing. Foaming to produce a cellular low-dielectric-constant material appears to be the only avenue by which plastics can effectively compete with paper as insulation in the larger sizes of local, trunk and junction cables.

In the second section of the Conference, of interest primarily to cable manufacturers, papers were presented on extrusion-die designs, extrusion theory, the effect of variation in composition on the extrusion of PVC, development in cable-manufacturing equipment, mechanisms of melt fracture and flow instability in polymer melts.

In the third section on service requirements and field experience, the opening papers were concerned with individual aging and failure mechanisms, i.e. stress-cracking and light aging. The phenomenon of stress-cracking is still not completely understood at the molecular level, but significant advances in avoiding this form of failure were reported in papers from Bell and Monsanto. The yield point in the stress-strain diagram for polythene is the danger point above which stress-cracking becomes possible. It is, therefore, important to ensure, as far as possible, in the design of cable sheath that the yield point is greater than the maximum stress likely to be encountered in practice. The effects of extrusion under critical temperature and shear conditions can also have a dramatic effect on the field performance of polythene. The measurements which are made of the melt-flow-index of samples of sheath from the finished cable, to give an indication of the extent to which the properties of the material have been affected by extrusion, are, therefore, a very important feature in quality control.

On light-aging, the dramatic effect of exposing thin sections of polythene and polypropylene in regions where they have real sunshine (e.g. Florida or Curacao) was adequately described. Judged by Post Office experience of changes in natural-polythene-sheathed cables left fully exposed to British sunshine, the accelerating factor for Florida must be at least 4–5. A further point to be borne in mind is that when thick sections of polythene are exposed, major deterioration occurs in a surface skin which partially protects the underlying material. In these circumstances exposure results on thin film give an over-pessimistic estimate of the field performance of thick sections, such as cable sheaths.

The results of thermal degradation studies on PVC compound were also reported. Thermal degradation produces three separate effects on a PVC compound: loss of plasticizer, cross-linking of the PVC, and release of hydrochloric acid. The first two produce hardening and embrittlement of the PVC itself; the third is significant for its possible effect on adjacent equipment. The broad conclusion was reached that, whereas practically all PVC compounds had a satisfactory life at 25°C, PVC could tolerate working temperatures up to 60°C for 30 years only if the best available plasticizers, stabilizers and antioxidants were specified.

Jointing was covered specifically in only one paper, presented by the British Post Office. There seems to be no doubt that British Post Office's jointing methods are at least as advanced as anywhere else in the world.

Papers were also presented covering the current situation in the U.S.A., France, Australia, Japan and the United Kingdom. It is readily apparent from the overall picture presented that each country has its own particular combination of geographical and topographical problems, availability and relative prices of raw materials, distribution of subscribers, and local hazards. Each combination results in a particular solution in terms of cable design, material selection, and jointing and maintenance techniques. It follows, therefore, that while individual improvements in cable design may very well spread from their country of origin, the way in which the improvement is incorporated into cable design elsewhere may very well be different. As an example, the bonded-foil barrier developed by Glover and Hooker in the United Kingdom has proved attractive for use in paper-insulated cables used in duct in the British Post Office exchange-to-cabinets section of the network. In the U.S.A. this section of the network is adequately (if expensively) provided for by the Bell Stalpeth design, and the bonded-foil barrier appears to be finding its place in direct-bury cable, beneath an outer sheath screened to provide lightning protection. It is this need to withstand lightning damage that makes British direct-bury cables impracticable in the U.S.A., and American designs unnecessarily expensive in the United Kingdom.

Peculiarly national hazards were cited, as in the prevalence of gopher attack on polythene-sheathed cables west of Mississippi. The great "outback" was brought vividly to mind on hearing of cockatoos swinging by their beaks on aerial cables in Australia—a gymnastic that has the same effect on the polythene sheath as a can opener on a tin of beans; if they counter this by putting them underground their cables promptly get eaten by termites and ants. Following on the accounts of the viciousness of sunshine in Florida, the delegates from the United Kingdom were heartened to realize that, whatever it might do to the human inhabitants, a country with warm winters, cold cloudy summers, permanently wet soil and a fauna that knows its place is a very good country in which to install cables.

The British contribution to this section included a detailed survey of the problems involving permeation of water vapour into polythene-sheathed cables. The conclusion was drawn that the Glover Barrier, plus a small amount of paper as a moisture sink, can cope with this permeation for many times the life expectation of the normal local cable. This discovery opens the way to the exploration of the use of cellular polythene as a wire insulant in place of paper for all local, trunk and junction cables.

The final section, on testing and analysis, was aimed at a somewhat specialized section of the audience and included a general survey of testing philosophy in the British Post Office and seven short papers. These covered the measurement of the power factor of polythene, determination of aldrin and dieldrin in PVC and polythene, carbon black in PVC, chlorinated wax in PVC, cell structure in plastic foams, and determination of vinyl acetate contents of ethylene vinyl-acetate co-polymer.

In addition to the Conference itself, an exhibition of British Post Office cables, jointing techniques, underground plant, and materials testing techniques, provided by the External Plant and Protection Branch and the Test and Inspection Branch, both of the Engineering Department, proved very popular.

To summarize, this Conference was held at a time when cable designs all over the world are undergoing a period of re-examination and rapid development. There would seem to be ample scope for another such Conference in, say, 3 years time when the place of plastics in most networks will have been settled for the next decade.

J.C.H.

Changes in Post Office Organization

U.D.C. 354.42

ELSEWHERE in this issue of the Journal will be found notes of recent changes in the top engineering posts of the Post Office.[1,2,3] There is nothing novel in this. This is a mark of the progress of time's arrow. Careers develop, mature, and end. Others, in turn, assume higher office, eager to maintain all that is virile and sapient in tradition and proven practice, yet aware of the challenge of change in ebullient technological development and its vital significance to our twin businesses of Posts and Telecommunications. All this is not novel. An article in this issue of the Journal traces the history of this over the past 97 years of engineering under the direction of Engineers-in-Chief.[4] Under each "Chief" the service adapted itself to the challenge of change as seen by the generation of the day; and all acted in the service of the community as the Professional Engineering Head of a Department of State.

What is novel about the changes now recorded, and brought into effect from 6 April 1967, is that they are one of a number of events that signal the first stage in the separation of the Post Office from Government, and its transformation into a Public Corporation. The proposals to make this change are set out in a White Paper.[5] The urge to change, itself, is not novel: successive Commissions, enquiries, Governments and officials have sought to adapt the status and structure of the Post Office to the essentially commercial character of its businesses. But the Government has now concluded

> ". . . . that the process begun in 1932 should be carried to its logical conclusion. A public corporation should be created to run these great businesses with a structure and methods designed directly to meet their needs, drawing on the best modern practice."

The constitutional, administrative, consultative and executive procedures to do this have now in fact been started. The changes in the appointments recorded on pages 138, 139, 150 and 151 are, therefore, changes that mark the beginning of the end of the former structure and the start of the transition towards the new. And they should be seen in that light. They do not record any diminution whatsoever in importance, or recognition of importance, of engineering. Rather the reverse. They should be recognized as some of the changes in the building of a bridge from the old to the new—an "old" in which engineering had demonstrated its vigour and worth as an essential but separate element of our business—a "new" in which it may well be that no element of the business can possibly be viable unless it has running through it a vigorous ferment of technology out of which can spring the stuff of growth, of economic viability, of community service, and of wise management.

Of the specific changes themselves only two comments may be made at this time. Firstly, the changes from "Director General" to "Deputy Chairman," from "Deputy Director General" to "Managing Director Telecommunications" and "Managing Director Posts," and from "Engineer-in-Chief" to "Senior Director of Engineering" all indicate changes to titles of more self-evident significance in the transition to Corporation organization. Secondly, these arrangements must be regarded as transitional. The creation of a new organization, more clearly fashioned to business and service ends, out of a Department of State organized according to Civil Service hierarchical customs is obviously a difficult task. Progress on this will be noted in the Journal as it becomes proper to do so.

But as we look to the future, two facts seem certain. There will be increased—not diminished—roles for Engineers and Scientists to play. There will be increasing, not diminishing, needs for means of free and open discussion of the essentials of telecommunications and postal technology. In all this, the Institution of Post Office Electrical Engineers and the Journal have a contribution to make that will be more, not less, than that which they have already made during the last six decades of the nearly ten decades of Engineers-in-Chief.

J.H.H.M.

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Book Review

"Computer Programming for Science and Engineering." B. A. M. Moon, M.Sc. Butterworth and Co., Ltd. 238 pp. 15 ill. 28s.

This book is an easily-read introduction to computational programming, and uses FORTRAN as a means of teaching good programming method. The text was found to be free of logical mistakes though the reader should challenge the technique or programming efficiency of some of the examples; there are few typographical errors. The main criticisms of this otherwise worth-while addition to the student's library were (*i*) the index should include references to all material covered by the author (e.g. ACCEPT, READ and PRINT statements), (*ii*) inadequate use of flow charts to illustrate the logic used to solve given examples, (*iii*) the omission of completely-worked examples, i.e. for space-saving reasons only, the main body of each example is given without the appropriate, and important, input and output formats, and (*iv*) the answers to the wide range of exercises suffer similarly and are sometimes too brief. However, this primer was not intended as a detailed manual and does succeed in its stated aim; it provides the student of any faculty with a good background of computing technique.

A.J.B. and F.C.H.

Electronic Telephone Exchanges: An Introduction to Switching Network Design

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This article describes the principles of the switching networks being used in the reed-electronic telephone exchange systems at present being developed in the United Kingdom, and the configuration of the networks exploiting the twin developments of electronic common-control and the reed relay as a switching element.

INTRODUCTION

THE arrival of reliable electronic control circuits and systems at economic prices is leading to their wider use for controlling the switching functions of telephone exchanges. The development of small reliable fast-operating reed-relay switches which can be directly controlled by electronic circuits provides an appropriate component for use as the switching element in these exchange systems. The configuration of switching networks to best exploit these twin developments is evolving, and this article describes the principles of the switching networks being used in the reed-electronic systems at present being developed in the United Kingdom.

REQUIREMENTS OF A TELEPHONE SYSTEM

General

A telephone network is required to provide the facilities for interconnecting the subscribers served by the network. Use of a single large telephone exchange to interconnect all subscribers is precluded by the need to restrict the length of the subscribers' lines. Thus, the network is based on local exchanges interconnected by trunk and junction circuits. The problem of the network can, therefore, be reduced to the problem of a single exchange which has its own subscribers and provides connexions (*a*) between subscribers on the same exchange by internal switching apparatus, and (*b*) to subscribers on other exchanges by giving access to junction circuits, which carry the traffic away via a hierarchical system of exchanges to the appropriate distant exchange. In general, such a telephone exchange could be defined as follows.

(*a*) It provides a means of interconnecting groups of circuits.

(*b*) It is continuously available to respond to calling signals from a calling line, which it can identify.

(*c*) In response to the information received from that line it can determine which of the relevant interconnecting paths are free, and select and establish a connexion over one of them—if necessary routing the call to another exchange.

(*d*) It can alert the called subscriber by means of signals, advising the calling subscriber of call progress.

(*e*) It can supervise, meter and release the connexion when necessary.

The connexion established should be noise-free, private, and suitable for transmitting either speech or data signals as required by the connected subscribers.

To design an exchange, the levels and expected variations in demand for these services from the subscribers and junctions must be assessed. It can never be known precisely, but theoretical probability studies enable assessments to be made. Thus, the problem of the exchange trunking is to provide economically, with an acceptable grade of service, an appropriate number of switches and circuits to handle the number of simultaneous calls expected to arise.

Economics

Coupled with the trunking there must be a means of selecting and operating the switches as demanded by the calling subscribers. The most economic and effective selection process is not independent of the trunking and forms part of the overall compromise.

Small exchanges, i.e. those with an ultimate capacity of less than about 2,000 lines, are most numerous. They are usually low-traffic exchanges, and it is very difficult to support any form of common switching control unless some compensating factors can be found. Any system, other than the individually-controlled Strowger-switch system, is faced with difficult economic barriers.

Large high-traffic exchanges, i.e. those above about 5,000 lines, are very favourable to high-speed common-control systems, particularly electronic systems, and successful competition with electromechanical systems is a real possibility as production increases, systems are refined, and component technology advances.

Exchanges between 2,000 and 5,000 lines, representing a substantial number of exchanges, are perhaps the most difficult of all, as solutions suitable for small exchanges become unwieldy and solutions suitable for large exchanges carry too large a burden of fixed costs for the common control. However, the provision in the early years of exchange life of electronic equipment that is initially higher in first cost than some competing electromechanical systems can often be justified when considered against the growth expectation of the exchange.

Thus, it seems inevitable that for some long time ahead there is little chance that a single electronic common-control system can cover the whole range of requirements commercially in competition with existing systems.

Compatibility

To succeed, any new system must be compatible with existing apparatus with which it must interwork, both at the detailed electrical level and on a national-network scale. On the electrical level, new equipment must work with existing equipment within the same exchange. On the network level, it is obvious that the existing telephone network cannot be changed overnight to a new method of working. This inertia to change is apparent not only when interworking to existing exchanges but also, and probably more important, when interworking to subscribers' apparatus. Existing transmission performance must also be maintained, if not improved, and it is unlikely that provision of apparatus on a per-line basis for this purpose will ever be economic.

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TYPES OF SWITCH

Over the years a large variety of switching systems have been used to fulfil the requirements of a telephone exchange.

Manual Systems

In the early days of telephony, manually-operated switchboards were used. System descriptions are unnecessary, but it is worth noting that the delightful electrical simplicity was achieved by the use of an expensive, but highly-adaptive, human control system.

Strowger-Type Switch Systems

The fallibility and expense of the manual system led to the invention of automatic systems. A prominent early system of the type which has survived for 60 years is the Strowger system, in which use is made of successive switching stages to route a call to the wanted line. The switch, in general, has one input and provides access to one of 10 contacts on one of 10 levels, enabling the digits dialled by the subscriber to directly route the call. To provide sufficient paths through the switching stages many selectors are used and their outputs multipled to give the required call-carrying capacity. All path-control and selection apparatus is associated directly with each selector stage. A feature of the system is that the outlets are very inefficiently used—only one of the 100 outlets per switch can be used at one time, although the very low cost per outlet makes this acceptable. The advantages of the flexible readily-adaptive control of the manual system were also lost.

Crossbar Systems

To improve the efficiency of the outlets, co-ordinate arrays of electromechanical relays were used to provide a multiple input and output switch early in the 1900s. However, to provide a 100-input, 100-output, switch requires 10,000 relays, and the need for a cheap cross-point relay becomes immediately apparent. This economy was obtained from the crossbar switch, which uses operating and holding components common to more than one inlet or outlet. The outlet efficiency of the switch is an improvement over that of the Strowger switch because all inlets or outlets, whichever is the least, can be in use at the same time. The need for some separate control of the switch offsets the economy gained by the more efficient use of the outlets.

Electronic Systems

Because of the probable cost of any available form of space-division switch, developments of electronic exchanges were devoted initially to time-division multiplex (t.d.m.) systems based on pulse-amplitude modulation (p.a.m.). These systems enable very many conversations to take place on the same pair of wires, secrecy between the simultaneous conversations being achieved by allotting a short time slot to each conversation. Although these systems were technically satisfactory the work did not result in a viable system for general use.

More recent work in the time-division field has concentrated on switching speech signals which have been converted from speech currents to time-division signals using pulse-code modulation (p.c.m.). This is expected to offer advantages over earlier p.a.m. systems in an environment where the junctions are already using p.c.m.

Despite the work on t.d.m. systems much effort was directed to reducing the price of cross-points for space-division systems, and attempts were made using gas tubes, transistor pairs and p-n-p-n diodes—work finally being concentrated on the reed relay.

SWITCHING PRINCIPLES

The Cross-Point

Gas tubes and present semiconductors are not electrically suitable for direct connexion to subscribers' lines, and their power-handling capability makes special interface equipment necessary on every line. They are uni-directional devices and, because of their cost, could be used only in a single-wire unbalanced network with limited signalling capability within the exchange. The reed relay overcame all these objections. It is a simple device consisting of a pair of magnetic blades sealed into a glass tube; the tube is filled with dry nitrogen at atmospheric pressure and the blade tips are gold plated. Four such devices are usually assembled in a wound bobbin to provide a four-contact-unit relay: three of the four contact units are used for the switched path, and the fourth provides an electrical holding path. In another form, two dry-reed contact units are assembled in a remanent-magnetic structure that may be in an operated or unoperated state. The state is changed by passing a current pulse through windings incorporated in the structure, the device requiring no holding current. It is known as the ferreed, and at present is in use in the United States and Canada. Details of the reed relay adopted as the standard switching relay for the electronic-exchange systems currently being developed in the United Kingdom are recorded in another article in this series.*

The Matrix

The main objective of the switching network of an

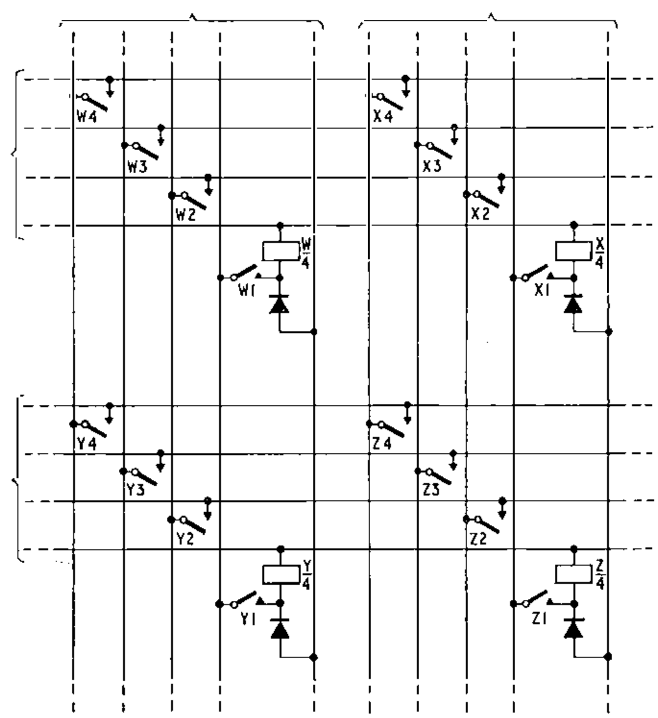
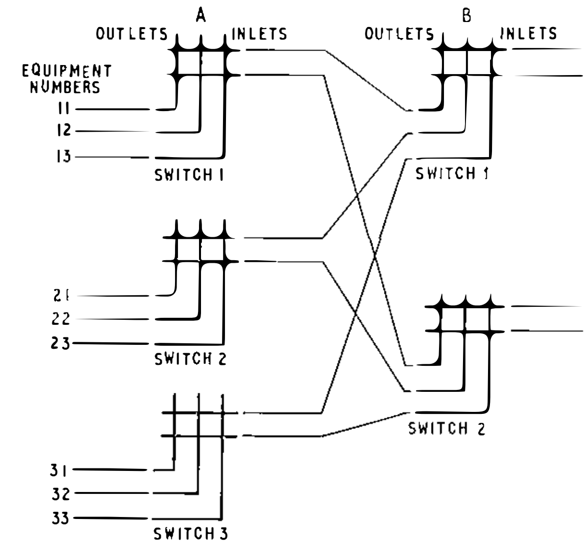


FIG. 1—SECTION OF A SIMPLE RELAY MATRIX

*ELEY, A. C., and LOWE, W. T. Electronic Telephone Exchanges: Reed Relays for Exchange Systems. (In this issue of the *P.O.E.E.J.*)

exchange is to interconnect the lines and to insert into each call an appropriate means of supervision. The switches may be required to interconnect a very large number of points. A very elementary switch is a matrix of relays, as shown in Fig. 1. The use of a single matrix rapidly becomes impractical as the number of inlets and outlets from the switch increase. Moreover, the cross-point efficiency drops as the switch size increases. Thus, a 5×5 switch with 25 cross-points can have 5 connexions and hence 5 cross-points in use simultaneously, i.e. 20 per cent. A 100×100 switch can use only 1 per cent at a time.

Large switches can be avoided by using multi-stage arrays; a typical two-stage array is shown in Fig. 2. A



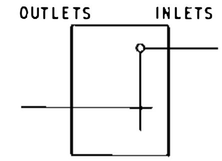
Note: The inlet/outlet sense of the switch is determined by the direction of marking
FIG. 2—A SIMPLE TWO-STAGE ARRAY

feature of the array is that there is only one path from each A-switch to each B-switch. Examination of the two-stage array shows that a particular terminal outlet can be reached from any inlet by applying conditions to the selected inlet and to the outlets of the two switches; the outlet numbers to which the conditions are applied are unique to the particular terminal outlet. The particular outlet numbers are known as equipment numbers and can be quite independent of the directory number of the subscriber connected to the outlet. Thus, a single path simplifies the network control; two or more paths may be used between each A-switch and B-switch with traffic-carrying advantage and greater control disadvantage.

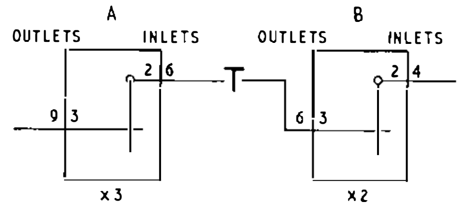
The simple single-stage array is a full-availability array. The usual multi-stage array provides full accessibility between all the inlets of the A-switch to all the outlets of the B-switch although, if more than a certain number of paths have been established, inter-switch paths may be fully occupied and new calls are said to be blocked. Non-blocking multi-stage arrays can be devised, but these soon become very costly. Thus, the general trend is for reed-relay systems to be organized around small unit switches, such as a 5×5 matrix or a 10×10 matrix, built into multi-stage arrays. Three to seven stages are typical.

Symbols

A symbol used to indicate a cross-point matrix is shown in Fig. 3(*a*). The two-stage switch array of Fig. 3(*b*) shows in symbolic form the switch matrices of Fig. 2; the commons indicate the size of the switches. Another method used for displaying the two-stage network is shown in Fig. 4.



(*a*) Single-Stage Switch



T indicates that there are transpositions in these interconnexions
(*b*) Two-Stage Switch Array

FIG. 3—TRUNKING SYMBOLS FOR SWITCH AND SWITCH ARRAY

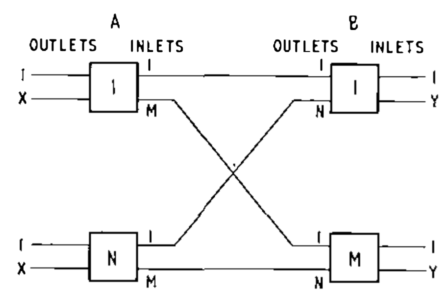


FIG. 4—ALTERNATIVE REPRESENTATION OF TWO-STAGE ARRAY

Control of the Multi-Stage Array

In the United Kingdom the most commonly-used arrangement for setting and holding the cross-point path through a multi-stage array is shown in Fig. 5. The call, when set up, is held with the cross-point coils in series. This offers a simple method for setting up and checking the successful completion of a connexion. Setting up requires that a suitable potential, say, negative as in the

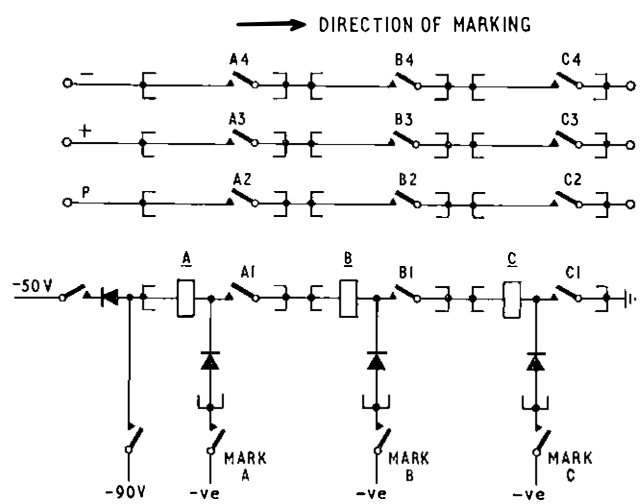


FIG. 5—SETTING AND HOLDING PATH THROUGH A MULTI-STAGE ARRAY

TXE3 system, is applied to one end terminal with a more positive potential to one of the marking leads. This operates the cross-point concerned, which passes the marking potential to the next cross-point, and so on until all have operated. Following a check of operation, the marking potential is removed and the negative potential at the end terminal is substituted for a more positive potential, allowing the cross-points to hold to an appropriate condition at the other end.

The sequence of marking the switches shown in Fig. 5 is for explanation only. In system applications there are usually merits in working from one end of the network or from the other, and the designer selects the more advantageous method.

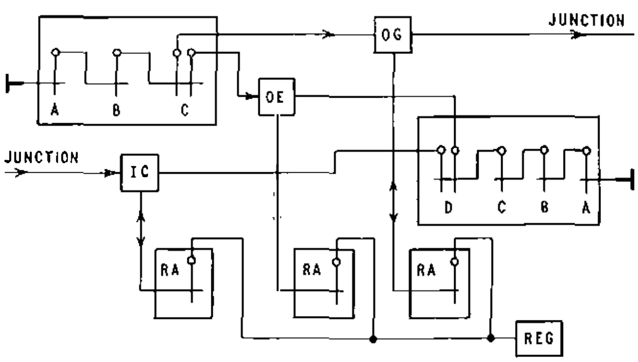
The number of stages that may be connected in series is a matter of detailed circuit design, taking into account tolerances on relays, resistors, and voltages. Normally, four stages are practicable and five are possible. However, marking and hold conditions can be repeated to successive stages at some small additional cost.

TYPICAL TRUNKING PLANS

The principles of trunking can be illustrated by reference to systems currently being developed in the United Kingdom.

The Small-Exchange System (*TXE*2)

A typical trunking plan for the small-exchange system is shown in Fig. 6. The plan demonstrates several points.



OE—Own-exchange supervisory circuit
OG—Outgoing-junction relay-set
IC—Incoming-junction relay-set
RA—Register-access switch
REG—Register

FIG. 6—OUTLINE OF SMALL-EXCHANGE TRUNKING

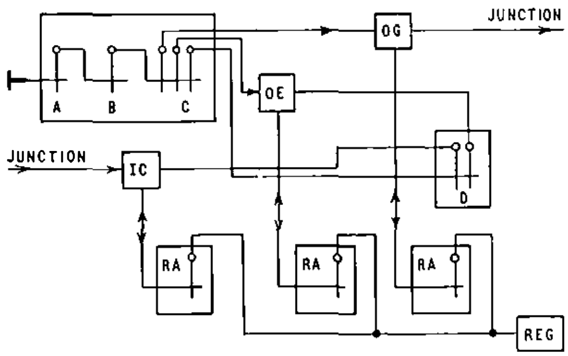
(*a*) Subscribers are low-traffic sources, and traffic concentration is needed between subscribers and supervisory circuits or registers, which are relatively expensive: typical supervisory or register occupancy of about 0·6 erlangs or more is the aim. Hence, the outgoing relay-set or own-exchange supervisory circuits are reached via three concentrating stages, A, B and C. Concentration via two stages is possible but is not often used because the A stages are kept small for economy. As a result the A–B connexion loading is low, and a third stage, C, is economic. A fourth stage is possible and can further load the supervisory circuits, but the extra cost and complication are usually not worthwhile.

(*b*) Incoming circuits are high-traffic sources and so can be connected directly to supervisory circuits.

(*c*) Terminating calls from own-exchange and incoming supervisory circuits pass over four stages to subscribers' lines. The three stages, C, B and A, perform in reverse, the function of the A, B and C stages for originating calls, but the D-switch is added to improve the access to the C-switches from the incoming and own-exchange supervisory circuits and thereby reduce traffic blocking.

(*d*) Access to registers is given from the supervisory circuits and requires the provision of a register-access switch. Registers are costly, and for economic reasons are connected from a point where the traffic is high. Even so, register traffic from each supervisory circuit is less than 0·1 erlang, and concentration is, therefore, needed before connexion to the registers. As register costs rise, more cross-points can be used for the register-access switch to improve the register load. However, typical limited-function registers seldom justify more than a single stage of access, especially as both register and supervisory costs can be reduced, and, incidentally, access-switch costs raised, by using more wires between registers and their access circuits.

(*e*) Own-exchange calls are treated as half outgoing and half incoming calls to simplify the control system. The plan is, in fact, folded back on itself, as shown in Fig. 7, so that the same A-switches, B-switches and C-switches carry traffic both outgoing from, and incoming to, the subscribers.



OE—Own-exchange supervisory circuit
OG—Outgoing-junction relay-set
IC—Incoming-junction relay-set
RA—Register-access switch
REG—Register

FIG. 7—SMALL-EXCHANGE TRUNKING

(*f*) Security of the switching network depends on the availability of alternative paths via the network, and relies upon the control system to steer calls meeting trouble via switches not showing faulty behaviour.

The Large-Exchange System (*TXE*3)

The switching plan for the large electronic exchange is shown in Fig. 8. Features of the system are as follows.

(*a*) Three stages are again used to provide the required concentration between subscribers and the supervisory, or link, circuits, but only three further stages are used from the supervisory circuit to the called subscriber. This is possible because selection of free paths between the subscribers is made over the whole six stages rather than in two sequences of three and four stages, as described for the small exchange.

(*b*) Junctions are also connected to A-switches as though they were subscribers, so that, effectively, the requirement for the D-switch of the small exchange is met by the C-switch, B-switch and A-switch between the central supervisory, or link, circuit and the junction

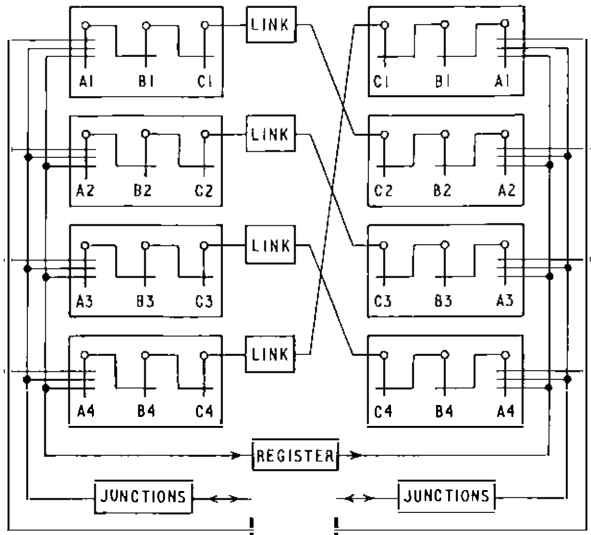


FIG. 8—OUTLINE OF LARGE-EXCHANGE TRUNKING

terminal.

(*c*) Registers are also connected to the A-switches so that the register-access facility is provided by the normal switching network, a path being established over six cross-points, i.e. the A, B, C, link, C, B, A stages, when the subscriber calls.

A second A-switch terminal is also assigned to each register enabling it to establish a path to an outgoing junction for pulsing out.

(*d*) The features described in (*a*), (*b*) and (*c*) arise from the desire for a general-purpose network that will enable any kind of peripheral equipment to be added to the system by connecting it to A-switch terminals without affecting the functions or organization of the network, i.e. the network always uses six stages for an A-switch to A-switch connexion irrespective of the facilities required.

(*e*) To provide the facilities with the general-purpose network, calls are serially-trunked (see Fig. 9). Thus, as an example, for an outgoing-junction call requiring sending facilities, a path (path 1) is first established through the network between the calling subscriber and a register A-terminal. This is followed by a path (path 2) from the outgoing-junction A-terminal to the register B-terminal, and by path 3 from the subscriber to the outgoing-junction A-terminal. Path 3 ensures that a path is available for the final set-up, and path 2 enables path 3 to be checked. The first path can now be released, and a path (path 4) from the register A-terminal to the outgoing-junction B-terminal can be established for digits to be sent from the register sender. When the register has finished pulsing out, paths 2 and 4 are released. Each path-setting operation is checked by the register.

(*f*) Security of the switching network depends on the existence of independent parallel switching networks to all of which subscribers are given access through their A-switch. If one of these networks is faulty, degraded services continue through the remainder.

(*g*) The switching plan is again folded-back so that the same A-switches, B-switches and C-switches carry bothway traffic, as shown in Fig. 10. This is really one unit of switching equipment with a capacity for about 1,000-4,000 lines, depending on the size of the B-switches and C-switches and the subscribers' calling rates. Within such a unit it is sufficient for link circuits to be connected between adjacent planes. As the exchange grows, new independent units of a similar kind are brought in, and each of such independent units is coupled by cross-connecting link circuits.

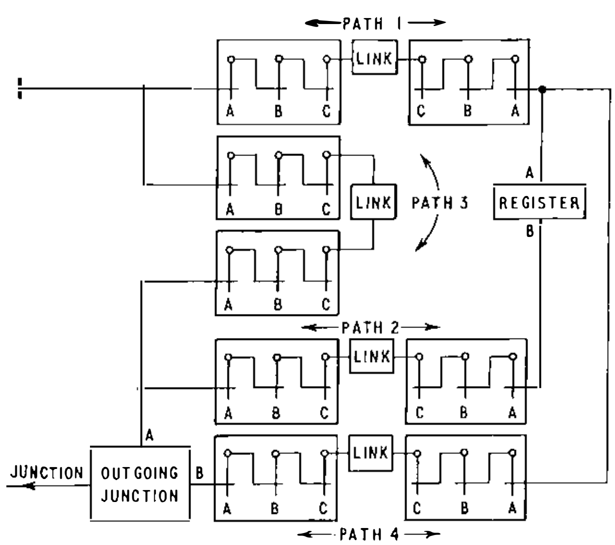


FIG. 9—TYPICAL USE OF SERIAL TRUNKING

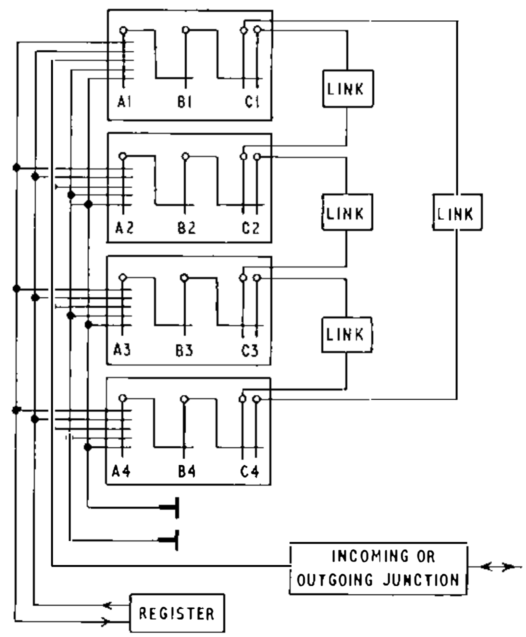
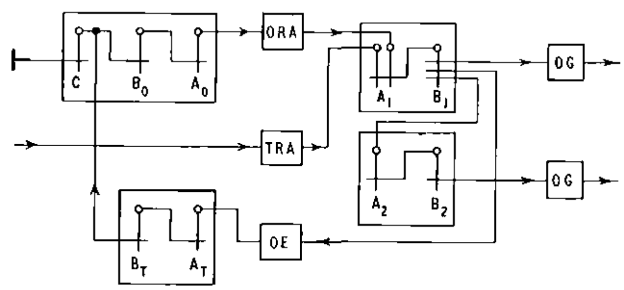


FIG. 10—LARGE-EXCHANGE TRUNKING SHOWING BOTHWAY USE OF CROSS-POINTS

The Reed-Selector System (*TXE*6)

The third plan is shown in Fig. 11. The familiar three-stage network is used to concentrate subscribers' traffic on to originating-register access circuits which provide access to registers. The remainder of the plan is quite different from the earlier ones. On leaving the originating-register access circuit, calls progress via one or more two-stage networks to outgoing-junction or own-exchange supervisory circuits. The number of such networks in series is a function of the number of separate routes



OE—Own-exchange supervisory circuit
OG—Outgoing-junction relay-set
ORA—Originating-register access circuit
TRA—Terminating-register access circuit

FIG. 11—OUTLINE OF REED-SELECTOR SYSTEM TRUNKING

required, but traffic may be trunked from any B-switch terminal. This offers useful economies in cross-points because heavily-loaded routes may be connected to earlier switching stages, and the more lightly-loaded routes to later switches in the series of two-stage networks. Incoming routes appear, via supervisory circuits, on A-switch terminals on the first of the two-stage networks. Terminals calls are routed from appropriate B-switch terminals and, thence, via own-exchange supervisory circuits to a two-stage terminal network (A_T-switches and B_T-switches), which is really part of the C, B_0 and A_0 switch array. It provides the reverse of the B_0-switch and the A_0-switch function. Registers are connected via register-access switches to the originating-register access circuits and terminating-register access circuits as described for the small exchange. A feature of the trunking is that each of the networks has its own control apparatus associated with it, and, if the proportion of exchange traffic to be handled by each unit is small enough, security in the network is inherent. Furthermore, piecemeal introduction of sections of electronic switching apparatus into exchanges during necessary extensions to existing apparatus may be made with the possibility of eventual turn-round to a completely electronic system. The plan provides a network that can grow to any size, and, with the provision of translation facilities at each control point, is extremely flexible in use. It offers an interesting example of how control simplicity can be achieved at the expense of some increase in trunking complexity.

Optimized Planning

So far, three basic plans have been described, all using similar techniques but differing fairly profoundly in their internal organization. It might be expected that an optimum solution could be found that would minimize the amount of switching plant needed. Optimum solutions do, of course, exist for any given exchange specification, although such solutions are usually impractical for several reasons.

(*a*) The difference in cost between different plans is fairly small when all factors have been accounted for.

(*b*) For manufacturing reasons it is preferable to have standardized switch sizes, which means that only a limited number of exchange specifications will result in optimum solutions.

(*c*) Exchanges grow throughout their life, and if an optimum solution is adopted at a given point it is very unlikely that this will continue to be true after extension. It would not be acceptable to have to rearrange the whole plan at every extension to maintain an optimum solution.

(*d*) Traffic data are seldom as accurate as the differences between various plans for a given specification.

CONTROL OF SELECTION

Selection Methods

Having decided upon a basic organization for a system the method of controlling the switches has to be determined. Broadly, there are two methods: overall selection or stage-by-stage selection.

Overall selection means that, having determined the two end points to be connected, the control system must be organized to determine which paths are available between the two points, and to select and connect a free path. In general, overall selection can lead to fewer cross-points for a given loading than with any other method, but it adds to the complexity and cost of the control system.

Stage-by-stage selection means that the general plan is subdivided into selection stages, and the number of switching matrices within a selection stage may vary. Within a selection stage, selection is still overall. Thus, in Fig. 8, selection is over all six switching stages, A-switch to A-switch, whilst in Fig. 11 selection is over two stages for A_1 and B_1, and A_2 and B_2, but over three stages for C, B_0 and A_0, and for C, B_T and A_T. The main differences between overall and stage-by-stage selection lie in the degree of complexity of the control and distribution of blocking in the switches. With overall selection over, say, six stages with centre links, free paths in each of the two sets of three stages can be matched and a suitable combined path selected. With stage-by-stage selection, first, via three stages from the periphery to the centre and, then, via three or four stages back to the periphery, a combined path might not be matched even though one is available. This blocking can be offset by providing more cross-points in each of the stages: this clearly costs more, but the control system may well be, at least, cheapened correspondingly.

Interrogation and Marking

The process of finding and selecting a free path between two points may be handled in two main ways. The network between the two end points may be interrogated to ascertain the state of each link and outlet in the network, and the data so obtained processed in a common path-selection unit to determine which path should be selected. Alternatively, a mark may be applied to one end point and allowed to fan out via the network to appear at all of the available free points at the other end of the network. Selection then becomes a process of reducing the available marking at each point in the network to a single choice, starting at the receiving end.

As an alternative to interrogating the network a memory map can be maintained in the central control of all connexions as they are established and cleared.

When not more than two intermediate links are involved in the interrogation process the fan-out method offers marked advantages in simplicity and economy with a minimum of common selection equipment. For three or more links the interrogate and path-choice method tends to be cheaper, even though it calls for more common equipment which has to be carefully secured from failure.

SYSTEM CONTROL

The control system of a reed-relay exchange is necessarily a common-control system in some form or another, and, for economy, it is necessary to take advantage of the high speed of the electronic equipment and of the reed relay by using as much as possible the principle of one-at-a-time operation. Speed of operation affects design: control of a system takes real time, and the slower the operation of the control system the less equipment it can control. Large systems can call for very-high control speeds, with attendant difficulty in noise immunity and ease of extension. General discussion of control principles will form another article in this series, but a summary of the main functions and principles is worth making here because of the interplay between network and control design in the overall system compromise.

The main functions of the control are

(*a*) to detect and identify calling lines,

(*b*) to detect and connect free devices such as registers, junctions, etc.,

(*c*) to process the data received from subscribers and devices requiring service, and complete the necessary connexions for provision of the requested facilities,

(*d*) to check operations and diagnose faults, and

(*e*) to provide certain common services such as pulses and traffic records.

The main points to be made about the control principles are that

(*a*) service must be securely protected,

(*b*) small controls usually lead to better results than large ones, especially if repair times of several hours are necessary, and

(*c*) dispersed control offers advantage in security, ease of extension and evolutionary capability.

FACILITIES

The telephone exchange provides facilities both for subscribers and for the administrative operation of the system. Clearly, any new system must retain the facilities already provided by existing systems; it should also be able to provide new facilities for the future, preferably by being able to make appropriate changes to the equipment quickly, at low cost, and without re-engineering. Flexibility can be obtained by having a computer-like call-processor at some point in a system controlled by a program that can be varied readily. Successful designs depend a good deal upon the type of store used for the program, and, ideally, this should be semi-permanent and electrically alterable. Given a suitable store, programs can be prepared to provide the basic facilities, and subsequent changes to the existing facilities can be achieved, to some extent, by changing the original program. The program revisions could be prepared centrally and distributed throughout the network to become operative at a particular date and time. Thus, a system with the flexibility advantages of the manual exchange may be achieved. In practice, the programming effort of this type of exchange can be very large. Moreover, many facility changes also involve some hardware change, and in a telephone-exchange environment a variable program of this sort may not offer as much as is hoped. The TXE3 exchange control system employs this principle, and, from this, experience will be gained; it is much simpler and less expensive than an all-out stored-program approach, although, of course, it is not so far-reaching.

EVOLUTION AND MAINTENANCE

Evolution

New systems will operate in a world of rapid technological change and must accept new techniques as soon as they become technically and commercially attractive, so that they can be extended in the future as economically as possible and with up-to-date equipment. These requirements call for a system capable of evolving, and this can have a profound effect on system organization. In general, they are less likely to be met by using large centralized controls, which may be out of date a few years after purchase, than by dispersed controls which are added as the system grows.

Maintenance

The simplified maintenance potentiality of electronic systems also has an impact on design. Adjustment is almost eliminated. Instead, emphasis is placed on fault diagnosis. Extensive built-in fully-programmed tests can be used to locate faults to a particular sub-unit of equipment, which may be as small as a plug-in circuit element, or more general indications of failure, derived from built-in checks, are used to locate failures to complete functional units. Either way, maintenance procedure has to be decided at the outset because of the effect on system organization. If faults can be pin-pointed and cleared quickly, probability of coincident faults in replicated equipment is reduced and some saving in system equipment achieved at the cost of diagnostic equipment. If long repair times can be, or have to be, tolerated, coincident failures are much more likely, and greater replication with simpler fault diagnosis results.

CONCLUSION

A general outline of some of the considerations that affect telephone-exchange switching network design has been given. Later articles in this series will give greater detail of each of the systems under development.

ACKNOWLEDGEMENT

Acknowledgement is due to Mr. J. A. Lawrence for assistance in the preparation of this article.

The Development of a Box-Building Vehicle

W. TYRRELL†

U.D.C. 621.11—47:621.315.68

A vehicle has been designed to meet the needs of a self-contained party employed on the construction and maintenance of jointing chambers. The final design represents a practical attempt to rationalize the handling methods involved in this class of work.

INTRODUCTION

FOR a long time box-building operations by direct labour have been executed using a variety of vehicles, none of which was specially designed for the purpose. The facilities for storing materials, tools and water were limited, and no convenient place was available for protective clothing, etc.

The most difficult job which faces the box-builder is the placing of heavy frames and covers, including "unit-type" ones weighing up to 5½ cwt each. This is because the positioning of a frame on a prepared base is a precise operation, and the heavy weight must be lowered to an exact position. In some cases vehicles have been specially adapted, e.g. an overhead longitudinal beam has been fitted on gantries to assist in handling the heavier loads.

FIG. 1—EARLY-TYPE JIB BEING USED TO HANDLE HEAVY MANHOLE COVER

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Two aids to handling have been used: a simple jib, as illustrated in Fig. 1, and the gantry with fixed beam. Both these handling aids are very limited in their application, in that off-loading can be done only from the tailboard and the area within which a load can be positioned is very small. Furthermore, the vehicle itself must be precisely positioned with relation to the jointing chamber, but this is not always possible when the jointing chamber is on the footpath or grass verge. Similar difficulties are encountered when placing the shells of cross-connexion cabinets in situ.

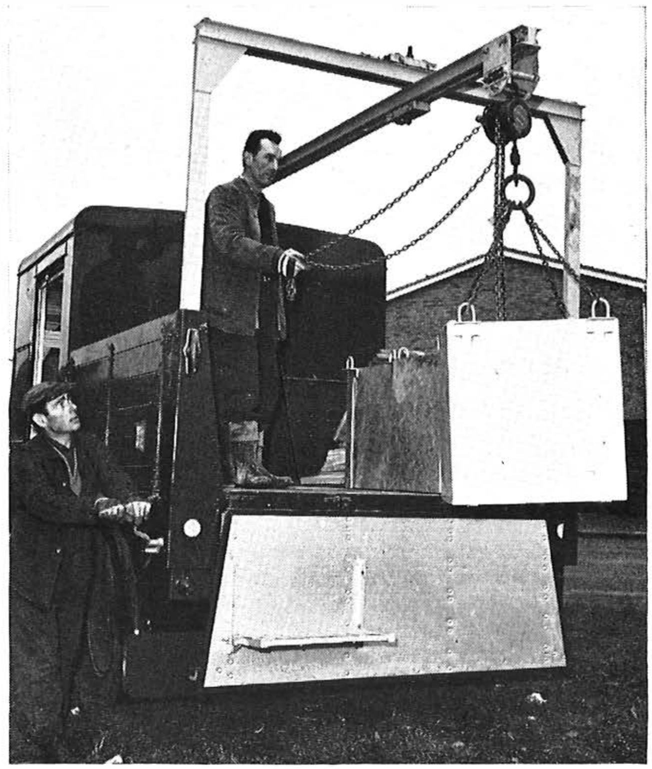

FIG. 2—PROTOTYPE VEHICLE SHOWING TRAVERSING ARRANGEMENTS AND OPERATING HANDLE

PROTOTYPE VEHICLE

The prototype vehicle, a general rear-end view of which is shown in Fig. 2, was designed to provide

(*i*) covered accommodation for tools, mechanical aids, cement, etc.,

(*ii*) open-platform accommodation for sand aggregate, spoil carrying, and heavy items such as frames and covers, and

(*iii*) a lifting device able to traverse over an area rather than being limited to a geometrical locus.

The box half-body and open rear platform fulfilled the first two design requirements, while the chain-operated

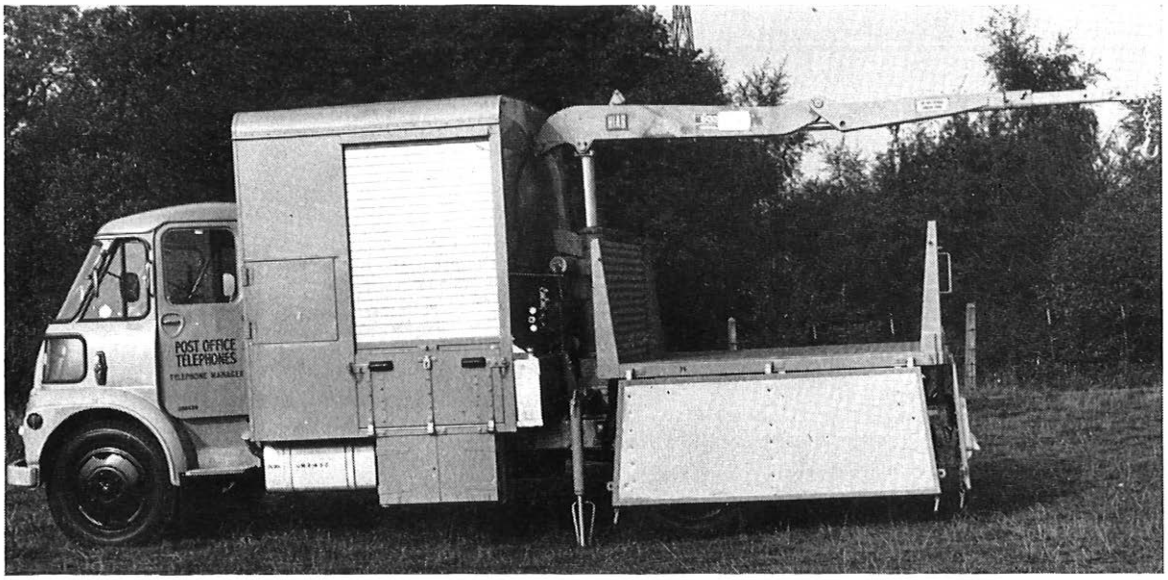

FIG. 3—NEW BOX-BUILDING VEHICLE SHOWING FULL OUTREACH OF CRANE

hoist on a traversing beam supported by a gantry fulfilled the third.

The body was built by the staff of the Motor Transport Branch, Post Office Engineering Department, on a 4-ton forward-control chassis. Racking was fixed in the box compartment to provide adequate accommodation for tools and equipment. The vehicle was equipped with a full complement of 110-volt mechanical aids deriving power from a propane-gas-operated 110-volt 2 kW generator, gas operation being introduced to dispense with the need to carry inflammable fuels inside the tool compartment. Consequently, external lockers were provided to carry the spare propane cylinder, paraffin cans and road-caution lamps.

Containers were provided to carry materials so that they might be kept clean (an essential requirement for the production of sound concrete), together with containers, designed for ease of tipping, to be used to dispose of spoil.

The mechanical-handling arrangements on the rear platform relied upon a gantry-frame supporting a retractable pin-jointed main beam made up from two 3 in. × $1\frac{1}{2}$ in. channel sections, back to back with sufficient space to allow a fixed pin to pass through the retractable beam. The rear end of the beam was suspended from the gantry to which the traversing arrangement was attached. The two small trolleys which made up the traversing gear were operated by means of a wire rope, attached to both ends of the upper trolley, passing down through the framework of the gantry, via pulley wheels, to a worm-and-wheel unit mounted below the rear platform. The actuating rod was operated by means of a cranked handle which could be fitted at either side of the vehicle (Fig. 2).

The field trial proved that, although the principle of a self-contained gas-operated generator to power the mechanical aids required was successful, the lifting gear was unsuitable. The frame lacked stability, which could only be provided by extra ironwork at high level, but this was undesirable. The traversing mechanism tended to jam and required too much effort from the operator, particularly when the vehicle was sloping because of cambered roads. It was decided, therefore, to improve the handling device and to mechanize its operations completely; a 1-ton hydraulic crane was chosen for this purpose.

CURRENT BOX-BUILDING VEHICLE

The vehicle which has evolved from the prototype is a purpose-built vehicle based on a 4-ton chassis (Fig. 3). The crane is mounted centrally, allowing use over a wide arc. The rear-platform sides and tailboard were made to drop down, and the corner support posts were made removable for ease of loading (see Fig. 4). The opportunity was taken to try the new safety colour for engineering vehicles: Traffic Yellow to British Standard 368.

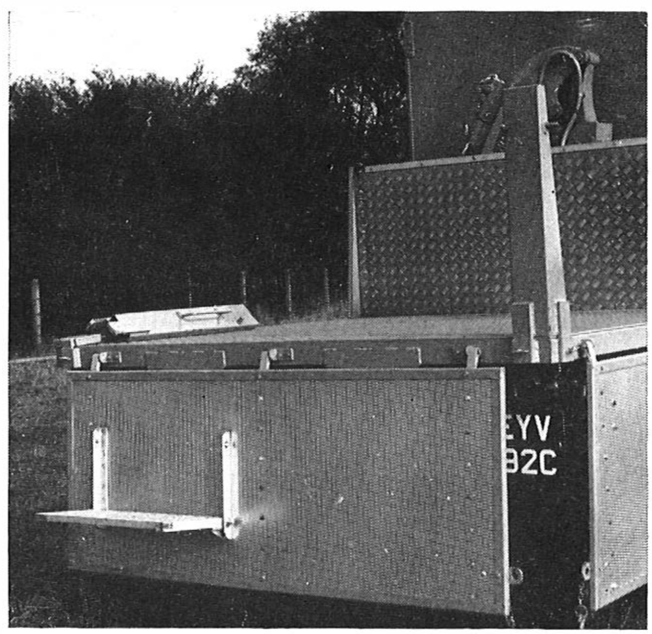

FIG. 4—REAR OPEN PLATFORM SHOWING POSTS, DROP SIDES AND TAILBOARD, TAILBOARD STEP AND VICE-PLATE

Handling Aid

The 1-ton crane is hydraulic, and the drive pump is operated from the vehicle power take-off. The articulated boom has two parts: an outer boom with a short manually-operated extension, and an inner boom.

Three independently-operated control handles (Fig. 3) are provided on both sides of the vehicle, inter-connected by means of a mechanical linkage. The separate functions are

(*i*) to raise and lower the main boom,

(*ii*) to raise and lower the outer boom, and

(*iii*) to slew the boom in either direction.

In order to prevent damage to the tool compartment, rotation of the boom is limited to 180 degrees. This enables operations to be carried out to the rear and at both sides of the vehicle. The maximum lifting capacities of the crane are 9 cwt at 11 ft 6 in. radius and 1 ton at 5 ft radius.

Stabilizers

Two stabilizer legs are positioned one on each side of the main structure of the crane to increase its stability and to provide a firm base for operations, thereby preventing undue stresses being brought to bear on the vehicle chassis and suspension. Each stabilizer consists principally of a cylinder containing a manually-operated piston which is lowered until its foot rests on the ground, thus allowing the cylinder to fill with hydraulic oil by gravity from the main reservoir tank. The shut-off valve is then closed, thereby forming a hydraulically-locked support leg. The stabilizer is returned to the travelling position by opening the valve and manually lifting the leg upwards, thus causing the hydraulic oil to return to the reservoir tank. Finally, the shut-off valve is closed to lock it in position.

Water Tank

The water tank on the prototype vehicle was made of fibre-glass with a capacity of approximately 40 gallons, but, due to lack of space, this had to be replaced on the current vehicle by a metal tank of approximately 27 gallons.

Containers

The containers for carrying materials were re-designed to allow them to be stacked into each other, and the capacity of the tipping skips was increased.

Towing Facility

The vehicle is provided with a light towing attachment to enable loads up to 45 cwt to be towed.

CONCLUSION

The total complement of these box-building vehicles will be 154—roughly three per Telephone Area. They should go far towards improving productivity in this sphere of work by increasing the speed of handling materials and reducing the physical strain of the work.

Pressure and Temperature Transducers for Deep-Sea Measurements

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U.D.C. 621.315.28: 531.787.9: 536.531

A transducer for measuring the depth in the sea of the free end of a length of Lightweight submarine cable is described. Subsequent developments have enabled the equipment to be used to measure sea pressure and temperature at any depth.

INTRODUCTION

IN evaluating the precise attenuation characteristics of a submarine cable, it is essential to know the effects of temperature, pressure and laying on the cable.* In a practical trial, it is therefore necessary that the temperature of the sea bed should be determined with a high degree of accuracy, and it is also very useful to measure directly the pressure existing at this point rather than to calculate it from a knowledge of the ocean depth concerned.

This article describes instruments developed by Post Office Research Station staff for the measurement of sea pressures and temperatures, and which were produced and used in trials carried out in the North Atlantic in the springs of 1964 and 1965 on H.M.T.S. *Monarch*.

The original instrument of the series was a pressure transducer designed to enable measurements to be made of the depth reached by the free end of a length of Lightweight submarine cable, which was being towed through the water at different speeds in order to measure its hydrodynamic constants. During the first trial, it was found possible to modify this equipment to enable sea temperatures at depths down to 3,000 fathoms to be measured. Subsequent to the first trial, a combined instrument was produced which enabled the pressure and temperature of the sea water to be determined simultaneously, and this instrument was used during the second trial, principally in order to determine the sea temperature during sonar experiments which were being carried out at the time.

PRESSURE TRANSDUCERS

One of the main restrictions which had to be observed in the design of the pressure transducer was that the profile of the transducer should in no way be different from that of the cable. This limitation was necessary to ensure that the transducer would have no effect on the hydrodynamic characteristics of the cable which were

†Post Office Research Station.

*BROCKBANK, R. A. A Note on the Laying Effect and Aging of Submarine Telephone Cables. *P.O.E.E.J.*, Vol. 54, p. 20, Apr. 1961.

being investigated. In addition, the conductors of the coaxial submarine telephone cable itself had to be used to enable the transducer signal to be measured. The measurement methods had, therefore, to be kept simple and preferably independent of changes of cable characteristics with changing sea conditions, and thus the requirements resulting from the nature of the tests had very restrictive effects upon the freedom of design.

After some consideration, it was decided that the best mechanical solution would be to measure the deflexion of a suitable diaphragm by means of a strain-gauge device. Silicon (semiconductor) strain gauges were found to be available with a high sensitivity and a suitable value of resistance; experiments showed that they were sufficiently sensitive to indicate adequately the strain induced under pressure on a diaphragm formed to the diameter of the cable. The transducer design therefore emerged as a hollow cylindrical cap, the closed end of which was used as the diaphragm.

In order to measure the strain in the diaphragm a silicon gauge was cemented on the inside of the end of the cap, and the two connexions from the gauge were taken to a local earth point and to the centre point of a coaxial connector formed within the cap. The details of this arrangement are shown in Fig. 1.

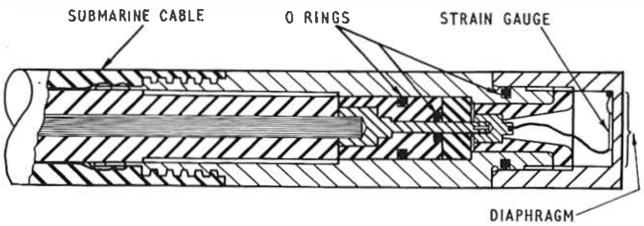


FIG. 1—PRESSURE TRANSDUCER AND CABLE TERMINATION

Theoretical and experimental work was necessary to arrive at the optimum dimensions for the cap, and diaphragm thicknesses of 0·090 in. and 0·140 in. were selected for maximum working pressures of 3,000 lb/in² and 9,000 lb/in², respectively. The caps were made of stainless steel to B.S. 970:1955‡, which was selected because of its high yield-point and good corrosion resistance to sea water. Considerable difficulties were encountered in obtaining a satisfactory and stable bond of the strain gauge to the stainless steel, and it was found necessary to etch the surface of the steel before using an epoxy-resin adhesive. Tests were carried out subsequent to bonding to ensure that the strain-gauge bonding was stable, that no signs of hysteresis or creep were observed, and that a high and stable insulation resistance was obtained between gauge and diaphragm.

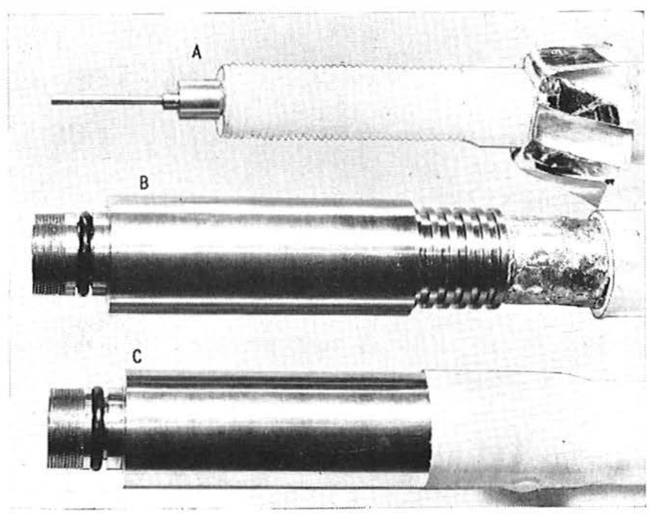
It was found possible to produce transducers with a nominal resistance of 350 ohms rising by about 47 ohms at the maximum working pressure of the diaphragm. This change of resistance is sufficiently high to enable any changes occurring in the resistance of the submarine cable on which the transducer was used to be ignored. It is unfortunate, however, that silicon strain gauges are highly temperature sensitive and, with the simple arrangements used, no means of temperature compensation was possible. However, it was assumed that the sea temperatures would be known whenever the pressure transducer was employed, and, consequently, families of calibration curves relating the resistance of the gauge to pressure and temperature were produced for shipboard use.

The high d.c. resistance of the strain gauges made it unnecessary to consider the use of anything other than d.c. methods of measurement, but care was taken that only relatively low currents were passed through the strain gauge to avoid damage due to overheating.

It is not proposed to deal in detail with the hydrodynamic tests carried out on the cable, but it is sufficient to say that the transducer worked well and results could be obtained with a high degree of accuracy and repeatability.

WATER-TIGHT CONNECTOR

In order to connect the transducer, just described, to the cable, it was necessary to produce a water-tight coaxial plug-and-socket joint. The connector was designed as a piece of tube which was screwed on to the polythene insulation of the core of the submarine cable and to which the outer tapes of the cable were attached by soldering. Subsequently, the sheath of the Lightweight cable was bonded to castellations on the outside of the tube by a plastic injection-moulding process. The centre conductor of the Lightweight cable was extended to form a connecting pin which engaged with a corresponding socket in the transducer itself. The details and assembly of the connector are shown in Fig. 1 and 2.



A—Cable end with electric pin termination soldered to centre conductor
B—Gland fitted on cable and outer conductor soldered to gland
C—Gland and cable end after moulding operation
FIG. 2—GLAND AND CABLE ASSEMBLY

The hydraulic seal to withstand the water pressure was formed by means of an O-ring held in a groove in the plug portion, and this O-ring engaged with a parallel portion on the cap; the screw thread merely served as a means to engage the cap with the end of the cable assembly. It was also necessary to take precautions against the effect of hydraulic pressure on the cable. This pressure could cause the polythene of the cable to extrude into the transducer or, alternatively, could cause air trapped within the cable to pass into the transducer: either event would cause a build-up of pressure on the low-pressure

‡British Standard 970:1955. Wrought steels in the form of bars, billets, and forgings, up to 6 in. ruling section, for automobile and general engineering purposes, EN Series. British Standards Institution, 1955.

face of the diaphragm and so give incorrect readings. To avoid this, high-strength polystyrene insertion pieces with pressure-sealing O-rings were fitted to give the necessary mechanical support and pneumatic seal. In practice, a number of short lengths of cable were prepared with such gland assemblies, and these cable lengths were then jointed as required on to the end of the lengths of submarine cable used for the trials. It is gratifying to report that there has been no evidence of any of the connectors of this design ever leaking, in spite of the fact that in some of the tests it was impossible to avoid using the same O-ring several times.

TEMPERATURE TRANSDUCER

During the course of the 1964 trials considerable difficulty was experienced in obtaining accurate measurements of the sea-bottom temperature. The classical way of doing this is by lowering mercury-in-glass thermometers either in the form of a maximum/minimum thermometer (assuming that the sea-bottom temperature is the lowest that will be encountered) or by the use of a reversing thermometer, which breaks a column of mercury in a manner rather similar to that of a clinical thermometer when the thermometer starts its return to the surface. Both types of thermometers have to be lowered from the ship to the sea bottom and carefully recovered. Not only are such measurements fraught with the difficulties of thermometry, but they are excessively time-consuming due to the procedures necessary to lower and raise delicate equipment. Moreover, no information on the test is obtained until the thermometer has been brought to the deck of the ship. It can easily take 8 hours for one temperature sounding to be carried out by such methods.

Faced with these difficulties during the trial, it was decided to attempt the construction of a resistance thermometer that could be used on the end of the cable in the same way as the pressure transducer. A similar cap to the pressure transducer, but of somewhat greater axial length, was machined on board H.M.T.S. *Monarch* under very difficult circumstances by one of the ship's engineering officers, and the winding of a relay was sacrificed to enable a small bobbin to be wound with copper wire and fitted inside the pressure-resisting cap. This in turn was filled with castor oil (from the ship's medical store) to improve the rate of heat exchange between the winding and the sea. A resistance of approximately 3,000 ohms was obtained on the winding, and this was considered sufficiently high to enable changes in the resistance of the Lightweight submarine cable (to be used as a connecting lead) to be ignored. The transducer was calibrated by immersion in water at different temperatures, and the relationship between temperature and resistance was established. Subsequent to the trial, the transducer was calibrated at the National Physical Laboratory and showed that the ship-board calibration was accurate to about 0·1°C.

The cable was terminated by the resistance transducer and paid out over the bows as a normal cable-laying operation. Thirty fathoms of heavy chain (weighing just over a ton in water) was used as a sinker and secured to the cable by a length of grapnel rope. The resistance of the thermometer was measured by a d.c. bridge, and it was found possible to observe the change in resistance of the thermometer as water layers of different temperatures were entered by the probe. When the resistance was seen to be changing, the paying out of the cable was stopped and resistance measurements were continued until a stable condition had been obtained. Generally speaking this took about 5 minutes. Some earth currents were observed during the earlier stages of the observations, but these currents did not become serious until about a mile and a half of cable had been paid out; a sheath fault on the cable then entered the water. This fault proved catastrophic to the measurements but was readily made good by temporary jointing procedures, and the observations were continued without undue difficulty until the loss of cable tension indicated that the chain had reached the sea bottom.

Temperature readings were plotted during both descent and ascent of the transducer; they showed negligible hysteresis and good agreement with expected values and reliable observations made by conventional thermometers. It was found possible to obtain reliable measurements to 0·1°C without undue delay.

A vertical temperature profile was thus measured with good accuracy, and sufficient observations were made to establish in about 5 hours the positions of different temperature layers in a depth of 3,000 fathoms; typical profiles are shown in Fig. 3. On another occasion, and with good weather conditions, a profile in 2,000 fathoms was measured in less than 4 hours.

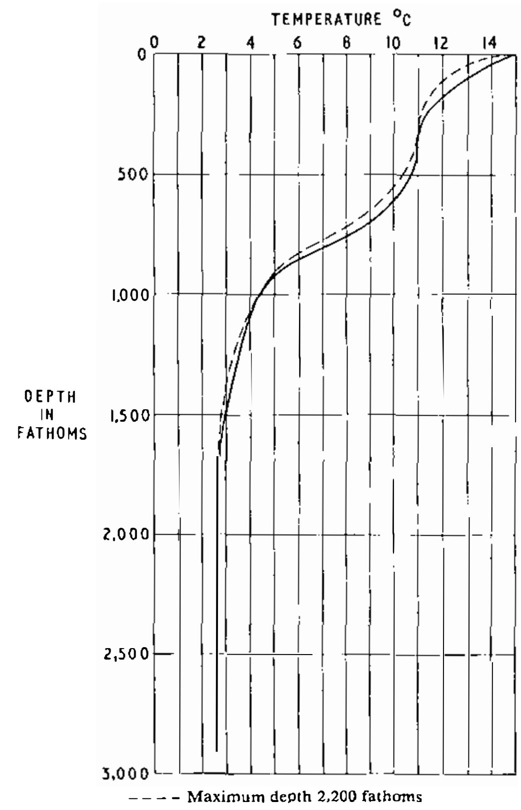


FIG. 3—VERTICAL TEMPERATURE PROFILE OF SEA MEASURED AT TWO DIFFERENT PLACES

FURTHER DEVELOPMENTS

As discussed above, the real interest in these measurements was to establish both the temperature and pressure experienced by a piece of experimental cable during actual laying trials. It was obvious that the two transducers could be readily combined into one unit and, provided selective methods were used, pressure and temperature could be independently measured. In order to keep the equipment in the sea as simple as possible, it was decided to use d.c. measurements of opposite polarity to measure temperature and pressure and to use semiconductor diodes to carry out the necessary discrimination. Suitable diodes were offered by a manufacturer shortly before the ship sailed for the 1965 trial, and a small stock of these was obtained. In order to enable the two transducers to be connected to the cable an additional T-piece connector (Fig. 4) was produced to

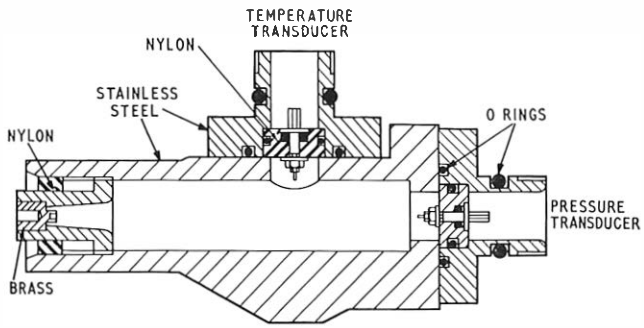


FIG. 4—T-PIECE ADAPTOR FOR PRESSURE AND TEMPERATURE TRANSDUCERS

screw on to the end of the cable and to provide two water-tight socket connectors for the two transducers; the diodes were to be incorporated in the body of the T-piece. Due to the usual pressure of work attending the departure of a ship on a complex series of trials, it was not possible to devote much preliminary work to the proposed system. Tests after sailing showed that the forward resistance of the diodes was higher than expected and very variable at the relatively-low measuring currents that were employed. It was, therefore, apparent that such diodes were quite unsuitable for use as a means of discrimination.

Fortunately, two connector T-pieces were available on board the ship as well as a number of small pressure-resisting housings that were equipped with similar connector sockets. It was found possible to fit together two of these T-pieces, one containing a pressure-indicating device and the other a temperature-indicating device. One end of the linked T-pieces was then fitted to the cable and the other end of the link was connected to the screwed socket of one of the small housings mentioned. The latter contained a switching unit consisting of a simple multivibrator using transistors and reed relays, and this was used to connect each device in turn to the cable for a period of about 4 minutes. Fig. 5 shows the unit before assembly. As the transducers and housing formed a relatively large projection on the cable-end a rough case to protect them was made from a large sheet-steel drum. It was unnecessary at this stage to consider the effect on the hydrodynamic characteristic of the cable as the measuring team were then only concerned with measurements of temperature and pressure.

In the year that had elapsed between the two trials, some work had been done on improving the speed of response of the temperature transducer, and a very elegant solution has been obtained in which the housing of the transducer was made of a copper cylinder closed at one end and containing a wound cylinder of insulated copper wire within the housing (see Fig. 6). The housing itself was re-entrant to enable heat exchange to take place as rapidly as possible on both sides of the winding and, by these means, the thermal lag coefficient of the original transducer used in 1964 was reduced from some 4 minutes to 0·12 minutes (see Appendix).

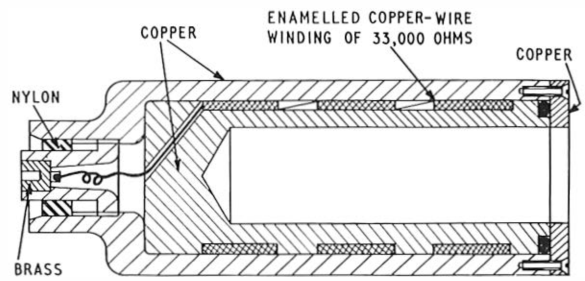


FIG. 6—DEEP-SEA TEMPERATURE TRANSDUCER

The results of two trials of this equipment showed quite clearly that the method of measurement of pressure and temperature was completely practicable, and that the pressure observations were confirmed by relating them to the amount of cable paid out (when it was certain that the cable was descending vertically) and to echo soundings of depth. It was also apparent that 4 minutes was more time than was really necessary to carry out a resistance measurement and that the cycle time of the switching equipment could well be reduced to one and a half or

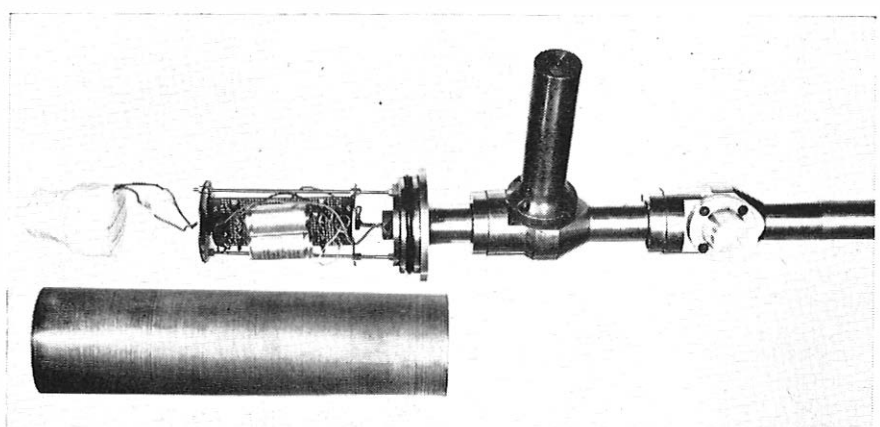


FIG. 5—COMBINED PRESSURE-AND-TEMPERATURE-MEASURING UNIT BEFORE ASSEMBLY

two minutes (no suitable capacitors were available on board to enable this time to be achieved). The resistance of the two transducers were sufficiently different to avoid any doubt as to which transducer was connected for measurement at any particular time.

CONCLUSIONS

The equipment described was developed very largely at sea under the pressure of special circumstances, and the results indicated that the equipment was capable of carrying out the required measurements with a surprisingly high degree of precision.

The principle of temperature measurement by these means is by no means novel, and its application to the measurement of deep-sea temperatures was proposed to the organizers of the famous H.M.S. *Challenger* oceanographic expedition of 1873–76: however, the technique does not appear to have been employed on that occasion.

In the trials described here, submarine cable was used as a down lead. This cable is relatively expensive and its use would normally be unwarranted. In the special circumstances of these trials a suitable length of cable was available which was at the end of its useable life; in fact, it failed completely during the latter stages of the second trial. Specially-designed "sounding" cables of adequate strength and flexibility are now available and, by a suitable selection of connectors, could be used for the measurement work described.

APPENDIX

Thermal-Lag Coefficient

The time of response of a thermometer is of great importance in sea-temperature measurements as it restricts the number of readings that can be taken in a given time. In addition, long times of response result in the introduction of an error if sufficient time to reach thermal stability is not given.

When a thermometer is immersed in a medium, it takes an appreciable time before it comes into equilibrium with its surroundings. This time depends on the so-called "thermal-lag coefficient," which, in turn, is a function of the physical properties of the thermometer and those of the medium in which it is immersed. In a general case, the cooling of a body, and thus of an immersed thermometer, obeys Newton's Law of cooling, so if the logarithm of the difference between the thermometer readings and the temperature of the medium against time is plotted the result is a straight line, the slope of which is a measure of the thermal lag.

The thermal-lag coefficient K is defined as the time required to reduce the difference $(\Delta t)_1$ of the temperature indication of the thermometer and the actual temperature of the medium at a given instant to $1/e$ of its value, i.e. to $(\Delta t)_2 = (\Delta t)_1/e$, where e is the base of the natural logarithms.

The lag coefficient can become independent of the properties of the medium if the velocity of the medium with respect to the thermometer is infinite. With a medium such as water, a velocity of 50 cm/sec can be regarded as nearly infinite since any further increase in velocity reduces the lag coefficient by about 10 per cent. Thus, vigorous stirring eliminates most of the thermal lag which is introduced by the medium in which the thermometer is immersed.

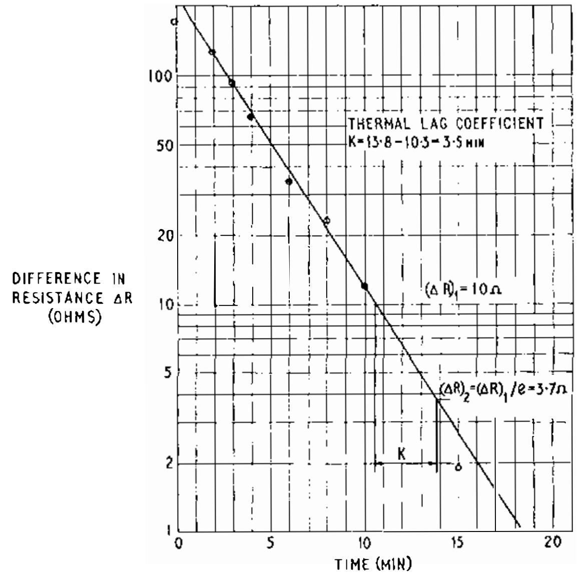


FIG. 7—TEMPERATURE LAG BEHAVIOUR OF ORIGINAL RESISTANCE THERMOMETER

The thermal-lag coefficient of the thermometer developed was determined by initially immersing it in warm water at approximately 33°C and then transferring it to a colder, well-stirred bath at 18·9°C. The resistance variation of the thermometer was recorded against time and from the results the value of the coefficient was determined. Fig. 7 shows the cooling curve and the determination of the thermal-lag coefficient of the thermometer constructed on H.M.T.S. *Monarch* during the first of the sea trials concerned.

Having the value of the thermal-lag coefficient, it is easy to determine the time t required to reduce (or increase) an initial temperature difference $(\Delta t)_1$ to any required value $(\Delta t)_2$ which can be accepted as being within the error of measurements. The equation is as follows:

$$t = K \log_e (\Delta t)_1/(\Delta t)_2.$$

For the above thermometer, which has lag constant $K = 3{\cdot}5$ minutes, if an error $(\Delta t)_2 = 0{\cdot}1$°C is acceptable, the time required to wait before taking a measurement after changing the temperature by 1°C is

$$t = 3{\cdot}5 \log_e 1/0{\cdot}1 = 8 \text{ minutes}.$$

The above theory is difficult to apply to a thermometer immersed in the sea, as the velocity of the water relative to the thermometer is indeterminate. However, experience has shown that a thermal-lag coefficient of less than 0·5 minutes (measured under laboratory conditions) is quite adequate for sea-going tests.

Book Review

"Infinite Matrices and Sequence Spaces." R. G. Cooke, D.Sc. Constable and Co., Ltd. xiii+347 pp. 20s.

This is a Dover paperback edition of a work first published in 1950 and covering most of the work on the subject since it began to be investigated in the late nineteenth century up to 1946. The first three chapters give various definitions, and deal with reciprocals of infinite matrices and linear equations involving them. Chapters 4 to 8 deal with the application of infinite matrices to divergent sequencies and series, Chapter 9 with Hilbert vector space and Hilbert matrices, and Chapter 10 with sequence spaces.

This is a book for the pure mathematician; applications, although hinted at, are not discussed, nor are the properties of special matrices, but of matrices in general. An acquaintance with the theory of finite matrices would be sufficient background to begin the book, for the author is very helpful in giving brief reviews of topics, for example "groups," "rings," "fields," "sets," "Hilbert vector spaces," as they have to be introduced; but there is so much meat in the book that a concentrated effort would be needed to digest it.

W.E.T.

Retirement of Mr. D. A. Barron,

C.B.E., M.Sc., C.Eng., F.I.E.E.

The retirement of Donovan Barron on 5 April 1967 marked the conclusion of a career in the service of engineering in the Post Office, and also the conclusion of a line of holders of the Office of Engineer-in-Chief. Elsewhere in this Journal reference is made to the history of this title, and the holders of the office. And a further article outlines some of the significance of the changing pattern of events that lie behind the change of title—events having, as their aim, the conversion of the Post Office from a Department of State into a Corporation.

But the purpose of this note is to record the particular contribution of Donovan Barron. The record of his career was amply sketched in these pages only a few years ago* on the occasion of his promotion, and need not be repeated. But the record of that experience gives the clues to so much of his later success. Out of the foundations of Telephone Area experience sprang his uncanny ability to negotiate with humanity and effect. He had done the job himself. He knew. Out of the extensions of that experience into International work—in India and later in the capitals of the world in the service of the C.C.I.T.T.—came the broadening of judgement and the elements that developed into professional elder statesmanship. For to him engineering is a profession jealously to be guarded; its standards to be maintained, firmly rooted in the necessary know-how of technology, and broadened and developed in the service of men. It is not a narrow thing but embraces judgements of technique, of economy, of relevance, of content and of human beings. To Donovan Barron, the true professional is a "whole" man.

S.T.D., inevitably, will be his middle name in the history of telecommunications in the United Kingdom, and indeed in Europe—not merely the brilliant bringing together of the teams that created it under his direction, but the patient persuasive negotiations to create a co-ordinated plan in Europe, and to make this a part of the world plan.

His colleagues—and particularly those on the Board of Editors of this Journal, in which he took particular interest—wish him happiness, contentment, and health in his retirement.

J.H.H.M.

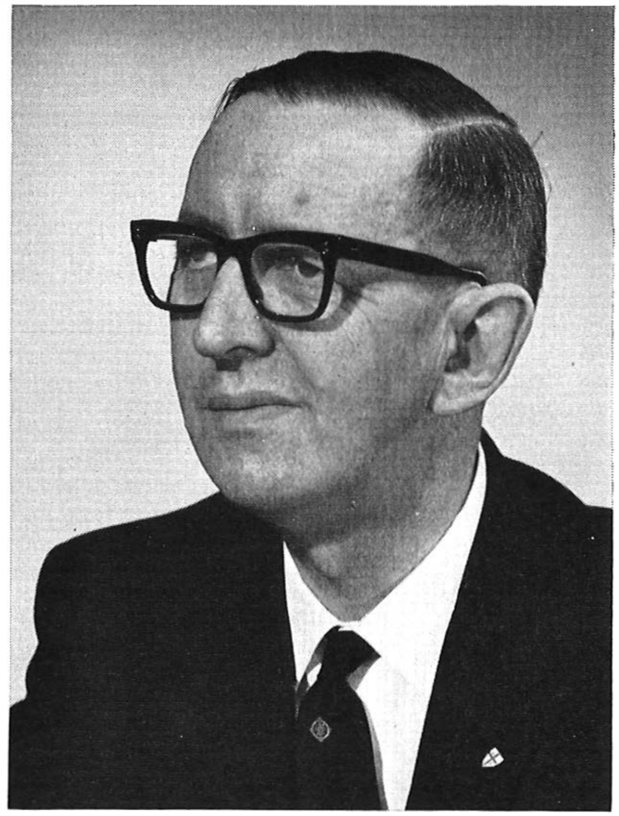
*Appointment of Mr. D. A. Barron, C.B.E., M.Sc., M.I.E.E., as Engineer-in-Chief. *P.O.E.E.J.*, Vol. 58, p. 51, Apr. 1965.

Appointment of Mr. J. H. H. Merriman,

O.B.E., M.Sc., A.Inst.P., C.Eng., F.I.E.E.,

as Senior Director of Engineering

These are times of great changes. Changes which are already beginning to set the shape of the Post Office for years to come. Amongst these changes is the replacement of the title Engineer-in-Chief for the head of the Engineering Department by Senior Director of Engineering. Some may feel that we have lost by the change of title. But it is people, not titles, that count in an organization: in this we are fortunate that Mr. J. H. H. Merriman has been selected as the first Senior Director of Engineering of the Post Office.



His previous experience has well fitted him for his new responsibilities. Until 1954 he was employed on various aspects of radio communication engineering in the Radio Laboratories at Dollis Hill and Castleton, and at Headquarters. In 1954 he attended the Imperial Defence College. This sabbatical year presents the opportunity for an engineer to think, to develop, and to widen his outlook to include world affairs and matters of Defence. That he had made full use of this opportunity was recognized by his appointment, soon after his return from the I.D.C., as an Assistant Secretary in the Treasury where he was responsible for the formulation of policies and programmes for the introduction of computers in Government Departments. His analytical ability coupled with sound judgement on the future application of managing techniques produced a report on automatic data processing in Government Service which is currently being implemented.

He returned to the Post Office in 1960 as Staff Engineer in charge, firstly, of the Overseas and, then, of the Inland Radio Branches. In 1963 promotion to Assistant Engineer-in-Chief on radio and allied matters widened his responsibilities to include all the radio engineering activities of the Engineering Department, of which satellite communications was the most pressing and most in the public eye. This reponsibility also required sound judgement and foresight in formulating technical policy, determination and drive in getting Goonhilly operational, and the ability to understand and work with colleagues in other countries.

In 1965 he was appointed Deputy Engineer-in-Chief, in which post he was responsible for planning staff policy and for negotiations with the Engineering Staff Side. His judgment and natural sense of fairness enabled him to balance the demands of the present against the needs of the future in a manner which earned the respect of all concerned. He has for many years played an active part in the affairs of the Institution of Electrical Engineers, having served on the Council from 1963.

In 1912 the Post Office took over the National Telephone Company which had as its head an outstanding man as Engineer-in-Chief. Since 1912 many eminent engineers have held the post and title of Engineer-in-Chief to the Post Office. Now that the wheel is turning, not perhaps full circle but a great deal further round, the Post Office will cease to be a Government Department and will become a Nationalized Corporation. The Post Office and its engineers are fortunate to have in Mr. Merriman as their first Senior Director of Engineering a far sighted and able administrator of outstanding technical ability, who can see the possibilities and practicabilities of the application of emerging scientific and engineering techniques as a means of significantly improving the quality of our service and the productivity of engineers. A man, too, who understands the needs and hopes of engineers to play their full part in the activities of the Post Office when it becomes a Corporation in 1969. He will, we know, as the first Senior Director of Engineering to the Post Office establish a standard which his successors will have difficulty in matching.

We look with confidence to the future under his leadership, and, assuring him of our support, wish him well in his new responsibilities.

C.E.C.

Electronic Telephone Exchanges: Reed Relays for Exchange Systems

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The reed relay has been adopted as the standard switching relay in all the electronic-exchange systems currently being developed. The reasons for this choice are outlined and a general description is given of its application in the systems.

INTRODUCTION

SINCE the introduction of the reed contact unit in 1936, by Bell Telephone Laboratories, considerable work has been done developing it to its present state, achieving stable operating characteristics with high reliability, and developing it in a form which lends itself to mass production at low cost. During the last world war, reed contact units were used in some military equipments because they were unaffected by atmospheric conditions, but it was not until many years later that they started to be used in significant quantities in telecommunication equipment.

In the early development of electronic telephone exchanges the inherent advantages of the reed relay made it an automatic choice for the switching function in one of the several possible systems which were being studied. In 1963 the British Post Office decided to concentrate development on systems using reed relays. The mode of operation and the basic principles and characteristics of reed relays have been described in a previous article,[1] and the present article describes the relays developed for current electronic-exchange systems and their application in those systems.

ADVANTAGES OF REED RELAYS

The advantages of reed relays may be summarized as follows.

(*i*) The contacts are sealed from contamination and corrosion, in an inert atmosphere.

(*ii*) Precious-metal plating of the contact surfaces gives a low and stable contact resistance.

(*iii*) No mechanical adjustment is required or possible.

(*iv*) Speed of operation is high.

(*v*) Reliability is high, and large numbers of operations without failure are attainable.

(*vi*) Component parts are few and relatively simple, and, for large quantities, low-cost automated production is possible.

The first reed relays introduced for use in Post Office equipment, the Types 14 and 15, used a relatively large and costly contact unit, with a glass capsule 2 in. long. This contact unit was used in the Leighton Buzzard prototype electronic exchange.[2] For production exchanges using large numbers of relays a contact unit of smaller dimensions and lower cost, but retaining the advantageous features of the larger unit, was clearly desirable. Units of small size were being developed, and a Post Office specification of requirements was issued for a standard contact unit, with a capsule 1 in. long, for use in all current developments.

MANUFACTURE OF REED CONTACT UNITS

The first supplies of standard contact units to the British Post Office specification were made, one at a time, on single-head hand-loaded machines using varying degrees of automatic process control. A cycle time of about 3 minutes is probably the best that can be achieved by this method, and the percentage of satisfactory units produced can vary widely. To produce the quantity of contact units which are needed for large-scale orders of electronic-exchange equipment, these methods would be both uneconomic and inadequate. Fully-automatic multiple-head machines with feedback quality control are needed, and several such machines have already been built, some of which are capable of producing 2 million contact units per annum.

Although there have been variations in the methods used in manufacture, the following are basic steps in the process.

(*a*) The raw material of the reed blades, 50:50 nickel-iron wire, is first cleaned, straightened, and then shaped in a heavy press to produce the individual reed blades. High standards of finish and accuracy are necessary.

(*b*) The reed blades are then tumbled with abrasives to polish the surfaces and to remove any burrs. This is followed by a thorough cleaning process, often involving several stages.

(*c*) Large batches of blades are then heat treated in a furnace with a reducing atmosphere to anneal and, at the same time, to minimize the amount of oxides on the surfaces.

(*d*) Next, the contact surfaces are gold plated. There are many variations of method, entailing differences in pre-plating treatments, plating solutions, current density, etc. Much development work has been done, aimed at a consistent, reliable, low-cost contact surface, but there is no simple formula for success, rigid control of materials and processes being an essential pre-requisite of successful plating. Further washing and drying prepares the reed blades for assembly, although in one method of contact-surface preparation the plating with gold is followed by a second heat treatment to partially diffuse the gold into the blade material.

(*e*) Glass tube for the capsules is cut to length, de-burred by flame treatment, and thoroughly washed and dried. Choice of glass composition is important. It must provide the right strength and be free from contaminants; it must also give the right characteristics of softening and flow for sealing to the reed blades.

(*f*) The blades and capsules are now ready for assembly. In the previous steps cleanliness has been emphasized, and this is of equal importance in the storage and handling of the parts before and during assembly. Air conditioning or "clean-room" conditions are essential for high-quality

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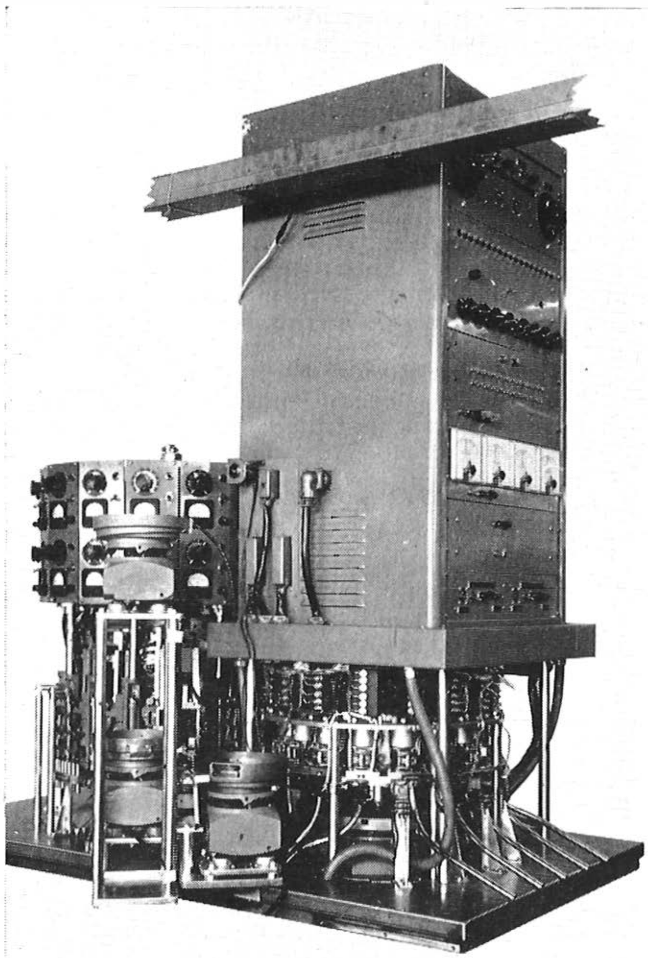


FIG. 1—AUTOMATIC MACHINE FOR PRODUCING REED CONTACT UNITS

production. Methods of assembly vary considerably but are generally as follows.

In a typical fully-automatic machine (Fig. 1), 12 or 18 assembly heads are arranged on a rotating circular turret so that each head passes through a sequence of process stations. Reed blades and glass tubes are fed into separate hoppers on the machine, where they are aligned and fed, one at a time, to the loading stations. Loading mechanisms fit the two reed blades into opposing chucks and the glass tube into a pair of jaws between them. The chucks then move the blades together within the tube so that correct overlap is obtained. The first seal is made by energizing a radiant-heating coil surrounding the tube end. During this operation the tube is flushed with the filling gas (usually nitrogen), and the blade being sealed is released by its chuck while being held in position, in contact with the fixed blade, by an applied magnetic field; this ensures parallelism of the blades. Before the second seal is made, the magnetic field is removed and the second blade moved, by its chuck, through a micrometer-controlled distance to give the required contact gap.

(*g*) The last stations on the machine are test stations at which the main characteristics of the completed contact units are measured. Faulty units can be rejected, and, at the same time, feedback can control the setting of the assembly heads to correct for out-of-tolerance conditions detected by the test stations.

SPECIFICATION OF REED RELAYS

In specifying the requirements for the standard reed contact unit, two lines of approach were possible: either to specify in detail all materials, dimensions and tolerances, or to specify the main dimensions necessary to achieve interchangeability together with the performance required from the unit. As this item was to be the majority component in future British Post Office exchanges it was imperative to specify the device in such a way as to leave scope for further improvements in design and techniques of manufacture to achieve the lowest possible cost consistent with adequate performance. Therefore, the dimensions specified by the Post Office include only the overall length and diameter, maximum length of glass, miminum length of glass seal, central position of contact overlap, and dimensions of the solder-coated wire ends (Fig. 2). The materials,

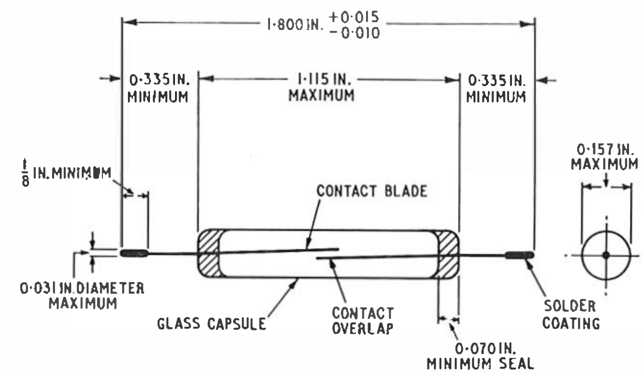


FIG. 2—DIMENSIONS OF REED CONTACT UNIT SPECIFIED BY POST OFFICE

contact surfaces, contact blades, capsule, gas filling, etc., are not specified. The main part of the specification covers the electrical performance required from each contact unit and the tests to verify this performance. The tests fall into two main categories: performance tests and switching tests.

Performance Tests

The performance tests are designed to ensure that the electrical parameters are satisfactory, and comprise the following checks.

(*a*) Current tests are based on the use of a standard test coil whose dimensions and winding are explicitly stated. With specified currents in the test coil, representing specific ampere-turn (AT) values, the contact units under test must satisfy the following conditions with the AT values applied in the order given:

(*i*) saturate at 100 AT,
(*ii*) hold at 27 AT,
(*iii*) release at 15 AT,
(*iv*) non-operate at 30 AT, and
(*v*) operate at 58 AT.

(*b*) Operate and bounce time. A stable contact resistance should be attained within 2 ms when the contact unit is operated with 80 AT.

(*c*) Release time. After operation at 80 AT, release time should not exceed 100 μs.

(*d*) Contact resistance. With the contact unit held operated at 40 AT, contact resistance should not exceed 150 milliohms.

(*e*) Insulation resistance. Measured at 500 volts d.c., insulation resistance must be greater then 500 megohms.

(*f*) Proof voltage. The contact unit must withstand 600 volts for not less than 5 seconds.

Switching Tests

The switching tests are designed to ensure that the product is consistent and that the contacts will satisfactorily perform an adequate number of operations in service. These tests are sometimes referred to as life tests or reliability tests, but the use of such terms is misleading in that the life or reliability of the device is determined by the circuit conditions under which it is used, as well as by the physical characteristics of the device as manufactured.

For each series of switching tests the normal sample size is 200 contact units, drawn at random from a production batch. These arc divided into two equal groups, one of which is subjected to a no-load test and the other to a full-load test, i.e. switching 100 mA in a non-inductive load. These tests are chosen as representative of the most onerous conditions: at 100 mA, erosion of the contact surface, and the formation of pips and craters, may cause failure due to high resistance or sticking; under no-load conditions on the other hand, because no material is removed or transferred by current switching, the contacts may approach perfect flatness and sticking may occur by "wringing" of the flat surfaces. The least onerous conditions of operation lie somewhere between these extremes. For the switching tests the contact units are placed in individual standard test coils and pulsed one million times at a rate not exceeding 20 pulses/second. Each contact is checked for operation and release each time it is pulsed. Contact resistance is checked every 2,000 operations (every odd thousand), and a voltage test to detect breakdown is made on the even thousands. Failures are classified as failure to make, failure to break, and high resistance (1 ohm on no-load test, 5 ohms on full-load test). To satisfy the requirements, a failure rate of 0·5 per cent on performance tests and 1·5 per cent on switching tests must not be exceeded.

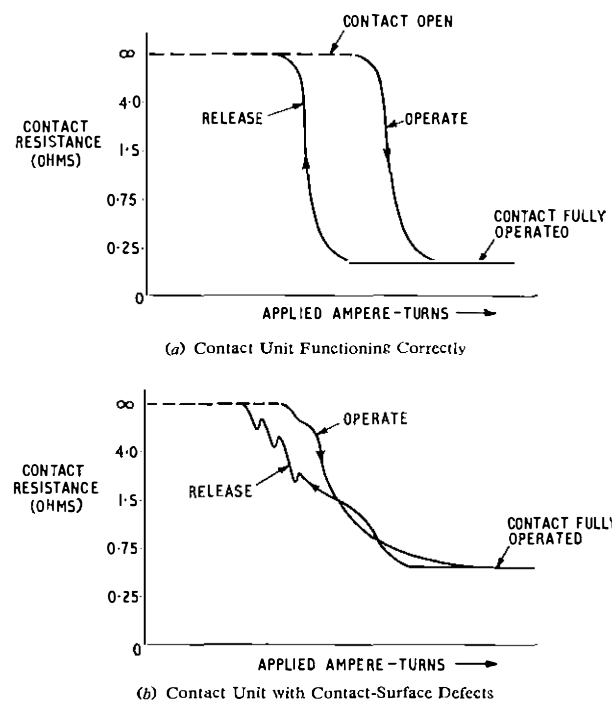
MAJOR FACTORS AFFECTING OPERATION

Mechanical Wear and Contact Resistance

The characteristics of a contact unit are generally very stable, the only significant change taking place if serious wear occurs. Only the contact area is subject to wear, which is caused primarily by electrical action. Wear can also be caused by mechanical abrasion after a large number of operations. During each operation the blades flex as they come together and then straighten, and the resultant "wiping" action, although eventually causing wear, is also beneficial because of the resultant cleaning action. The wearing away of the contact plating could be eliminated by using a solid precious-metal contact stud at the tip of each reed blade; this would, however, increase the spacing of the blades, which in turn would drastically reduce the sensitivity of the contact unit, and is, therefore, regarded as impracticable. The wear due to electrical action can be minimized if the voltage across the contact unit, and the current switched by the blades, is kept low.

Wear of either kind can cause changes in contact resistance. In new contact units the resistance will be in the range 20–150 milliohms. If a contact unit is used in a speech transmission path, a contact resistance of several ohms can be tolerated in most applications, provided that it is stable with time. In practice, the initial contact resistance is one or two orders better than this. Slow variations of contact resistance with time can be ignored; it is, however, essential that rapid fluctuations in resistance should not occur, as these will appear in the circuits as noise. This effect occurs rarely in contact units used within their correct ratings. When, however, contact units are used at currents or voltages, or both, in excess of their specified ratings, the usual mode of failure is a progressive increase in contact resistance, leading eventually either to welding of the contacts or to an open-circuit condition. If the current which is switched by the contact unit is within the specified rating, the unit can be expected to perform many millions of operations without failure. A typical life for a contact unit is 5×10^7 operations.

Many months of laboratory life-tests may be required to ascertain whether a contact unit will work reliably in a given circuit, and this method is frequently used to determine the safe working conditions, but the tests are laborious and time consuming. The main difficulty is that the wear or deterioration of the contact unit takes place at a very slow rate, and cannot be readily detected or measured. Bell Telephone Laboratories have developed a method[3] to detect small changes in a contact unit's characteristics which indicate a degradation of the contacting surfaces, and these changes are revealed after a comparatively short operating life. The results can sometimes be used to predict the probable mode of failure under long-term life conditions. A simplified and economical version of this test has been developed by the British Post Office. The principle of the method is to produce a graph of the contact resistance plotted against the current through the coil as the current is increased from the non-operate value up to the operate value, and then decreased back to the release value. The resultant graph is in the form of a hysteresis curve, Fig. 3(*a*)



(*a*) Contact Unit Functioning Correctly

(*b*) Contact Unit with Contact-Surface Defects

FIG. 3—TYPICAL CONTACT-UNIT HYSTERESIS CURVES

illustrating a typical oscilloscope trace obtained from a correctly-functioning contact unit. The trace of a faulty contact unit is shown in Fig. 3(*b*), where abrupt changes occur in the contact resistance. The changes are only of the order of a few milliohms, but these usually indicate an incipient fault in the contact surfaces and call for a further study of the circuit element concerned.

Contact Bounce

Another characteristic of reed contact units is that the blades almost invariably bounce when they operate, and sometimes do so on release. The mechanism causing bounce on make is complex and will not be discussed here; the practical effect is equivalent to a period of oscillation of the contact blades (making and breaking) before full contact is established. A typical contact unit may bounce four or five times in a period of about 1 ms before settling in the fully-operated position. On release, the following three effects occur which can cause bounce.

(*i*) When the blades move apart, each acts like an undamped cantilever vibrating at its natural-resonance frequency, which is typically about 1 kHz. They can, therefore, touch again if minor flux changes occur within the coil due to movement of the other contact units.

(*ii*) When one or more of the four contact units in a coil release, an instantaneous change occurs in the flux distribution; this change may cause another contact to reoperate.

(*iii*) As a contact unit opens, and while the blade separation is small, a high electrostatic field can be produced across the gap, particularly if the contact unit is breaking an inductive load and a high back-e.m.f. is produced. The electrostatic force may be sufficient to re-operate the contact unit and allow the back-e.m.f. to partially discharge through the closed contact before the blades open again.

No cheap and reliable contact unit which is bounce-free has yet been developed. It should, therefore, be noted that contact bounce has the following three main effects.

(*i*) If the contact unit is operating electronic circuits these will usually respond to each bounce, and will operate several times to one make operation of the contact unit; precautions must, therefore, be taken in the electronic circuits to mask the effect.

(*ii*) At each bounce the contact unit breaks the circuit current, thereby increasing the effective total number of operations of the contact.

(*iii*) In circuit designs an adequate allowance must be made for the time elapsed up to the end of the bounce period. In practical terms, a contact unit may close within 500 μs from the start of coil energization, but it may require at least 3 ms to elapse before bouncing is over.

Applied Current and Voltage

Two other major factors affecting the operating life of a contact unit are the current and voltages involved. The effect of voltage and current include both the d.c. conditions which are applied to the contact unit, and also the surge voltages and currents due to inductance and capacitance in the circuit. Even where a contact unit is controlling a purely resistive load, stray capacitance on wire leads is frequently sufficient to materially affect the life of a contact unit. These two factors will be discussed further under "Practical Application of Reed Relays."

PRACTICAL APPLICATION OF REED RELAYS

Two separate sets of information have been compiled on the reed contact units which are used in electronic-exchange systems, and it is important to distinguish between them and use each set of data appropriately. Firstly, there is the test-acceptance specification already described and, secondly, the design information. As previously explained, the test-acceptance specification information is used during manufacture of the contact units to check that they are of acceptable quality and meet a specified sensitivity. The specified sensitivity tests are not related to actual circuit conditions, nor are the tests carried out using a standard reed relay; they are performed in a special test coil whose physical dimensions and construction are closely specified. Therefore, the ampere-turns figures quoted in the test-acceptance specification for operate, hold, release and non-operate must not be used in circuit design.

For circuit design, the design information is used; this data takes into account the many and variable factors that affect the performance of a contact unit. The circuit designer requires to know, or to have specified for him, the characteristics of a complete reed relay. This must include the following information.

(*a*) The minimum or maximum, or both, ampere-turns figures for operate, hold, release and non-operate of the reed contact units when inserted in the relay coils in which they are to be used. It is again emphasized that these figures are different to those given in the acceptance-test specification for the contact units when inserted in a test coil, because allowance is made for the different flux distribution and field strength of a multi-contact reed relay compared with a test coil, the magnetic interference from adjacent reed relays (this is particularly important in reed-relay matrices), the variations in coil assemblies, the effect of vibration, deterioration of contact sensitivity with life, speed of operation, and other factors which are discussed below. These ampere-turn figures are the basic design information which must be adhered to in order to ensure reliable operation of the reed relays.

(*b*) The resistance of the relay coil at room ambient temperature (20°C) and the manufacturing resistance tolerance, which is typically $\pm$ 10 per cent on the stated nominal resistance. This information is used in calculating that the design ampere-turns from (*a*) are met in the worst-case circuit conditions for voltage and resistance.

(*c*) The variation of the coil resistance with temperature. This change is approximately 0·4 per cent per 1°C. The ambient temperature range is assumed to be from +5°C to +55°C, which causes a resistance change of −6 and +14 per cent, respectively, from the 20°C figure. Combining (*b*) and (*c*) gives total tolerances of +24 and −16 per cent on the specified nominal resistance at 20°C.

(*d*) The number of coil turns on the relay. On the reed relays used in electronic-exchange systems there is no manufacturing tolerance on the number of turns; these are wound to an exact value. As the number of turns on a given type of relay is constant, and the design ampere-turns figures are fixed, it is only necessary to calculate the minimum or maximum current required to meet each of the design operating figures.

As mentioned in (*a*), allowances are made in the design ampere-turn figures for variable factors. For example, the design ampere-turn figure for operate must ensure, with a margin of safety, that all contact units, including

Typical Design Information for Reed Relays

Design Resistance	Turns	Wire Size		Maximum Coil Resistance	Minimum Coil Resistance	Minimum Volts at 55°C		Maximum Volts at 5°C		Current Limits (mA)			
R_1 Ohms	T	Mils	S.W.G.	R_2 Ohms	R_3 Ohms	Operate	Hold	Non-operate	Release	Operate (I_1) $\nless$	Hold (I_2) $\nless$	Non-operate (I_3) $\ngtr$	Release (I_4) $\ngtr$
15,000	35,000	2·0	47	18,600	12,600	53·2	37·2	8·6	3·6	2·86	2·00	0·68	0·29
7,200	24,100	2·4	46	8,930	6,050	37·0	26·0	6·0	2·5	4·16	2·91	1·00	0·42
4,050	18,500	2·8	45	5,020	3,400	27·2	19·0	4·4	1·84	5·4	3·79	1·30	0·54
2,350	14,000	3·2	44	2,915	1,970	20·8	14·6	3·4	1·41	7·1	5·0	1·71	0·71
1,520	11,500	3·6	43	1,885	1,278	16·4	11·5	2·6	1·11	8·7	6·1	2·09	0·87
985	9,200	4·0	42	1,220	827	13·3	9·3	2·1	0·90	10·9	7·6	2·51	1·09
665	7,545	4·4	41	825	558	11·0	7·7	1·78	0·74	13·2	9·3	3·18	1·32
485	6,500	4·8	40	602	407	9·3	6·5	1·50	0·62	15·4	10·8	3·70	1·54

Relay Constants

Circuit Design Ampere-Turn Values	Operate Hold Non-Operate Release	100 AT 70 AT 24 AT 10 AT
Maximum Power Dissipation for Continuous Energization		1 watt
Average Value of $T/\sqrt{R_1}$		294

those at the extremes of the specified sensitivity, will function correctly in any relay coil.

The speed of operation of a contact unit is affected by the applied operate ampere-turns, and, within certain limits, increase of ampere-turns increases the speed of operation. The design operate ampere-turns figure takes account of this, and achieves a more uniform speed of operation of the four contact units within one relay.

Another factor is that it is not sufficient to "just operate" a contact unit, because the resultant light pressure between the contacts gives a high, and possibly variable, contact resistance.

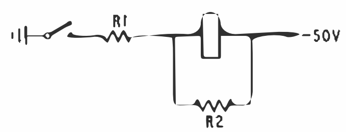
In a reed relay containing four contact units, when the operate flux is applied, the first contact unit to operate alters the flux distribution within the relay, thus increasing the operate time of the other three. Mechanical and electrical vibrations can also modulate the contact resistance of a weakly-operated contact unit. Adequate contact force also helps to break down very thin whisker growths between the contact areas of the reed blades, which might occur with certain electrical loads.

Taking the operate ampere-turns as a typical example, during manufacture the contact units are checked for operation at 58 AT when placed in the standard test coil, but in actual circuits in electronic-exchange systems a minimum of 100 AT is used to operate reed relays. The coil current corresponding to each design ampere-turn figure for every relay is given in the design information, and takes into account the resistance/temperature characteristics referred to in (*b*) and (*c*), thus minimizing the design work of the circuit engineer. A portion of this information is shown in the table.

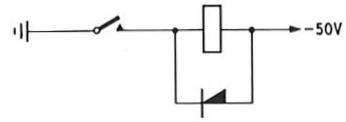
It can be shown that, for a relay with a given winding space and operating to specified ampere-turns figures on a given supply voltage, there is one value of coil resistance which meets the requirements and also gives minimum power dissipation. In practice, there may not be available a gauge of wire to wind the coil exactly to this value, and the nearest gauge size is chosen. In some circuits, such as those in which two relays are used in series, the optimized value of coil resistance cannot be used, but this situation is avoided wherever possible because economies can be made by restricting the number of types.

The Post Office reed contact unit operates reliably when switching voltages up to 50 volts d.c., and only a marginal improvement in life is obtained if the voltage is reduced below this figure. It is capable of switching currents of about 100 mA for many thousands of operations, and this is adequate for use in subscribers' line circuits or speech cross-point relays where the total number of operations in 30 years is less than 200,000. For applications where a high number of operations is required, typically 5×10^7, the current switched by a contact unit should be limited to less than 40 mA, and this condition has been adopted as a design requirement for the present systems. If the contact unit is operating another relay, a spark quench must be used to limit the surge voltage which appears across the contact when it opens. A very effective method of protecting the contact unit is the use of two resistors, as shown in Fig. 4(*a*): the shunt resistor can be selected to limit the surge voltage to any required value, and the series resistor restricts the instantaneous surge of current which flows through the contact when it is closed and the stray-wire capacitance discharges through it. The value of the shunt resistor determines the release time.

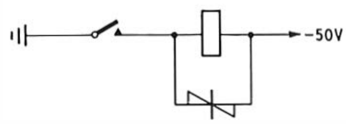
Another commonly-used method is the diode quench shown in Fig. 4(*b*). When the contact opens and the coil flux collapses the back-e.m.f. produced causes the diode to conduct: the voltage at the contact can not exceed −50 volts, thus sharply defining the maximum voltage excursion at the contact. When the diode is conducting, its resistance is low and little energy is dissipated within it. Consequently, current flows through the relay for a relatively long period and the release period of the relay is greater than with no quench or with a resistor quench.



(a) Two-Resistor Method of Spark Quenching



(b) Diode Spark Quench



(c) Non-Linear Resistor Spark Quench

FIG 4—CONTACT PROTECTION USING A SPARK QUENCH

A non-linear resistor may also be used as a quench, as shown in Fig. 4(*c*). The graph of Fig. 5 shows the variation in resistance with applied voltage for a non-linear resistor. It always offers an appreciable resistance, even at high surge voltages, so that the energy dissipation within the device is high during the surge period, resulting in a faster release for the relay than with a diode quench. A typical peak surge voltage produced at the contact unit in the circuit of Fig. 4(*c*) is in the order of 180 volts, and is more damaging to the contact unit than the voltages occurring in the two other methods. In general, the resistor-type quench shown in Fig. 4(*a*) is to be preferred whenever circuit requirements permit its use.

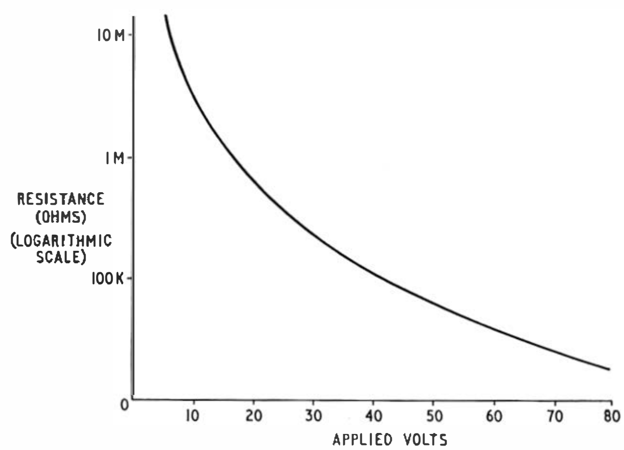


FIG. 5—RESISTANCE/VOLTAGE CHARACTERISTIC OF NON-LINEAR RESISTOR No. 2

DEVELOPMENT OF REED CROSS-POINT RELAYS

In reed exchange systems the majority of relays are used as switch cross-points[4] and usually need four contact units. The four-contact-unit relay has therefore been developed primarily for cross-point use, but it is used in other applications wherever possible. Small numbers of other types of relay are needed in special applications, and these are described later.

A cross-point relay should ideally meet the following six requirements.

(*i*) It should use the standard reed contact unit.

(*ii*) It should accommodate the range of coil windings needed for 12-volt, 24-volt and 50-volt working, and for the operation, or holding, of up to four cross-point paths in series. The need to depart from this limited range of coils should be rare.

(*iii*) The relay must be compact, with an efficient magnetic circuit.

(*iv*) It should be simple in construction, and suitable for automatic methods of production at low cost.

(*v*) The mounting and terminating arrangements should be suitable for the construction of co-ordinate switch matrices.

(*vi*) For maintenance the wiring and terminations should be readily accessible, and the relay and contact units replaceable.

Four main types of relay have been developed by the manufacturers participating in the Joint Electronic Research Agreement. For the purposes of this article they are referred to as Type A (Ericsson Telephones, Ltd.), Type B (Associated Electrical Industries, Ltd.), Type C (Automatic Telephone and Electric Co., Ltd.), and Type D (General Electric Co., Ltd.). Type A was the first to be developed, and Types B, C and D followed, in that order. Fig. 6 and 7 show two types of cross-point relay, and Fig. 8 and 9 show cross-point relays connected in matrices.

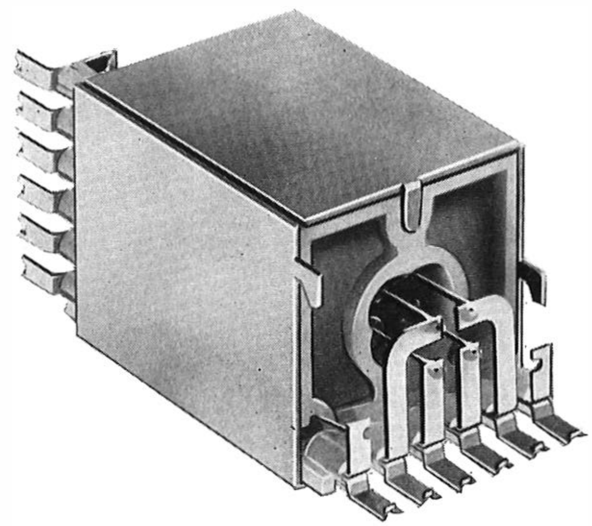


FIG. 6—COMPLETE FOUR-CONTACT-UNIT CROSS-POINT REED RELAY

The coil former of the Type A relay is in two parts, each consisting of a tubular portion integral with an end piece, 1 in. square, moulded to provide anchorage for winding tags. On assembly the tubular portions slide one into the other and form the coil bobbin. The relative positions of the tags at the ends can be varied by relative rotation of the end cheeks before assembly. After winding the coil, the relay body is enclosed in a mild-steel screening can which also forms part of the magnetic circuit. The relays are mounted on a pierced steel plate and fixed in position by bending the tabs on the end of the metal screening can. Multiple wiring may be obtained by means of straight runs of bare wire soldered to the wiring tags, or by wiring forms. In a cross-point array the relay tags on one side of the assembled block will be the input commons and on the other side the output commons. To obtain straight wiring runs the rows of tags on opposite ends of each relay are arranged to be at right angles.

In the development of the Type B cross-point relay the aim was to provide a simple form of self-supporting building-brick assembly, and to incorporate a method of multiple connexion suitable for automatic assembly methods. The coil former is a one-piece moulding with end cheeks 0·8 in. square. An additional end-cheek fitted with tags, and with four holes for locating the wire ends of the contact units, fits at each end. The tags at each end are mutually at right angles for co-ordinate matrix assembly. A mild-steel screen encloses the wound coil and locks the end-cheeks in position. Relays are assembled to form a switch matrix simply by locking each relay to its neighbours with a spring circlip. The relay end-cheek moulding has, at each corner, a small quadrant-shaped pillar which abut three similar quadrants on adjacent relays. The circlip clips together each set of four adjacent quadrants, thus holding four relays together. Specially shaped mouldings (0·8 in. long) are placed around the outside of the relay matrix to provide wiring gutters and terminating tags for external wiring. These mouldings also have fixing quadrants to mate with those on the outside rows of relays. After fitting the circlips, the relay matrix with its gutter mouldings forms a self-supporting block. The shape of the outer mouldings is such that the completed block can be clamped into the frame of a plug-in equipment unit without any fixing screws in the matrix assembly.

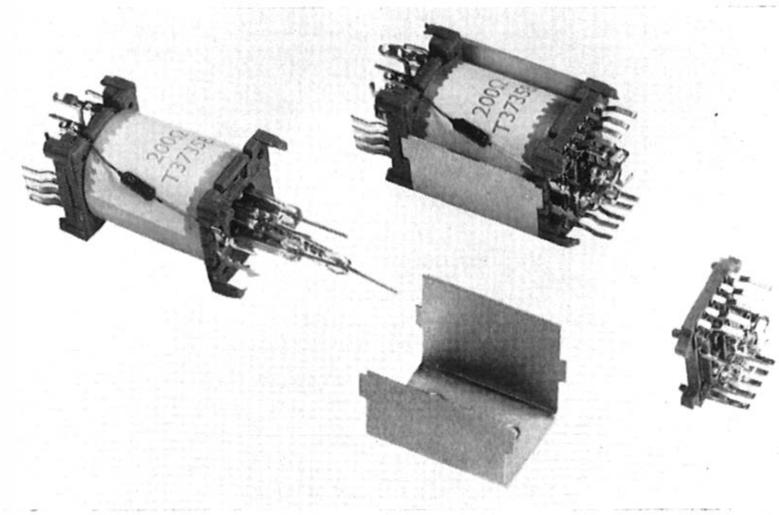


FIG. 7—PARTS OF A CROSS-POINT REED RELAY

Multiple wiring of the matrix formed from Type B relays is unnecessary, since the tag arrangement is designed to provide automatically a series multiple between relays in each row. At each end of the relay are five multiple connexions (for four contact-units and one coil termination). Each connexion consists of a continuous strip shaped so as to make a multiple tag at two opposite sides of the end cheek, with the centre part shaped to embrace the wire end of one of the contact units, or a coil termination. The multiple tags are set so that their tips are sprung slightly outwards from the body of the relay. When the relays are assembled together, the multiple tags on adjacent relays make contact under spring pressure, thus providing a series multiple for each

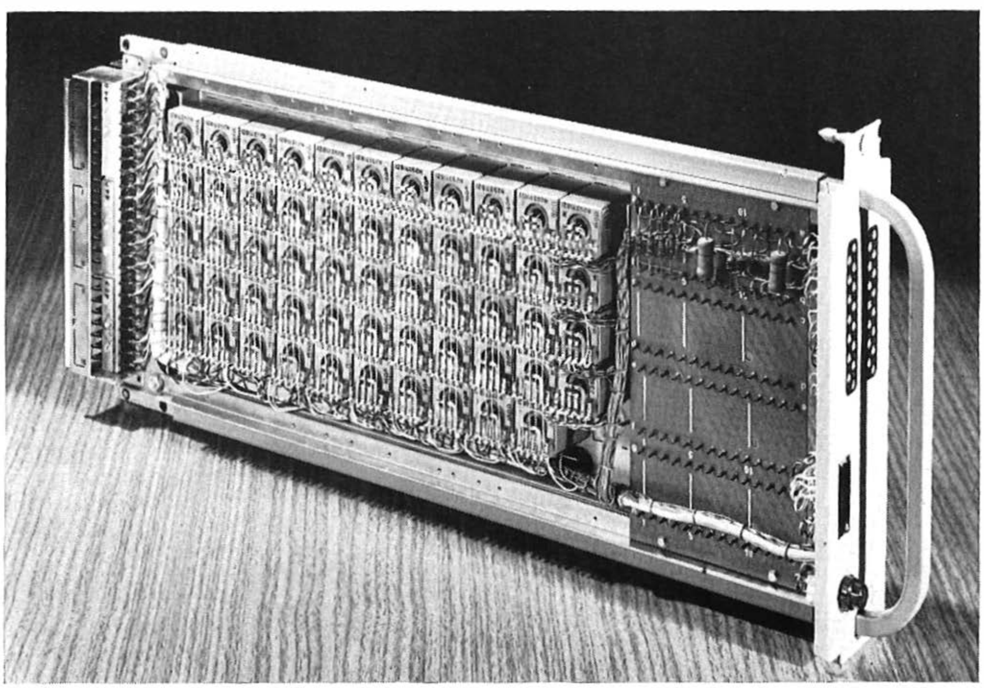


FIG. 8—MATRIX USING THE CROSS-POINT REED RELAY ILLUSTRATED IN FIG. 6

row. On opposite sides of a matrix the directions of the series multiples will be at right angles. The joints are completed by flow soldering the complete array.

The Type C relay has been designed so that the coil former is a one-piece moulding without tags or separate end-cheeks. No screen is fitted as part of the relay, the magnetic screen being provided by the mounting arrangement. This comprises a simple "egg-box" or honey-comb structure made up from thin mild-steel strip, with the ends of each co-ordinate strip formed to slide into the shaped frame member of the plug-in unit. In making up a matrix, wound relays are placed in the compartments of the honey-comb structure and secured by twisting tabs on the honey-comb strips. No tags are fitted to the individual relays, the multiple connexions being provided by shaped strips, continuous across the width of the matrix, added after assembly of the relays. The strips are pressed into grooves moulded in the relay end-cheeks, and cups, shaped in the multiple strip, fit over the appropriate contact unit or coil termination. When all multiple strips have been fitted, again mutually at right angles on opposite sides, the joints are completed by flow soldering. The multiple so provided is continuous, teed to each cross-point, instead of the series arrangement of Type B.

The contact units of the Type D relay are in a "flat-four" arrangement with a moulded coil-former of approximately rectangular cross-section. A two-piece steel screen fits over the coil, and is shaped to lie close to the wire ends of the contact units near the glass seal, reducing to a minimum the air gap in the magnetic circuit. The length of the coil is only 0·75 in., so that the magnetic circuit is short and of high efficiency. These design features result in a relay which is compact and of high sensitivity. The design dispenses with multiple tags, the multiple connexions being made direct to the wire ends of the contacts. To give a straight-line multiple connexion on both sides of a matrix without the 90° displacement of the end-cheeks, the relays are mounted at 45° to the rectangular axes of the matrix. In this way straight-line co-ordinate wiring can be obtained directly between the contact-unit ends on both sides of the matrix. The relays are mounted directly on a printed-wiring board carrying the multiple wiring for that side of the matrix. Fixing is by twisting the coil tags, and flow soldering completes the joints between the relay and the wiring pattern. On the other side, the multiple is obtained by straight bare-wire connexions, wrapped round each contact-unit end or coil tag, and flow soldered.

Relay Types A, B, and C are similar in overall length when the multiple is added (approximately 2·1 in.), but Type A has a larger wiring capacity because it has a 1 in. square cross-section compared with the 0·8 in. square cross-section of Types B and C. Type A can, therefore, be used in control applications where greater sensitivity is needed. Relays of similar construction to Types B and C but of 1 in. square cross-section are also available for this purpose.

The Type D relay is shorter in length than the others because of the absence of multiple tags or strips, and its cross-section is approximately 1·0 in × 0·56 in. In matrix formation some space is wasted at the edges by the 45° arrangement, and in small matrices the cross-sectional area per relay approximates to 0·64 in². Because of its greater efficiency a Type D relay, fully wound, has similar sensitivity to the 1 in. relays and a separate version for control-circuit application is not necessary.

OTHER TYPES OF REED RELAY

Six-Contact-Unit Relays

For special applications, relays with six contact units are available. In construction they follow the same principles as the four-contact-unit types described.

Relays with Change-Over Action

Reed contact units with a change-over action are available commercially, but these have not been used in the present Post Office systems because of their more complex construction, greater cost and lower sensitivity. A typical construction is shown in Fig. 10. The central moving blade is mechanically biassed against one of the fixed contact members (the "break" contact member) with sufficient tension to ensure a low contact resistance, and a higher operating force, compared with a simple make contact unit, is therefore required to move the central blade over to the other fixed contact member (the "make" contact member). The fixed break contact

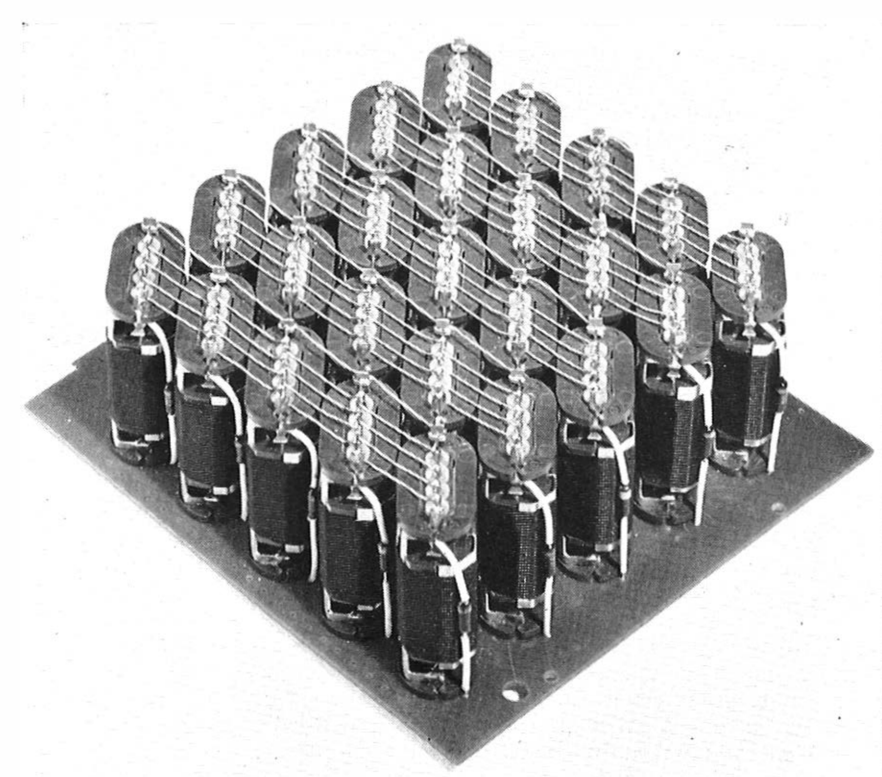


FIG. 9—MATRIX USING FLAT-FOUR CROSS-POINT REED RELAY

B

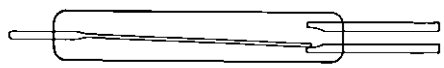
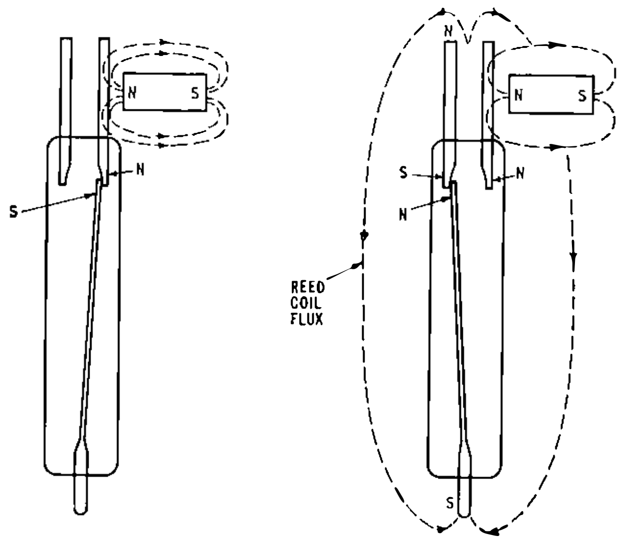


FIG. 10—CHANGE-OVER TYPE REED CONTACT UNIT WITH MECHANICAL BIAS

member is made of non-magnetic material and the central moving blade and the fixed make contact member are made of magnetic material; thus, when a magnetic field is applied by the relay coil the central moving blade is attracted to the fixed make contact member. On release of the coil, the central blade is returned to the break contact member by the mechanical bias.

An alternative form of construction, in which magnetic bias is used instead of mechanical bias, is shown in Fig. 11.



(a) Coil Unenergized (b) Coil Energized

FIG. 11—CHANGE-OVER CONTACT UNIT WITH MAGNETIC BIAS

During manufacture, the moving blade is positioned centrally between the two fixed contact members. All the contact members are of magnetic material. A small permanent magnet with a precisely controlled field strength is placed adjacent to one of the fixed contact members, as shown in Fig. 11(*a*), and the moving blade is attracted to that side. When the operating coil is energized, the flux distribution changes, as shown in Fig. 11(*b*), and the moving blade moves to the other fixed contact member.

Relays with Break Action

In the present electronic-exchange systems the use of reed contact units with a break action has been wholly avoided, except for one application in the subscriber's line circuit of the TXE3 exchange system. The break contact action of a change-over contact unit as described above could have been used, but considerable savings in mounting costs and maintenance can be made by using a modified version of the standard reed relay. This has been achieved by placing a small magnet close to a standard make contact unit.[5] The magnet holds the contact unit closed when the relay coil is not energized. The actual arrangement is shown in Fig. 12, with two contact units and two permanent magnets placed together. The four items are inserted into a standard reed-relay coil. When current flows through the coil, the flux produced is

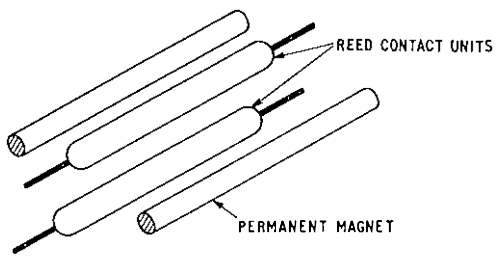
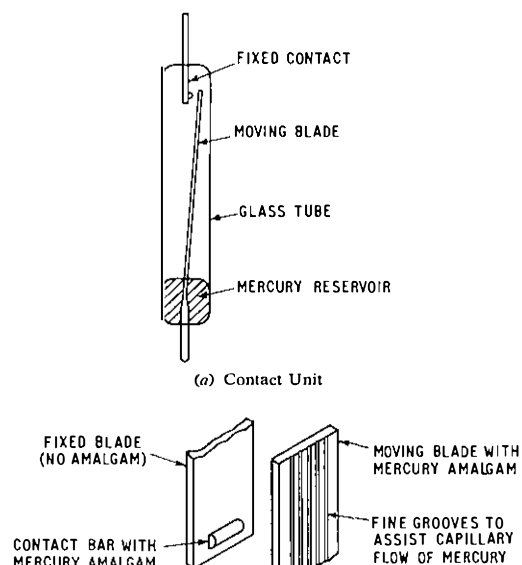


FIG. 12—CONTACT ARRANGEMENT FOR "BREAK" REED RELAY

equal in magnitude but in opposite polarity to the flux of the permanent magnets and the contact units release. The electrical operating conditions are rather more exacting then for a standard make contact unit.

Mercury-Wetted Relays

Fig. 13 shows the construction of a mercury-wetted contact unit. It operates on the same magnetic principles as the dry-reed contact unit, but the moving reed blade is covered by a film of mercury, and the actual contact area when the blades touch is created by liquid mercury. A mercury-wetted contact unit does not require a high contact pressure to give a good electrical contact, and, therefore, its current rating is higher than that for a comparable dry-reed contact unit; versions are available which will safely switch up to 5 amperes.



(a) Contact Unit

(b) Enlarged View of Contacts

FIG. 13—MERCURY-WETTED CONTACT UNIT

The film of mercury on the moving blade is maintained by capillary action from the pool of mercury at the bottom of the glass capsule, and the blade is specially processed to assist this action. Usually a series of fine parallel grooves are cut length-wise in the blade and the surface is given a granular finish. On the fixed blade, the contact point is usually a pip of precious metal, and only the pip is treated to allow it to be wetted by the mercury. This avoids flooding of mercury at the contact area, which would cause permanent bridging. On release, as the blades move apart, a column of mercury is drawn out between the contacts. As the blades move further apart, the column collapses, giving a clean snap-action break, and no bounce occurs. If sparking occurs at the break, a small amount of mercury is vaporized, and condenses on the glass capsule to return eventually to the reservoir. There is virtually no wear at the contact surfaces on the blades, and a mercury-wetted contact unit is therefore capable of a very high number of operations. The unit must be operated in the vertical or near-vertical position.

In addition to the single make action just described, other versions are available with change-over action, including make-before-break and non-bridging types. These latter two actions are achieved by careful control of the gap between the contact members and the amount of mercury at the contact area. The magnetic circuit and operation is similar to that of a dry-reed contact unit with change-over action as previously described. To achieve long life with a mercury-wetted contact unit it is essential to use a surge suppressor across it, to limit the rate of rise of current on closure, and, for inductive loads, the rate of rise of voltage across the contact unit when the relay releases.

The number of mercury-wetted contact units used in the present electronic systems is relatively small compared with the dry contact units, and their use has been restricted to where the current switched exceeds that permitted for the dry contact unit, or where a very high number of operations (typically 10^8) is required during the life of the unit. Development work is now in progress to produce a satisfactory mercury-wetted contact unit, similar in dimensions to the standard dry contact unit, for use in the standard reed-relay coil.

Latching Relays

No latching contact units are used in the present electronic-exchange systems, but a brief description of them is given here for interest. Several designs have been developed, but the greatest interest is in those using a sealed contact unit and employing magnetic bias to achieve latching or locking action. Such a device can be defined as a relay, with two stable states, which will remain in either state without the expenditure of energy. If the latching action is achieved by magnets, the most favourable type of contact unit to use is the mercury-wetted unit in view of the low contact forces involved. Fig. 14 shows a typical arrangement for a latching relay using a mercury-wetted contact unit. A small permanent magnet is placed adjacent to each of the two fixed contact members, and the field strength of each is sufficient to hold the moving centre blade over to its own side once the centre blade is moved in that direction. The relay coil surrounding the contact unit provides the main flux to move the centre blade, and the direction of the coil flux determines the direction of movement of the centre blade. The coil is usually operated by a current pulse of the appropriate polarity, about 5 ms usually being adequate to ensure correct operation. The two small magnets require precise adjustment, and their field strength must be very stable and unaffected by the coil flux to ensure reliable operation over a long life.

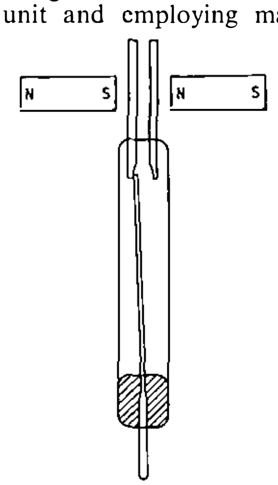


FIG. 14—MERCURY-WETTED CONTACT UNIT WITH LATCHING ACTION

CONCLUSIONS

The standard reed contact unit and its application in electronic telephone-exchange systems has been described with particular reference to its use in cross-point matrices, and a general view has been given of other types of reed contact units which are available at present, such as mercury-wetted types and those with change-over action.

The extensive development which has been carried out to make this ostensibly simple device a cheap and reliable item has been indicated, and particular stress has been placed on the importance of controlling the circuit conditions in which the contact unit is used in order to achieve a long life with minimum failures.

ACKNOWLEDGEMENTS

Acknowledgements are due to the telephone manufacturers for their work on the development of reed relays, contact units and mounting practices for electronic telephone-exchange systems, and for the photographs used for Fig. 6–9. Thanks are also due to Ericsson Telephones, Ltd., for permission to use the photograph of the automatic machine illustrated in Fig. 1.

References

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[2]SHEPPARD, S. H. The Leighton Buzzard Electronic Telephone Exchange. *P.O.E.E.J.*, Vol. 59, p. 255, Jan. 1967.

[3]Bell Telephones Technical Publication 4965.

[4]MARTIN, J. Electronic Telephone Exchanges: An Introduction to Switching Network Design. (In this issue of the *P.O.E.E.J.*)

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Notes and Comments

Birthday Honours

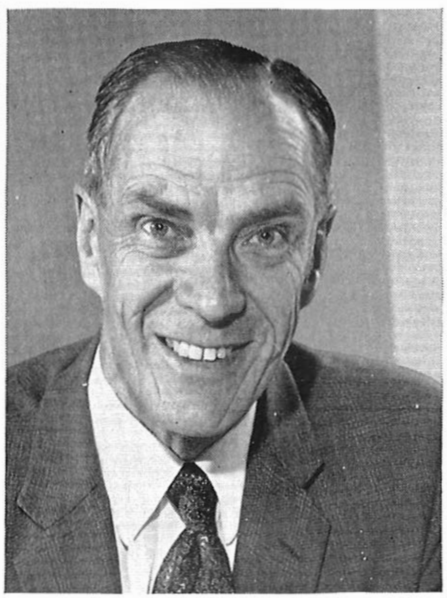
The Board of Editors offers congratulations to the following engineers honoured by Her Majesty the Queen in the Birthday Honours List:

Coventry Telephone Area	H. Hobbs	Lately Area Engineer	Member of the Most Excellent Order of the British Empire
Engineering Department	S. J. Sellwood	Executive Engineer	Member of the Most Excellent Order of the British Empire
London Postal Region	A. E. Stimson	Technician Class I	British Empire Medal
London Telecommunications Region	W. H. Soundy	Assistant Executive Engineer	Member of the Most Excellent Order of the British Empire
Post Office Headquarters Northern Ireland	C. R. J. Ferris	Workshop Supervisor, Grade III	British Empire Medal

C. E. Calveley, O.B.E., E.R.D., B.Sc.(Eng.), C.Eng., F.I.E.E.

Mr. C. E. Calveley took up his appointment as Director of Engineering on 6 April 1967 after 7 years as Assistant Engineer-in-Chief.

In his new post he will be especially concerned with long-range planning, line transmission, switching and subscribers' apparatus, development, provision and maintenance, and with engineering personnel. His promotion will cause no surprise to those who know him, for he brings to his new duties a breadth of experience both within and outside the Post Office which has seldom been equalled, coupled with infectious energy and enthusiasm for progress.



He joined the Engineering Department as a Probationary Inspector in 1928, and passed the open competition for Assistant Engineers (old style) in 1930. During the first 10 years of his career he served in London and the Provinces, and his work covered both installation and maintenance over the whole range of internal and external plant. In 1938 he was promoted to Executive Engineer in the Engineering Organization and Efficiency Branch of the Engineering Department, where he was concerned with planning and organization for the introduction of Telephone Areas.

As an officer of the Supplementary Reserve, he served with the Royal Corps of Signals in Europe throughout the 1939–1945 war, and at the time of his demobilization had reached the rank of Colonel, as assistant to the Chief Signals Officer for the L. of C. for north-west Europe. After the war he maintained very actively his association with the Territorial Army and the Army Emergency Reserve, and was appointed Aide-de-Camp (A.E.R.) to King George VI in 1952 and Honorary Colonel of 80th Signal Regiment (A.E.R.) in 1963.

Shortly after his return to the Post Office, he was appointed, in 1946, as the first Principal of the Engineering Department's training school near Stone, where he served until his promotion to Staff Engineer of the Telephone Branch of the Engineering Department in 1954. In the Telephone Branch he was concerned with the many new developments in the switching and signalling field that were leading up to S.T.D. and I.S.D. In 1956 he was appointed Chief Motor Transport Officer, and for 4 years, until his promotion to Assistant Engineer-in-Chief, he was involved in a very different set of problems in the reorganization of motor transport and the introduction of a new range of vehicles specially adapted to Post Office requirements.

With his promotion to Assistant Engineer-in-Chief in 1960, Mr. Calveley again became directly concerned with the development of telephone switching and signalling systems, and throughout the past 7 years has provided a driving force behind the expansion of S.T.D. services, the development of electronic exchanges, and the introduction of a range of modernized subscribers' equipments. In the last few years of rapid expansion of the telephone system, he has also successfully borne the brunt of the problems of improving the performance of plant in service in the face of acute shortages and the initial troubles due to sudden expansion of the productive capacity of the industry.

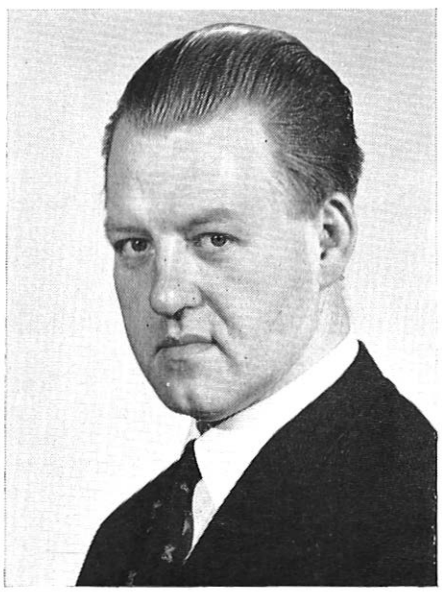
In 1947 Mr. Calveley was awarded a Commonwealth Fellowship, which enabled him to spend a year in America studying personnel selection and training with the American Telegraph & Telephone Company and their associates, and also to attend an advance management course at the Harvard Business School. Since then he has made a number of further visits to America and Europe to discuss aspects of the development and maintenance of telecommunications services that may be of use in the Post Office system.

His many friends in the Post Office and the telecommunications industry at home and overseas are delighted at his promotion and wish him success and pleasure in his new duties.

W.A.H.

D. Wray, B.Sc., C.Eng., F.I.E.E.

Mr. D. Wray, who has been appointed Deputy Director of Engineering, entered the Engineering Department as a Youth-in-Training in 1941, beginning his career in the Post Office Research Station, Dollis Hill, as a laboratory assistant in the Telegraph Development Laboratory. By part-time study he gained an Honours B.Sc. Degree in electrical engineering at London University together with the Walmsley Memorial Prize, and was promoted Executive Engineer in 1946. His new duties at Dollis Hill gave ample scope for his inventiveness and flair for experimentation, and during the decade that followed he made valuable contributions in the field of multi-channel telephony and television transmission involving coaxial-cable and microwave radio-relay systems. Many of his colleagues will recall his hilarious script-writing and enthusiasm for the Radio Division pantomimes that were the high-light of Christmas parties at Dollis Hill during his stay.



On promotion in 1957 to Senior Executive Engineer he was transferred to Main Lines Branch, where he was responsible for the operation and maintenance of television networks installed by the Post Office for program companies and industrial users. The experimental side of his nature found outlet in the development of special equipment for closed-circuit colour-television transmissions.

In 1959 he was seconded for 1 year for service with Imperial Chemical Industries under a scheme for the exchange of personnel between the Post Office and outside industry. On his return he joined the newly formed H.M. Treasury's Automatic Data Processing Technical Support Unit and rapidly became an acknowledged expert in the field of computer technology.

With the advent of satellite communications he was transferred in 1962, on promotion to Assistant Staff Engineer, to the Space Communication Systems Branch of the Post Office Engineering Department with responsibility for the provision, maintenance and operation of the experimental earth station at Goonhilly Downs in Cornwall. Much of the success of the early experiments with TELSTAR and RELAY, culminating with the inauguration of the first commercial transatlantic satellite-communication service via EARLY BIRD in June 1965, was due to his untiring efforts as a planner and installer of the complex equipment at Goonhilly. In July 1965 he became Joint Staff Engineer, Space Communication Systems Branch, with the overall responsibility for Goonhilly Radio Station, including the initiation of its extension.

It was not surprising when in 1965 he was selected to attend a course of study for 1 year at the Imperial Defence College. On his return in January this year, he succeeded Mr. R. H. Franklin as Staff Engineer of the Main Lines Development and Maintenance Branch, and it was from this post that he was promoted Deputy Director of Engineering.

A gentle giant of a man, full of understanding and possessed of a well-developed sense of humour, Donald Wray prefers to lead by his own example rather than by more forceful means. His many friends and colleagues in the Post Office and in industry are glad to learn of his latest appointment and will wish him continued success in his future career.

S.C.G.

J. C. Billen, C.Eng., M.I.E.E.

Mr. J. C. Billen, who has recently been promoted to Staff Engineer in charge of the Main Lines Development and Maintenance (LMD) Branch, joined the Post Office as a Youth-in-Training at Bournemouth in 1929. He became an Inspector in 1936, and, after training, was employed in the Bristol area. In 1938 he was appointed a Probationary Assistant Engineer (old style) and spent some time in the Welsh and Border Counties Region and in the Cardiff Telephone area. He was transferred to the

Engineering Department, Lines Branch, in March 1940. The early 1940s were a period of rapid development in transmission equipment, the first Carrier Systems No.7 with crystal filters and new audio equipment were introduced, and many early coaxial systems were being provided to meet the heavy war-time demand. He was also engaged on the design and provision of the submarine-cable schemes which were prepared for the invasion. In 1944 he took a very active part in the implementation of these schemes. Following the invasion, he was resident Liaison Officer in France for the British Post Office with SHAEF, in charge of a War Office Signals unit which restored the Calais–Paris carrier cable system and provided large installations of carrier systems in Calais, Amiens and one of the Paris repeater stations.

In June 1948 Mr. Billen was promoted Senior Executive Engineer in Main Lines Branch and took charge of the cable-maintenance duty, but in July 1949 he returned to submarine cables for a long spell on this work. In the late 1940s there was a rapid increase in submarine-cable systems to augment the circuits to the Continent, and Mr. Billen was heavily engaged on these. He was also associated with the submarine cables provided for NATO, amongst which were schemes in the Mediterranean. He continued on this work until December 1958 when he was promoted Assistant Staff Engineer in LMD Branch, taking charge of the then very much expanded submarine-cable systems section and being associated with the CANTAT, COMPAC, SEACOM schemes, etc. He also was responsible for the provision of many 120-circuit submarine-cable systems to Germany, Denmark, Netherlands, Jersey, etc. He has recently been engaged on a number of systems using transistor-type submerged-repeaters, including the forthcoming United Kingdom–Portugal submarine-cable scheme.

Mr. Billen has also been very active in the C.C.I.F. (now the C.C.I.T.T.), and from 1951 onwards has attended meetings of the Maintenance Study Groups. He has been vice-chairman of the C.C.I.T.T. Study Group IV, and chairman of a Working Party dealing with the maintenance of inter-continental circuits. This association with submarine cables and the C.C.I.T.T. has made Mr. Billen a great traveller, and during the course of his work he has visited most countries in Europe, and Canada, U.S. and Ceylon.

It will be seen that Mr. Billen's promotion to Staff Engineer of LMD Branch is very well merited: he brings a vast experience to this post, and, during the long period he has been in LMD Branch, developments both in inland transmission systems and submarine-cable systems have been both rapid and extensive.

He will find that his very considerable experience will prove to be of great use to him and also to the Branch of which he is now in charge. His quiet purposeful manner, together with a latent sense of humour, has made his new appointment most popular both with members of LMD Branch and with his many friends in other Branches. They all wish Mr. Billen every success in his new post.

J.R.

Retirement of Dr. R. A. Brockbank, O.B.E., Ph.D., B.Sc., C.Eng., F.I.E.E.

Forty-five years of professional practice is no mean achievement and Dr. Brockbank must look back with satisfaction on a career of considerable distinction. Graduating at the early age of 19 he entered industry, where he worked for a short while at Siemen Brothers in the Signalling Laboratory, and then went on to Western Electric (now S.T. & C., Ltd.) where he specialized on the design of cables, with special reference to dielectric and sheath losses. In 1933 he entered the Post Office and was soon put to the considerable task of designing the repeater equipment for the first London–Birmingham coaxial cable. This system, the first of its kind, was put into service in 1938. From 1938 to 1947, as an Executive Engineer, he was engaged in work on standardized coaxial-line equipment until promotion to Assistant Staff Engineer first brought him on to the design of submerged repeaters—the beginnings of work for which he will be long remembered.

Success with shallow-water repeaters had by 1950 directed thoughts to the possibility of a transatlantic telephone cable. However, it was soon demonstrated as impractical to recover the Post Office type of rigid repeater with conventional deep-sea cable because the twisting effect set up by the armour wires damaged the cable. This serious setback was completely overcome in 1951 when Dr. Brockbank invented the revolutionary cable wherein tension twisting was avoided by use of a torsion-balanced central steel member. This so-called Lightweight cable was invented, developed and proved in sea trials by Dr. Brockbank right up to the point where it was accepted by both British and Americans as the optimum economic alternative for all deep-sea telephone systems. It was first used in the United Kingdom–Canada cable of 1961, with Dr. Brockbank in technical charge on the ship throughout the laying operation. Since this laying of CANTAT all deep-sea systems, both British and American, have used the Lightweight cable, which experience has now shown to be virtually free from all the disadvantages of conventional armoured cables.

In 1954 Dr. Brockbank was promoted to Staff Engineer to take charge of the Submarine Repeater Division of Research Branch, which later expanded by partnership with Cable and Wireless, Ltd., into the Joint Submarine System Development Unit. Since the laying of CANTAT, COMPAC and SEACOM this Unit has developed a 3 MHz system (360 circuits) and more recently started on a 12 MHz system (1,500 circuits).

In an age of increasing specialization Dr. Brockbank has maintained a refreshing versatility, combining successfully the functions of both manager and practising engineer right up to the end of his career. Although cautious by temperament he has always welcomed the opportunity to enter new fields, even when these have involved grave risks to a professional reputation. Great developments in any new field require stamina and courage, and these Brockbank has shown in full measure. His many friends wish him and Barbara every happiness in the years to come.

G.H.M.

F. Scowen, B.Sc., A.Inst.P., C.Eng., M.I.E.E.

Frank Scowen, who has recently been promoted to Staff Engineer of the Submarine Transmission Systems (RG) Division in Research Branch, brings a long experience in the field of carrier transmission to his new post. He entered the Department as a Probationary Inspector in 1934, and, after a year's general training, was posted to Research Branch where for the next 2 years he was employed on cable and crosstalk investigations at carrier frequencies. He then transferred to the carrier group and devoted his efforts to work on carrier transmission systems for the next 13 years. During this period (in 1940) he became an Assistant Engineer (old style), acquired a degree in physics, wrote a book on the design of filters, and, during the invasion of Europe, spent 18 months in the Royal Corps of Signals, attaining the rank of Major. In 1950 he was promoted to Senior Executive Engineer, and for 4 years his attention was devoted to work on the development of electronic telephone exchanges; for 2 years of this period he was a Principal Scientific Officer, but finally decided that he preferred to be an engineer.

Then his talents were again required in the transmission field, and he filled a temporary appointment as Assistant Staff Engineer in 1954, which was confirmed in 1956. As a member of RG Division concerned with submarine telephone-cable systems he has contributed to the development of the Aberdeen–Bergen, TAT-1, TAT-2, CANTAT and COMPAC systems.

Outside his official duties he has pursued a number of paths. Formerly, he lectured on transmission at South East London Technical College: more recently, he has been an examiner in the subject for the City & Guilds of London Institute; and he was a very active officer of the local branch of the Society of Post Office Engineers. His personal hobbies have been, for many years, photography and horses (from a non-financial standpoint!). He has also for many years held office in the Civil Service Riding Club, being successively secretary and treasurer, chairman and vice-president, and is undoubtedly very rare amongst Post Office engineers in having kept horses in his own demesne. It is reported that only recently has the motor car supplanted the horse in the Scowen mênage.

Added to his technical ability, his calm conscientious personality, leavened by a quiet but acute sense of humour, will undoubtedly ensure success in his new rank.

L.K.W.

T. J. Morgan, C.G.I.A., C.Eng., M.I.E.E.

John Morgan has recently been appointed to the third Chief Regional Engineer's post now set up in the London Telecommunications Region (L.T.R.). He will be responsible for the day-to-day planning for exchange and external work in the rapidly growing London network. This is a task for which he is eminently suitable, having been engaged on exchange design and planning work for most of his official career.

He entered the Post Office in 1936 as a Youth-in-Training in the Newcastle Telephone Area, rapidly rising to Skilled Workman Class I, and was engaged on the maintenance of switching, signalling and transmission equipment before being called up for National Service in the Royal Corps of Signals.

He was appointed to the Assistant Executive Engineer grade by special selection in 1945, taking up a post in the Equipment Branch of the Engineering Department. In 1948 he was successful in the Executive Engineer (Reconstruction) examination and continued to work in Equipment Branch, where he became a Senior Executive Engineer in 1957 and continued in this role until 1962. During his long stay in Equipment Branch he was responsible for determining exchange-design standards, the introduction of new facilities, trunk mechanization leading to S.T.D., and the establishment of Regional long-term planning groups. During this time he established himself as a specialist consultant in the exchange-design field and an inveterate globe-trotter, undertaking assignments in Malaya, Ceylon, Singapore and Hong Kong. His direct approach to people and problems, a relic from his North Country upbringing, had a particular appeal to rising technologists in the countries which he visited, and he maintains a friendly relationship with a number of overseas colleagues.

In 1962 he was transferred to the L.T.R. to undertake the initial study of trunk switching in London, and his recommendations were subsequently confirmed by the London Task Force Study Group. He was appointed Regional Engineer in the L.T.R. in 1964, having responsibility for exchange designs and specifications, and for transmission-equipment installation. In 1965 he was selected to join a Headquarters team which visited the United States and Canada to study exchange-plant provision practice.

Mr. Morgan obtained the City and Guilds of London Institute's Insignia Award in Technology in 1959. He is the author of a number of books on telecommunication subjects, perhaps the best known of which is "Telecommunication Economics" which rapidly became a standard text book in the engineer's library.

A popular man, his promotion to Chief Regional Engineer gave pleasure to his many friends and colleagues.

A.J.T.

Board of Editors

The Council of the Institution has appointed Mr. N. C. C. de Jong to be Chairman of the Board of Editors in place of Mr. J. H. H. Merriman, O.B.E., who recently was appointed Senior Director of Engineering and is, thereby, President of the Institution.

The Council of the Institution has also appointed Mr. G. E. Brett and Mr. A. J. Barker members of the Board of Editors in place of Mr. E. J. Markby and Mr. E. Hoare, respectively, who recently completed their terms of office as members of Council.

Nomenclature used in the Journal

For many years it has been the practice of the Journal to indicate that part of the Post Office organization in which an author is serving at the time of publication of his article. For those officers serving in the Post Office Engineering Department this has been indicated by reference to the author's Branch, coupled with the explicit, but out-of-date, phrase "E.-in-C.'s Office." Furthermore, in the "Staff Changes" lists this phrase has been used in the abbreviated form "E.-in-C.O."

As indicated elsewhere in this issue of the Journal, the post of Engineer-in-Chief has been superseded by that of Senior Director of Engineering. This, therefore, is considered an appropriate time at which to replace the misnomer "E.-in-C.'s Office" by the correct term "Engineering Department;" for the "Staff Changes" this will be abbreviated to "Eng. Dept."

Institution of Post Office Electrical Engineers

Institution Field Medal Awards, 1965–66 Session

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

Field Medals were awarded to the following authors for papers read during the 1965–66 session:

J. D. Hitchcock, Telephone House, Bedford. "Incentive Schemes in Industry."

R. Corbishley, Telephone House, Manchester. "Local Line Planning for Service and Satisfaction."

H. A. Byatt, Engineering Branch, Midland Region. "Efficiency in Motor Transport Servicing."

Result of Essay Competition, 1966–67

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

R. Williamson, Technical Officer, Norwich. "The Design of Condenser Microphones—Some Practical and Theoretical Problems."

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

T. H. Hopkins, Technical Officer, Banbridge, Co. Down. "Industrial Accident Prevention."

J. F. Crake, Technical Officer, Blackburn. "A Local Line Planner's Account of an Exchange Transfer."

E. P. Goodwin, Technician IIA, Mount Pleasant. "Carbon Arc to Tungsten Glow—The Story of the Incandescent Electric Lamp."

J. G. Wardle, Technical Officer, Birmingham. "A History of Radio Astronomy."

Institution Certificates of Merit have been awarded to the following five competitors:

R. Brewer, Technical Officer, Newark-on-Trent. "Mainly Routine."

P. Bews, Technical Officer, York. "The Telephone Business."

E. R. Horler, Technical Officer, Bristol. "30 Years Development in A.C. Signalling and Dialling."

D. C. Ferguson, Technical Officer, Old Meldrum. "The British Telephone System—Can it Survive?"

H. Yearl, Technical Officer, Chesterfield. "A Short History of the Discovery and Development of Magnetism."

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

N.B.—Particulars of the next competition, entry for which closes on 15 January 1968, will be published later.

A. B. Wherry,
General Secretary.

Additions to the Library

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

Members are reminded that Prize Essays, Associate Section Prize Papers, and various unpublished papers are held in the library for loan, and that a list will be sent on request. Field Medal award-winning papers are also held for loan and are listed in the Supplement to the Library Catalogue. Please note that the 1967 Supplement to the Library Catalogue is now available from Local Secretaries or direct from the Librarian I.P.O.E.E., 2–12 Gresham Street, London E.C.2.

2897 *Microwave Valves.* C. H. Dix and W. H. Aldous (Brit. 1966).
A fundamental approach, aimed at the technically-educated reader of graduate or Higher National Certificate level.

2898 *Applied Electricity.* A. T. Starr (Brit. 1957).
Covers the syllabus of Applied Electricity for Part 1 of London University B.Sc.(Eng.) Degree and Higher National Certificate.

2899 *The Theory of Practice in Management.* R. W. Evans (Brit. 1966).
Sets out to define the process of management common to all intelligently planned and executed activities, and defines what it is that makes management an occupation different from all others.

2900 *Basic Principles of Electronics and Telecommunications.* M. D. Armitage (Brit. 1966).
A modern treatment, at about second-year level, of the fundamentals of electricity and magnetism, thermionic valves and the transistor.

2901 *Domestic Hot-Water Supplies and Central Heating.* D. H. Beattie (Brit. 1966).
A clear and simple treatment of the principles upon which systems of hot-water supply and central heating by hot water should he designed and installed.

2902 *The Contributions of Faraday and Maxwell to Electrical Science.* R. A. R. Tricker (Brit. 1966).
The object of this study is to understand something of the genesis of the ideas in the field of induction of currents.

2903 *The M.K.S. Approach to Electricity and Magnetism.* A. W. Russell (Brit. 1966).
Suggests a method of approach which not only incorporates M.K.S. units hut achieves continuity of subject matter.

2904 *Strength of Materials.* P. Black (Brit. 1966).
Meets the requirements of those studying for Higher National Certificate and Diplomas in mechanical engineering.

2905 *Introduction to the Theory of Switching Circuits.* E. J. McCluskey (Amer. 1965).
Intended as a first course in "classical" switching theory for engineers, the emphasis being on practical importance in the selection of topics and methods of exposition.

2906 *Television Receiving Theory.* G. H. Hutson (Brit. 1966).
Written for technicians engaged in the servicing or manufacture of television receivers and for students of television engineering generally, and should be useful to those preparing for the intermediate and final examinations in radio and television servicing (C. & G. and Radio Trades Examination Board) and to those studying electronic and radio engineering subjects generally.

2907 *Transmission Lines and Networks.* W. C. Johnson (Amer. 1950).
Presents the basic principles of transmission lines and the elementary analysis of passive four-terminal networks in a form appropriate for both power and communication engineers.

2908 *Pure Mathematics.* A. Geary and G. A. G. Garreau (Brit. 1965).
Covers the syllabus in pure mathematics at A-level, and a large part of the syllabus for the special papers in pure mathematics.

2909 *Outline of Radio and Television.* J. P. Hawker (Brit. 1966).
Attempts a fresh look at the subject, taking into account the progress with transistors; a non-mathematical approach has been adopted.

2910 *Modern Electronics.* H. de Waard and D. Lazarus (Amer. 1966).
A first course in electronics for students in science and engineering or those whose training in electronics was minimal or lacking; preserves a familiarity with elementary physics and simple passive d.c. and a.c. circuits.

2911 *On Human Communication.* C. Cherry (Amer. 1966).
Intended as a review, a survey, and a criticism; written to serve as an introduction to a forthcoming series.

2912 *Maths for Electronics Technicians.* R. L. Evans (Amer. 1966).
Presents the basic principals of mathematics commonly used by electronics technicians, and their applications to electrical and electronic circuits; assumes a knowledge of algebra, but no prior knowledge of electricity or electronics.

2913 *An Anthology of Philips Research.* Edited by H. B. G. Casimir and S. Gradstein (Dutch 1966).
Deals primarily with work of the last 15 years of the Philips Company.

2914 *Transistor Circuit Design and Analysis.* E. Wolfendal (Brit. 1966).
A largely mathematical comprehensive introduction, for engineers, physicists, and undergraduates who are applying or studying electronics.

2915 *Measuring Methods and Devices in Electronics.* A. C. J. Beerens (Dutch 1966).
Deals with measuring instruments in common use in factories and workshops.

2916 *Loudspeakers and L.S. Cabinets.* P. W. Van der Wal (Dutch 1966).
Includes practical hints for "do-it-yourself."

2917 *A Course in H.N.C. Maths.* R. S. Morland (Brit. 1966).
Written primarily for the final years A2 and A3 of the Higher National Certificate and the D2 and D3 years of the Higher National Diploma courses of mechanical and electrical engineering and physics; assumes the elementary work on differential and integral calculus to have been covered.

2918 *G1 Science for Engineers.* A. B. Robb (Brit. 1965).

2919 *G2 Science for Engineers.* A. B. Robb (Brit. 1966).
Gives the syllabus for first and second year engineering science in the new scheme for a general course in engineering.

2920 *Elective Physics for the O.N.C.s and Diplomas in Science.* K. D. Barritt (Brit. 1966).
Assumes a knowledge of physics to G.C.E. O-level, or credit passes at C.S.E.

2921 *The World's Telephones.* The American Telephone and Telegraph Company.
General statistics covering 1964 onwards.

2922 *Communication Switching Systems.* M. Rubin and C. E. Haller (Amer. 1966).
Describes the techniques used in the application of automatic switching in communication systems.

W. D. FLORENCE,
Librarian.

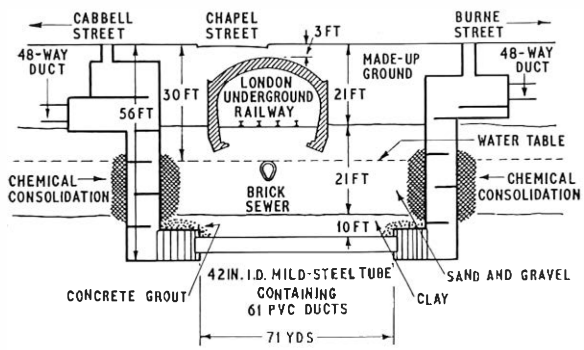
Regional Notes

London Telecommunications Region

AN UNUSUAL DUCT AND MANHOLE PROBLEM

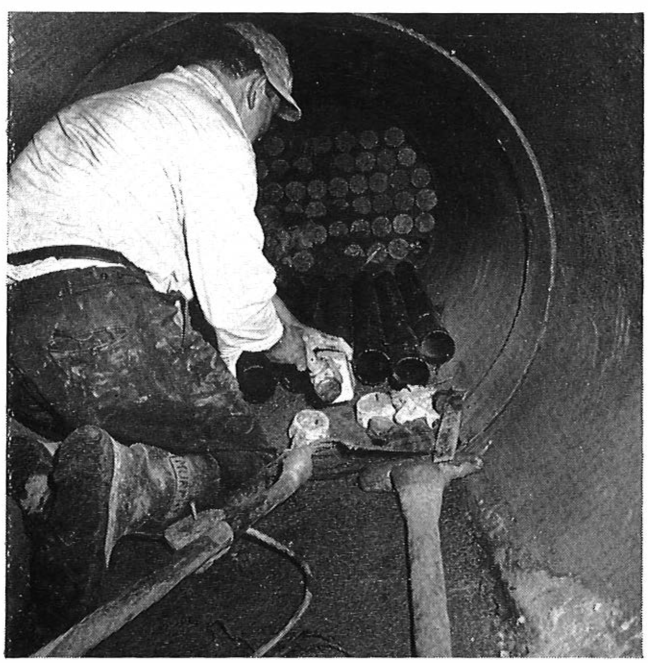
The construction of a large flyover for the "west-cross" route over the Edgware Road made it necessary to abandon 48 ductways and 11 manholes.

The replacement duct route, consisting in the main of 48 ductways, with one section of 60-way, and needing some 20 manholes, was of standard construction except for a section of 75 yards where it crossed beneath the Metropolitan Railway. Here it was planned to construct two three-deck manholes and a tunnel beneath the railway at a depth of approximately 45 ft. Previous borings near the site showed the strata from the surface to be 21 ft made-up ground, 15 ft sand and gravel, and then blue clay. There was no indication of excessive water. The arrangement is shown in the illustration.



TUBE OF PVC DUCTS USED TO UNDERPASS THE UNDERGROUND RAILWAY AT EDGWARE ROAD

At a depth of 30 ft excessive water was encountered, and, as the pumps were also discharging large quantities of sand and because of the proximity of multi-storey buildings near each excavation, the use of timber for lining and supports was discontinued in favour of inter-locking sheet-steel piling



LAYING PVC DUCT IN THE MILD-STEEL TUBE

and chemically consolidating the soil by injecting solutions of sodium silicate and calcium chloride. These two compounds, when mixed, produce a soft chalk-like substance which when injected into the sandy soil produced a soft sandstone. A total of 150 injections, using 6,000 gallons of each solution, were made at each excavation.

When the excavations were 42 ft deep, clay was encountered; the clay was found to be of the unstable fissured type requiring an alternative to timber in the construction of the proposed tunnel heading. An "umbrella" of concrete grout was injected under pressure, into the clay above the proposed duct route. This was followed by the construction of a short tunnel, 12 ft long, of 8 ft diameter concrete segments to provide a secure area for pipe thrusting.

A 42 in. mild-steel pipe, in 5 ft lengths with butt-welded joints, was then thrust the 71 yards between the two excavations at a depth of 52 ft. The jacking equipment consisted of four hydraulic jacks equally spaced on the circumference of the pipe and able to produce a thrust of 600 tons per ft^2. In fact, the thrust never exceeded 25 tons per ft^2 and the average rate of progress was 1 ft per hour. Excavation inside the pipe was carried out manually, and on completion a total of 61 PVC ducts were laid in the large steel pipe and the interstices filled with concrete, as shown in the photograph.

Finally, two multi-floor manholes, one at a depth of 54 ft and the other at a depth of 49 ft, were constructed in the excavations. The work is now complete and cabling and jointing have presented no problems.

P. S.

North Eastern Region

CLOSED-CIRCUIT TELEVISION AT THE UNIVERSITY OF LEEDS

In the face of competition from commercial undertakings, the Post Office succeeded in being awarded a contract for the provision of a closed-circuit television system for Leeds University. The first stage was planned and installed within six months to meet an opening date of 12 January 1967.

This first stage comprised v.h.f. receiving points in 18 lecture theatres; in 15 of the lecture theatres complementary wiring was provided for video and sound distribution from master sets to slave monitors. A further section, comprising 3 v.h.f. receiving points, requested for use at the Students Union on 26 February 1967, was completed by that date. The present high-quality transmissions are in monochrome but the system is also suitable for colour transmission.

At the present time, one working and one spare channel have been provided; a second working channel will follow later this year as part of the second stage. The system is designed to ultimately carry 8 programs simultaneously.

Programs are being transmitted from a temporary studio on the south side of the University, provision having been made for a convenient transfer to the proposed permanent studios beneath a new lecture-theatre block around 1969.

The whole distribution system progresses north from the temporary studio using a single-tube 0·62 in. solid-polythene-dielectric coaxial cable as the main feeder, type 361 (Aerialite) flexible coaxial cable being used for the spur feeders.

Cabling facilities are being provided within the University grounds (some 90 acres excluding external departments), consisting of earthenware ducts in roadways (one duct line passes beneath crane tracks and a large building under construction), and cable trays in the main service ducts and rising shafts.

Amplifiers are being housed in cupboards in the service ducts, the dividing and splitting units being mounted on the cable trays. One section, to the dental and medical schools, will be routed in the Post Office street duct network, two amplifiers on route being housed in a distribution cabinet and being power fed over the cable.

Surveys and estimates are well in hand for the completion of the second stage to be completed in August 1967.

In addition to the transmission system a contribution system is to be installed as part of Stage II, using a polythene-insulated single-quad cable, one pair for video transmission, the other for program sound. Programs will be fed back from an originating source to the master control for recording or transmission into the v.h.f. network.

The design and commissioning of the v.h.f. and contribution systems is being carried out by Main Line Development and Maintenance Branch, Engineering Department, and the survey and installation work by the Leeds Telephone Area staff.

A. N. P. and J. A. S.

A TRANSPORTABLE APPARATUS HOIST

The need for lifting tackle for hauling racks of equipment into apparatus rooms on direct-labour jobs has until now been met by hiring suitable equipment locally, or, if a Post Office contractor's equipment happened to be available, by borrowing this.

This unsatisfactory situation has been rectified by purchasing a suitable winch from a local firm and mounting it on the chassis of an old trailer tool cart. Sufficient space was provided on this for two side panniers to hold the sling chain, ropes, wheel chocks, etc. Two double-groove wire-rope pulley blocks, snatch block and jockey wheel were also purchased, and sufficient wire rope ($\frac{3}{8}$ in. lift rope) for an 80 ft haul was obtained from the Supplies Department. The total cost of non-rate book items was about £50. The outfit is completely portable and can be towed by a 15 cwt van.

A $15\frac{1}{2}$ cwt winch is heavy enough to be used without a snatch block and the rope is taken direct from the winch to the cathead. Using double-sheave pulleys the maximum pull on the rope is only $6\frac{3}{4}$ cwt so there is no danger of lifting the winch off the ground. The winch is fastened to the anchor point with 3 in. rope taken through the towing eye, and the retractable feet at the back and front of the trailer are lowered to the ground and a wooden chock is put under each wheel.

A technique has been developed for fixing the pulley block to the cathead. This involves climbing a ladder to the cathead from the loading platform but to guard against accidents the ladder is first roped so that it cannot be dislodged and a safety rope is also provided for the man climbing the ladder.

A rope is first lowered from the coping of a building or a window above the cathead so that it hangs on the opposite side of the cathead to that on which the ladder will rest. The rope is securely tied to what will be the inner stile of the ladder, one or two rungs from the top as convenient. The ladder is then propped up to the cathead so that the rope now runs from the ladder under the cathead to the window above. The free end of the rope is now dropped so that if falls on the ladder side of the cathead and the rope is pulled tight and fixed to the outer stile of the ladder as high up as can be reached from the loading platform. The ladder is now bound to the cathead, and, as an additional precaution, the remaining rope is taken inside the apparatus room at an angle to pull the ladder against the cathead and is secured to an apparatus rack or similar secure fixture. The bottom of the ladder is also roped to the hand-hold at the side of the apparatus door. A second rope is now lowered from the window and the pulley block is hauled up until the hook is just under the cat trolley. A volunteer can now climb the ladder and hook the pulley block on to the cat trolley without having to bear any of the weight of the pulley block, but before he does this he puts on a safety belt (as used by overhead gangs) to which is securely fastened a third rope lowered from the window. The upper end of this rope is tied round a heating pipe or similar fixture inside the room above the cathead before the man climbs the ladder; as he climbs the slack on the rope is taken up from above so that if he were to slip the rope would prevent him falling more than a few inches. The illustration shows the man wearing a safety belt on the ladder which has been secured by ropes to the building.

ATTACHING THE PULLEY TO THE CATHEAD

The technique can be varied to suit individual local circumstances, and, provided the safety precautions are thoroughly and carefully observed, it is comparatively simple and safe. It has been used many times in this Telephone Area on catheads up to 80 ft above ground level.

I. J. B.

Northern Ireland

INSTALLATION OF EXPEDIENT RACKS IN TELEPHONE EXCHANGES

Areas are provided with a number of composite racks consisting of 50-point linefinders, final selectors and meters to provide temporary relief to exhausted exchanges. These racks are recovered following the next normal exchange extension and re-used elsewhere.

Shifting these racks is thus a frequent occurrence, and methods are being tried of simplifying installation and avoiding obstruction during the subsequent extension.

The cables from the rack to the M.D.F. are made of adequate length to cater for any reasonable location of the rack, and terminated at the M.D.F. end on two 100-circuit verticals which can be bolted to the non-growing end of the M.D.F. Any surplus cable length is coiled up.

The expedient rack has its own I.D.F. and, when the rack is shifted, the I.D.F. record card is shifted with it. The receiving exchange usually finds that very little alteration to the I.D.F. jumpering is necessary. Two further simplifications are under consideration.

The 50-point linefinders have, at present, to be connected to 20 existing uniselectors in the exchange being relieved. In fact, a waiting list exists for these racks, and by the time the rack is installed there are often no spare uniselectors available, and costly rearrangement is necessary. Consideration is being given to providing each rack with another small rack of 20 uniselectors, connexion between the linefinders and these uniselectors being effected with plugs and jacks. The outlets from the uniselectors can be teed to existing uniselector outlets or taken to new first selectors, depending on the loading of the existing grading.

In order to avoid obstructing the projected permanent extension and shifting light switches and other fittings on the end of bays, the expedient rack is often placed on a free-standing position, necessitating the construction of special ironwork supports. Experiments are proceeding with telescopic supports which can be adjusted at will to hold these racks in a rigid state.

F. C. H.

Midland Region

KIDDERMINSTER INNER RING ROAD

Kidderminster Corporation is involved in constructing an inner ring road and feeder roads to relieve conjestion in the town centre. The first section of the road, which is nearing completion, includes a new bridge over the River Stour and two subways. Post Office works resulting from the project have been extensive and several difficult problems have arisen. Of these the most interesting arose at the junction of the ring road and Mill Street where the Staffordshire-Worcestershire canal passes beneath Mill Street. The space above the bridge arch is completely filled with service pipe, of which seven are Post Office steel pipes.

Additional duct capacity was required immediately for two new junction cables, one 2,000-pair P.C.U.T. cable, and two carrier cables. An "improvement line" at this point commences at an occupied electrical shop, then passes through a derelict house and joins the ring road. A public house is built over the canal.

Discussion with the Local Authority, British Waterways Board and the property owners resulted in wayleave being obtained to construct a new duct line of 16 steel pipes. Eight of these were laid over the bridge arch within the public house and eight were attached to the bridge wall. The two groups were then brought together in the public house cellar in a 4 × 4 formation, and from this location the tunnel was driven beneath the electrical shop. The pipes were accurately placed to line up with a new footpath and bridge extension.

The tunnel, which was 34 ft long, 4 ft wide, and 5 ft deep, was timbered using normal Post Office methods, and excavated in seven days by three men. The whole of the work, including shaping steel pipes, excavating and backfilling with ready-mix concrete, took 14 days.

The successful completion of the work was due to excellent co-operation between the staff of the Contractor, Telephone Area, Region and Engineering Department.

T. McC. and J. D. C.

Scotland

ROCKET-ASSISTED MAINTENANCE

On Wednesday 21 December 1966 the worst flooding conditions experienced for many years occurred in parts of Inverness-shire and Ross-shire in Aberdeen North telephone area. The River Glass in Inverness-shire rose to more than ten feet above its normal level and in places flooded over its banks into adjoining territory. At two points, near the villages of Cannich and Struy, where subscribers' overhead lines crossed the river the wires were brought down and, as at these points the river was a raging torrent 150 yards wide, there appeared to be no immediate method of restoring the circuits.

Use of a boat was out of the question because of the turbulent conditions and floating debris.

One of the technical officers involved then suggested the use of rocket-firing equipment to get a line across the river, and a set of Schermuly Pistol Rocket Apparatus was hired. The pistol is hand held and fires a rocket by means of cartridge ignition. The rocket used was capable of carrying a specially coiled $\frac{3}{16}$ in. hemp rope for a distance of 250 yd. The ropes are expendable and cannot be coiled up and used for a second attempt.

As the staff involved had no experience of the equipment they could only follow the written instructions very carefully. The pistol had to be firmly held at an angle of 30° and two or three feet of rope had to be pulled out of the rope container before firing to reduce initial drag on the rocket. As a possible precaution against powder burns gloves were worn. After courage was summoned to fire the first rocket, the operation was a complete success and only three rockets were used to get ropes across the river at both affected points. The operation enabled telephone service to be restored within 24 hours where otherwise it could have taken more than a week.

The total cost of hiring the rocket-firing equipment including a charge made for rockets, cartridges and ropes used was £7.

A. C. and J. I. M.

Editor's Note. It is regretted that a Regional Note published in the April issue describing the work on the Severn Bridge was ascribed to South Western Region instead of to Wales and Border Counties.

Associate Section Notes

London Centre

How to prove all angles are right angles! This was just one item from a talk by Dr. G. A. Garreau (Reader in Mathematics, City University) at our February meeting. The talk was entitled "Fun With Mathematics" and dealt with facilities, paradoxes, multigrades, magic squares, Euler squares, circle squares, etc. This was something far removed from the usual lecture, and proved most entertaining as well as instructive.

Our March lecture was called "The Electrification of British Rail" by Mr. D. Viney of the Divisional Public Relations Office, British Rail. Mr. Viney dealt mainly with the problems involved with the electrification of lines in the London Midland Region, and supported his talk with two films on modernization. At some future date it is hoped to take a party of our members to Euston to see the communications side of British Rail.

"Air-Traffic Control" was the subject of a talk by Mr. R. B. Rofe (Operations Manager, International Aeradio, Ltd.) at the April meeting. With the aid of colour slides and tape recorder, Mr. Rofe took us on a hypothetical flight from London to Rome. We were all amazed at the amount of behind-the-scenes work which is necessary to ensure the safety of passengers and aircraft on even the shortest of flights. The talk was followed by a film which amplified all Mr. Rofe had said, and was a fitting end to a most enjoyable evening.

These monthly meetings are not as well attended as they could be, which is a pity because those members who do turn up always have a very pleasant and instructive evening.

On 12 April a visit was made to the Rank, Bush and Murphy factory at Welwyn Garden City where we were shown pocket-sized transmitter/receivers for use by police forces and other sets which had been ordered by the Post

Office. The main attraction was the latest equipment for the television transmission of film in colour, along with the necessary test gear and monitoring sets. It was very interesting and most members were exceptionally pleased with the finale which was a showing of "Thunderbirds" in colour.

Messrs. Dimplex of Southampton were the hosts for our second visit which took place on 20 April. Unfortunately, the late arrival of the coach caused the first part of the day (a tour of the docks) to be rather hurried. After an excellent lunch we were conducted round the factory where we saw sheets of steel finish up as an oil-filled electrically-heated radiator.

Our thanks to these manufacturers for their patience with our many questions and for their fine hospitality.

The annual conference in May signalled the end of the present session. The new session starts in September.

R. W. H.

Manchester Centre

The Manchester Centre was re-formed last November, and a program of three talks and a visit to the A.B.C. television studios has been completed very successfully.

The annual general meeting was held on 18 April and the following officers were elected: *Chairman:* Mr. C. F. Driver; *Secretary:* Mr. G. Chapman; *Treasurer:* Mr. E. Walter. The constitution of the re-formed Centre was agreed and a discussion took place on ideas for the next session's program.

The membership now totals 185 and we look forward to an interesting session for 1967–68.

G. C.

Stoke-on-Trent Centre

The annual general meeting took place with Mr. J. A. Hart as chairman on 12 April, and members were pleased to hear the president, Mr. K. Gray, Telephone Manager, describe their Centre as a flourishing unit. Mr. Gray went on to add that attendances at meetings exceeded his experience and expectation. It is hoped that the new session will produce more high attendances.

In comparison with 1965–66, attendances were more than double in 1966–67: membership also climbed significantly, whilst the numbers taking the *P.O.E.E. Journal* rose to 184.

Our visits were again fully supported, and interest is already concentrating on the next program.

The formal meetings were as follows: "Meet the Area Board," a Film Show, "Subscribers' Telephone Instruments: Some Possible Future Developments," by Mr. T. C. Harding, "Radio-Controlled Models," by Mr. G. A. Buck and "The Crossbar System," by Mr. B. A. Elliott.

As a result of promotion during the session, we lost the valued services of Mr. W. D. Paterson, and in his stead welcomed Mr. Roy Sutton to the committee as the Stafford representative.

The following officers were re-elected to serve the Centre for the new session: *President:* Mr. K. Gray; *Chairman:* Mr. J. A. Hart; *Vice-Chairman:* Mr. A. E. Fisher; *Secretary:* Mr. S. P. Hancock; *Assistant Secretary:* Mr. K.T. Bevington; *Treasurer:* Mr. E. A. Hudson; *Librarian:* Mr. E. J. Foden; *Committee members:* Messers. Roberts, Winfield and Sutton; *Auditors:* Messers. Colclough and Yates.

S. P. H.

Sheffield Centre

The annual social was held on 28 January. Members and their families saw a selection of films and enjoyed a supper followed by games and dancing, organized by the chairman and his wife.

During February about 20 members visited the stainless-steel strip mill of Messer. Firth Brown's in Sheffield. They saw large billets being prepared, heated and then hot-rolled, a process which is now quite rare. The rolls of strip are taken to a second mill where the highly-polished finish is applied.

On 16 March, Mr. Anderton of the North-Eastern Region headquarter office gave a talk entitled "Quality of Service and Reliability." He explained how quality of service can be measured and what can be done to improve it. The subject proved controversial and a lively discussion ensued.

B. A. S.

Salisbury Centre

The program for the last three months has consisted of two lectures and two visits.

A party of members visited the British Railways workshops at Swindon and had an interesting afternoon, being shown over the diesel locomotives section and the apprentice training school.

The first lecture, which was on "S.T.D. in Salisbury," was given by Mr. F. N. Beaver, Assistant Executive Engineer, and was found to be interesting and informative and well received by the members.

Next came a visit, this time to Harveys of Bristol. After a tour of the museum we were shown a film which covered all the phases of sherry making. Blending and bottling was then explained to us by the guides. The high-light of this very well attended evening visit came with the tasting of six different sherries.

The 1966–67 session came to a close with a lecture on "An Introduction to 5005 Crossbar Exchanges" given by Mr. A. S. J. Cottell, Assistant Executive Engineer, of Bristol. After a most interesting talk the speaker was asked a number of questions from an appreciative audience and dealt with them adequately.

R. H.

Exeter Centre

Support for Centre activities continues to grow; the 1966–67 winter program attracted an average attendance of 64.

The venue for next winter's program will be The Queens Building, Queens Drive, University of Exeter. The members will appreciate this move to more congenial surroundings.

Membership now totals 277; this is an overall increase, albeit small, in spite of the usual losses due to promotions, etc.

The annual general meeting was held on 6 April, when the following officers and committee members were elected. *President:* Mr. E. H. K. Brown; *Chairman:* Mr. R. Powlesland; *Vice-Chairman:* Mr. P. James; *Hon. Secretary:* Mr. T. Kinnaird; *Hon. Asst. Secretary:* Mr. J. Anning; *Librarians:* Messrs. N. West and G. Strodzinski; *Treasurer:* Mr. C. A. E. Chandler; *Committee:* Messrs. L. Hines, J. Petherick, M. Saunders, G. Sealey and J. Summers; *Hon. Auditors:* Messrs. G. Hall and D. Hitchcock.

Mr. J. Anning has been elected as Hon. Assistant Secretary; his enthusiasm will be of great benefit to the Centre. Mr. M. Saunders has also been elected to serve as committee member, we are all indebted to him for the work he has done in the past and will find his experience a great help in the future.

The librarians have now completely reorganized the magazine circulation. A vast amount of work has been done by them to speed up the circulation, and success now depends entirely on the members.

T. F. K.

Bristol Centre

The first meeting of the fifth year of the Bristol Centre was held in October, when 140 members and guests were addressed by Mr. N. A. Lincoln of the Automatic Telephone and Electric Co., Ltd., on "Crossbar 5005" at Bristol University. In January we were invited to a lecture on "The Future of Telecommunications" by Mr. J. H. H. Merriman. This was followed in February by an invitation by the Institution of Railway Signal Engineers to a talk on the "Crewe Electronic Telegraph Relay Centre."

In March Mr. Thaine and Mr. Wells of the Engineering Department gave us a lecture and film on "Work Study"—this turned out to be so interesting that the speakers were kept busy until almost eleven o'clock with questions.

April brought the only visit of the session—to the Westinghouse Brake and Signal Company at Chippenham—where we were shown over the Post Office work assembly section and the semiconductor division.

The annual general meeting was held on 27 April when the following officers and committee were elected. *Chairman:* Mr. A. Manley; *Vice-Chairman:* Mr. R. Crespin; *Secretary:* Mr. H. Punchard; *Treasurer:* Mr. R. Stovell; *Committee Members:* Messrs. K. Andrews, B. Body, H. Drew, J. Kennett, J. Trott and A. Wilkins.

H. P.

Middlesbrough Centre

The 1966–67 session has been a full and varied one. The session started with a forest drive-through and a picnic on Forestry Commission land which had the points of natural interest marked and catalogued. Unfortunately, we had not arranged for the right kind of weather but those who braved the early rain found it most interesting.

Our talks this season were on the "North Sea Gamble," "Amateur Photography," "Telex," "Railway Signalling Systems," and "Looking Ahead," the latter being given by Mr. P. D. Gilbey, our Telephone Manager.

Our visits were to the television relay station at Arncliffe Wood, Tyne-Tees television studios, and a planetarium at South Shields. We also had a small celebration buffet in conjunction with the Darlington Centre in honour of Messrs. Scott and Purvis who obtained the 2nd and 3rd Awards for their articles in the *N.E. Regional Journal.*

We also carried out a recruitment drive during the season, and after a little success we now have a membership of 125.

At the annual general meeting in April the following officers were elected. *Chairman:* Mr. W. Outhwaite; *Secretary:* Mr. K. Whalley; *Treasurer:* Mr. R. G. Inns; *Assistant Secretary:* Mr. R. D. Purvis; *Librarian:* Mr. D. A. Pratt; *Committee:* Messrs. K. Roe, R. Oliver, J. R. Vipond and T. Pennock.

Some concern was shown at the relatively small number of members actually attending talks and suggestions were invited as to how to induce members to take a more active part in the coming season.

The program arrangements for the next session are already well under way, and some are already arranged, so once again we are looking forward to an interesting session.

K. W.

Aberdeen Centre

The following meetings have been held.

February: A talk by Mr. A. G. Duguid, one of our members, on "Gas Pressurization." Some 30 members and guests were present at this interesting lecture; Mr. Duguid described how cables were pressurized and the methods used for fault location.

March: A visit to Wiggins Teape Co., Ltd., paper mills at Stoneywood.

April: A talk by Mr. P. Summer of the Standard Telephones and Cables, Ltd., East Kilbride factory on "The BX 1100 Crossbar System." This was a most interesting and informative lecture which was exceptionally well presented.

R.M.

Ayr Centre

The present session has been very successful with good attendances at meetings. The meetings held were as follows.

October: A visit to the Skefko roller bearings factory at Drybridge.

November: A talk by Mr. W. N. Shannon on "Radio as an Aid to Maintenance."

January: A lecture demonstration entitled "Building Construction and Materials," given by the staff of Ayr Technical College.

February: A talk on computers by Mr. Wallace, the engineering officer in charge of the Appollo computer at Prestwick airport.

March: A talk by our Telephone Manager, Mr. W. T. Warnock, on a very topical subject, "Whither the Post Office."

A.B.

Dundee Centre

Our program for 1966–67 ended on Friday, 7 April, with a most successful visit to the Standard Telephones and Cable, Ltd., factory (Crossbar Switching devision) at East Kilbride.

Next session it is hoped to hold some of our meetings in Perth or Montrose or both meanwhile, the committee wish to thank members for their continued support at meetings and visits.

R.T.L.

Edinburgh Centre

The past session has been a successful one; meetings have been well attended and our membership has increased by some 25 per cent. The program was briefly as follows.

October: Film show by Mr. Plenderleith.

November: Talk, "Electronic Exchange Type TXE2," by Mr. Haggart.

December: Visit to B.B.C. Television Studios in Glasgow.

January: Talk, "Planning," by Mr. W. Slater.

February: Talk, "The Crossbar Exchange System," by Mr. Spinks, Mr. Hall and Mr. Skinner.

March: Visit to Hamilton & Tait, Film Colour Processing laboratory.

March: Talk, "Telecommunications in Sweden," by Mr. T. Martin.

April: Talk, "P.O. Power Plant," by Mr. G. Chapman.

We completed the session with our annual general meeting and dinner at the Iona Hotel on 12 April. The following office bearers were elected. *Chairman:* Mr. J. A. Coghill; *Secretary:* Mr. G. A. K. Robertson; *Assistant Secretary:* Mr. M. K. Finland; *Treasurer:* Mr. R. Elder; *Librarian:* Mr. T. Woolard; *Auditors:* Mr. J. Fitter and Mr. R. Telford; *Committee:* Messrs. M. I. Collins, J. Alexander, L. McQuaite D. Stenhouse, R. Renton, I. Finlayson, I. Barkley and J. Duncan.

G.A.K.R.

Inverness Centre

The following meetings have been held.

February: A panel of local speakers dealt with subjects of local interest. Mr. J. Fraser, "WB 400"; Mr. C. Horn, "S.T.D. for U.A.X.s," and Mr. J. J. Laughlin, "C.R.M.X."

A large and representative audience which, including outstations receiving broadcast facilities, numbered 50, were treated to a most informative and varied evening.

March: A talk by Mr. MacDowell of the North of Scotland Hydro-Electric Board on "Power-System Earthing."

March: A visit by 16 members to the new pulp mill of Wiggins Teape Co., Ltd., at Fort William. Although the weather was not very good, Mr. J. R. Cairns, the visitors liaison officer provided the party with a most informative afternoon.

A.R.H.

Staff Changes

Promotions

Name	Region, etc.	Date
Deputy E.-in-C. to Senior Director of Engineering		
Merriman, J. H. H.	Eng. Dept.	6.4.67
Assistant E.-in-C. to Director of Engineering		
Calveley, C. E.	Eng. Dept.	6.4.67
Staff Engineer to Deputy Director of Engineering		
Wray, D.	Eng. Dept.	6.4.67
Regional Engineer to Chief Regional Engineer		
Morgan, T. J.	Eng. Dept.	17.4.67
Assistant Staff Engineer to Staff Engineer		
Billen, J. C.	Eng. Dept.	6.4.67
Scowen, F.	Eng. Dept.	14.2.67
Area Engineer to Assistant Staff Engineer		
Mayne, R. T.	S.E. Reg. to Eng. Dept.	11.1.67
Senior Executive Engineer to Assistant Staff Engineer		
Ravenscroft, I. A.	Eng. Dept.	11.1.67
Holdon, R.	Eng. Dept.	11.1.67
Ellis, D. R. B.	Eng. Dept.	19.1.67
Sewter, J. B.	Eng. Dept.	19.1.67
Belton, R. C.	Eng. Dept.	2.2.67
Hughes, C. J.	Eng. Dept.	13.2.67
Nunn, R. G. W.	Eng. Dept.	7.2.67
Martin, J.	Eng. Dept.	13.2.67
Stoate, K. W.	C.A.S./T.S.U.	1.3.67
Catt, L. H.	Eng. Dept.	9.3.67
Rubin, M. J.	E.T.E. to Eng. Dept.	10.3.67
Benson, D. L.	Eng. Dept.	10.3.67
Holt, J. B.	Eng. Dept.	13.2.67
Area Engineer to Regional Engineer		
Wadeson, D. E.	L.T. Reg.	11.1.67
Berresford, B. H.	Mid. Reg.	26.1.67
Bidgood, D. F.	S.W. Reg.	26.1.67
Mansfield, P. M.	Scot.	19.1.67
Rolls, A.	Scot. to W.B.C.	15.3.67
Senior Executive Engineer to Deputy Principal		
Woolley, C. E.	Eng. Dept.	1.3.67
Area Engineer to Deputy Telephone Manager		
Hulcoop, G. J.	Mid. Reg. to W.B.C.	13.2.67
Senior Executive Engineer to Telephone Manager III		
Spurlock, K. E.	Eng Dept. to W.B.C.	1.2.67
Executive Engineer to Area Engineer		
McWitty, A. H.	Eng. Dept. to L.T. Reg.	2.1.67
Ferguson, A.	Scot.	2.1.67
Marshall, L. C.	L.T. Reg.	16.1.67
Pile, D. W.	E. Reg. to W.B.C.	2.1.67
Allan, M. W. J.	Scot.	30.1.67
Bell, N.	Eng. Dept. to L.T. Reg.	1.2.67
Tomlin, V.	Eng. Dept. to L.T. Reg.	1.2.67
Babb, H. G. G.	Mid. Reg.	9.3.67
Glover, P. A.	Mid. Reg.	9.3.67
Shipman, E.	N.E. Reg. to S.E. Reg.	13.3.67
Bartlett, D. L. G.	S.W. Reg.	23.3.67
Executive Engineer to Senior Executive Engineer		
Barrow, R. V.	Eng. Dept.	12.1.67
Gilham, M. P.	Eng. Dept.	12.1.67
Bennett, T. A.	Eng. Dept.	19.1.67
Easterbrook, B. J.	Eng. Dept.	17.1.67
Hepplestone, L.	Eng. Dept.	2.1.67
Hoskins, R. F.	Eng. Dept.	2.1.67
Carter, P. E.	L.T. Reg. to Scot.	19.1.67
Knight, A. V.	Eng. Dept. to Scot.	13.2.67
Fox, N.	Eng. Dept.	13.3.67
Cole, A. C.	Eng. Dept.	9.3.67
Brand, A. T.	Eng. Dept.	9.3.67
Baxter, B. W.	Eng. Dept.	9.3.67
Lisney, D. L.	Eng. Dept.	9.3.67
O'Dell, S. H. G.	Eng. Dept. to E. Reg.	20.3.67
Turnball, M. G.	Eng. Dept.	20.3.67
Makemson, A. A.	Eng. Dept. to L.T. Reg.	13.3.67
Bailey, K. G.	Eng. Dept. to Factories Dept.	20.3.67
Executive Engineer (Open Competition)		
Hill, P.	Eng. Dept.	2.1.67
Rattans, I. A. A.	Eng. Dept.	2.1.67
Richman, G. D.	Eng. Dept.	20.1.67
Assistant Executive Engineer to Executive Engineer		
Morley, B. L.	S.W. Reg. to H.C. Reg.	2.1.67
Virgin, R. M.	S.W. Reg.	14.12.66
Turton, R.	N.E. Reg.	24.1.67
Field, A. C.	S.W. Reg.	2.1.67
Reeves, L. F.	S.E. Reg.	24.1.67

Promotions—*continued*

Name	Region, etc.	Date
Allison, C.	N.E. Reg.	24.1.67
O'Neill, R. T.	E.T.E. to Eng. Dept.	9.1.67
Leckenby, G.	N.E. Reg.	14.12.66
Simpson, A. F.	Mid. Reg.	9.12.66
Shapley, D. H. E.	S.W. Reg. to E. Reg.	9.1.67
Webb, A. G.	Scot.	7.12.66
Reece, L. J.	Mid. Reg. to E. Reg.	9.1.67
Wood, H. E.	Mid. Reg.	9.12.66
Underhill, K. C.	Mid. Reg.	9.12.66
Boothroyd, E. A.	N.E. Reg.	11.1.67
Toll, E. C.	L.T. Reg.	9.1.67
Tolboys, P.	N.E. Reg.	11.1.67
Pike, D. J.	Eng. Dept.	16.1.67
Stocker, H. J.	L.T. Reg.	9.1.67
Chapman, J. R.	N.E. Reg. to Scot.	6.2.67
Linsley, N. O.	L.T. Reg.	24.1.67
Leith, W. F.	Scot.	27.2.67
Clark, S. J.	Eng. Dept.	21.2.67
Neill, K. D.	N.I.	24.2.67
Alton, K. D.	N.I.	24.2.67
Black, B. J.	E. Reg.	21.2.67
Williamson, H. M.	S.W. Reg.	24.2.67
Harvey, W. G.	Scot.	21.2.67
Lamberton, A. H.	L.T. Reg.	21.2.67
Baker, A. C.	L.T. Reg.	21.2.67
Trinnaman, A. J.	L.T. Reg.	21.2.67
Abson, G. J. R.	L.T. Reg.	21.2.67
Green, H. M.	L.T. Reg.	21.2.67
Burt, A. J.	L.T. Reg.	21.2.67
Elliott, D. A.	L.T. Reg.	21.2.67
Norton, H. C. W.	Eng. Dept.	21.2.67
Smale, I. W.	Mid. Reg.	24.2.67
Evans, E. A.	N.W. Reg.	27.2.67
Jenner, E. P.	S.E. Reg.	21.2.67
Chesser, J.	Eng. Dept. to T.S.U.	21.2.67
Skyner, J. P.	N.W. Reg.	27.2.67
Hutton, S. J.	Eng. Dept.	21.2.67
Howard, R. E.	L.T. Reg.	21.2.67
Robertson, R. H.	Eng. Dept.	21.2.67
Massey, A. W.	Eng. Dept.	21.2.67
Collins, R. F.	Eng. Dept.	21.2.67
Clements, K. F.	Eng. Dept. to T.S.U.	21.2.67
Senior, R. C.	Eng. Dept.	21.2.67
Wright, R. T.	Eng. Dept.	21.2.67
Smith, H. E.	Eng. Dept.	21.2.67
Doherty, M.	Eng. Dept.	21.2.67
Humphreys, S. F.	Eng. Dept.	27.2.67
Allmark, A. A.	Eng. Dept.	21.2.67
Reaves, E. W.	Eng. Dept.	21.2.67
New, R.	L.P. Reg. to T.S.U.	21.2.67
Wise, J. H.	Eng. Dept.	21.2.67
Craddock, N. W.	Eng. Dept.	21.2.67
Willis, G. J.	Eng. Dept.	21.2.67
Hathaway, H. A.	Eng. Dept.	21.2.67
Heath, G. S.	Eng. Dept. to T.S.U.	21.2.67
Picsing, J. E.	Eng. Dept.	21.2.67
Ward, S. A. L.	Eng. Dept.	21.2.67
Kendall, P. C.	Eng. Dept.	21.2.67
Wheatley, R. T.	E.T.E.	24.2.67
Howse, K. R.	Eng. Dept.	21.2.67
Wardle, R. M.	Eng. Dept.	23.2.67
Smith, G. W.	Eng. Dept.	21.2.67
Watson, E. A.	Eng. Dept.	21.2.67
Reynolds, A. St. J.	Eng. Dept.	21.2.67
Lander, A. C.	Eng. Dept.	21.2.67
Holligon, E. R.	Eng. Dept.	21.2.67
Kingdom, D. J.	Eng. Dept.	21.2.67
Tamblin, M. P.	Eng. Dept.	21.2.67
Westaway, H. E.	C.E.S.D. to Eng. Dept.	21.2.67
Sinclair, B. R.	E. Reg.	21.2.67
Caldwell, B. J.	N.W. Reg.	13.3.67
Claireaux, I. M.	Scot.	1.3.67
Martin, R. J.	Mid. Reg.	24.2.67
Sutherland, N. R.	Scot.	21.2.67
Farrell, F. C.	E. Reg. to Eng. Dept.	20.3.67
Handley, L. B.	Mid. Reg.	24.2.67
Murdoch, J.	N.W. Reg.	20.3.67
Manuel, W. H.	L.T. Reg.	6.3.67
Thorpe, T. W.	L.T. Reg.	21.2.67
Browne, V. J.	L.T. Reg.	1.3.67
Smith, W. P.	L.T. Reg.	21.2.67
Searle, W. F.	Eng. Dept.	13.3.67
McCulloch, J. H.	Mid. Reg. to Eng. Dept.	28.3.67
Kift, B. H.	L.T. Reg. to Eng. Dept.	20.2.67
Redfern, F. C.	W.B.C.	24.2.67
Graham, A. S.	Eng. Dept. to L.T. Reg.	5.4.67
Inspector to Assistant Executive Engineer		
Muirhead, J. L.	Scot.	9.1.67
Butler, H. E.	S.W. Reg.	16.2.67
Graham, H.	N.E. Reg.	26.1.67
Turner, B. E.	N.E. Reg.	26.1.67
Smith, R. J.	N.E. Reg.	23.2.67
Stephenson, T. S.	N.E. Reg.	23.2.67
Langley, R.	N.E. Reg.	13.2.67
Furniss, L.	N.E. Reg.	23.2.67
Nichols, E.	N.E. Reg.	23.2.67
Birchmore, A. L.	L.T. Reg.	17.3.67

Promotions—*continued*

Name	Region, etc.	Date
Warman, H.	L.T. Reg.	17.3.67
Natt, V.	L.T. Reg.	17.3.67
Dewey, F. R.	L.T. Reg.	17.3.67
Burnham, J. T.	L.T. Reg.	17.3.67
Duckmanton, E. J.	L.T. Reg.	17.3.67
Olive, J. T. S.	L.T. Reg.	17.3.67
Stiles, E. J.	L.T. Reg.	17.3.67
Higgins, A. J.	L.T. Reg.	17.3.67
Amos, E. G.	L.T. Reg.	17.3.67
Harley, L. A.	L.T. Reg.	17.3.67
Hamilton, G. W.	L.T. Reg.	17.3.67
Harris, F. G.	L.T. Reg.	17.3.67
Kemp, J. A. C.	L.T. Reg.	17.3.67
Page, P. F. E.	L.T. Reg.	17.3.67
Dash, F. E.	L.T. Reg.	17.3.67
Leeds, P. E. A.	L.T. Reg.	17.3.67
Grant, J. W.	L.T. Reg.	17.3.67
Blacklee, A. E.	L.T. Reg.	17.3.67
Brown, L. W.	L.T. Reg.	17.3.67
Gatward, A. E.	L.T. Reg.	17.3.67
Bird, F. R. W.	L.T. Reg.	17.3.67
Jesson, P. D.	L.T. Reg.	17.3.67
Holmes, R. F.	L.T. Reg.	17.3.67
Weightman, H. C.	L.T. Reg.	17.3.67
Watson, W. H.	L.T. Reg.	17.3.67
Wigley, E. R.	L.T. Reg.	17.3.67
Leman, W. A. N.	L.T. Reg.	17.3.67
Foard, K.	L.T. Reg.	17.3.67
Technical Officer to Assistant Executive Engineer		
Howard, J. M.	Scot.	9.1.67
Duffy, F. E.	Scot.	31.1.67
Dobbie, W. G.	Scot.	5.12.66
Johnston, S.	Scot.	20.2.67
Knight, R. F.	E. Reg.	6.2.67
True, B. A.	N.E. Reg.	26.1.67
Gault, D. B.	N.E. Reg.	26.1.67
Stockdale, M. V.	N.E. Reg.	26.1.67
Heslop, R. G.	N.E. Reg.	26.1.67
Williamson, P.	N.E. Reg.	26.1.67
Hudson, S.	N.E. Reg.	26.1.67
Lofthouse, E.	N.E. Reg.	26.1.67
Herschell, K. J.	Mid. Reg.	3.2.67
Richardson, E. J.	Mid. Reg.	3.2.67
Mullis, G. E.	Mid. Reg.	3.2.67
Johnson, G. J.	Mid. Reg.	3.2.67
Hutty, B. D. F.	Eng. Dept.	27.2.67
Payne, J. L. T.	S.W. Reg.	21.2.67
Sleeman, F. R. G.	S.W. Reg.	21.2.67
Dobbs, W. A.	Mid. Reg.	16.3.67
Gray, A. O.	N.E. Reg.	23.2.67
Sparkes, E. E.	N.E. Reg.	6.3.67
Yardborough, J.	N.E. Reg.	23.2.67
Nevin, F. W.	N.E. Reg.	23.2.67
Slater, J. M.	N.E. Reg.	23.2.67
Dobbs, N. B.	N.E. Reg.	23.2.67
Jones, B.	N.E. Reg.	23.2.67
Preston, R.	N.E. Reg.	23.2.67
Morrison, P.	E. Reg.	26.3.67
Wagstaffe, W. F.	L.T. Reg.	17.3.67
Lardner, O. H.	L.T. Reg.	17.3.67
Chapman, R. H.	L.T. Reg.	17.3.67
Backshall, R. D.	L.T. Reg.	17.3.67
Oliver, A.	L.T. Reg.	17.3.67
Lye, J.	L.T. Reg.	17.3.67
Christian, J. R.	L.T. Reg.	17.3.67
Deller, B. W.	L.T. Reg.	17.3.67
Hollman, R. B.	L.T. Reg.	17.3.67
Young, D. L.	L.T. Reg.	17.3.67
Fanning, D. R.	L.T. Reg.	17.3.67
Cowdrey, C. E.	L.T. Reg.	17.3.67
Page, F. E.	L.T. Reg.	17.3.67
Rickeard, B. J.	L.T. Reg.	17.3.67
Catchpole, E. W.	L.T. Reg.	17.3.67
Clark, D. A.	L.T. Reg.	17.3.67
Huddy, R.	L.T. Reg.	17.3.67
Watson, G. T.	L.T. Reg.	17.3.67
Phillips, C. W.	L.T. Reg.	17.3.67
Cross, E. J.	L.T. Reg.	17.3.67
McCarthy, R. H.	L.T. Reg.	17.3.67
Sewell, J. H.	L.T. Reg.	17.3.67
Childs, T. A.	L.T. Reg.	29.3.67
Andrews, W. R.	L.T. Reg.	17.3.67
Coppola, V. G.	L.T. Reg.	17.3.67
Egleton, E. A.	L.T. Reg.	17.3.67
Batten, G. R. J.	L.T. Reg.	17.3.67
Mobbs, G. E. P.	L.T. Reg.	17.3.67
Saywell, E. C.	L.T. Reg.	17.3.67
Hardinges, R.	L.T. Reg.	17.3.67
Jackson, E. F.	L.T. Reg.	17.3.67
Ralph, G. D.	L.T. Reg.	17.3.67
Cooke, P. J.	L.T. Reg.	17.3.67
Pease, J. A.	L.T. Reg.	17.3.67
Swire, J. R.	L.T. Reg.	17.3.67
Burgoyne, L. F. W.	L.T. Reg.	17.3.67
Watson, J. G.	L.T. Reg.	17.3.67
Hussey, F. J.	L.T. Reg.	17.3.67
Williams, A. C.	L.T. Reg.	17.3.67

Promotions—*continued*

Name	Region, etc.	Date
Margetts, R. G.	L.T. Reg.	17.3.67
Shelton, J. E.	L.T. Reg.	17.3.67
Hogben, A. G.	L.T. Reg.	17.3.67
Harvey, W. H. A.	L.T. Reg.	17.3.67
Reader, W. R.	L.T. Reg.	17.3.67
Westall, A. F.	L.T. Reg.	17.3.67
Laing, P. D.	L.T. Reg.	17.3.67
Chandler, H. K.	L.T. Reg.	17.3.67
Powell, J. K.	L.T. Reg.	17.3.67
Evett, N. R.	L.T. Reg.	17.3.67
Hadwen, R. L.	L.T. Reg.	17.3.67
Newman, S. D.	L.T. Reg.	17.3.67
Richards, D. W.	L.T. Reg.	17.3.67
Harris, K. I.	L.T. Reg.	29.3.67
Rayner, A.	L.T. Reg.	17.3.67
Ellis, R. P.	L.T. Reg.	17.3.67
Higgins, G. W.	L.T. Reg.	17.3.67
Dixon, A. W.	L.T. Reg.	17.3.67
Moore, J. W.	L.T. Reg.	17.3.67
Wilkinson, T.	L.T. Reg.	17.3.67
Pearce, J. D.	L.T. Reg.	17.3.67
Burchell, A. P.	L.T. Reg.	17.3.67
Flynn, M. E.	L.T. Reg.	17.3.67
Smith, A. L.	L.T. Reg.	17.3.67
Williams, J. R.	L.T. Reg.	17.3.67
Mason, R. A.	L.T. Reg.	17.3.67
Gadsby, P. R.	L.T. Reg.	17.3.67
Brown, E. A.	L.T. Reg.	17.3.67
Davis, P. J.	L.T. Reg.	17.3.67
Owen, G.	L.T. Reg.	17.3.67
Buckle, E. G.	L.T. Reg.	17.3.67
Parker, E. J.	L.T. Reg.	17.3.67
Patterson, A. S.	L.T. Reg.	17.3.67
Bird, B. R.	L.T. Reg.	17.3.67
Skilton, A. C. S.	L.T. Reg.	17.3.67
Chamberlain, F. W. C.	L.T. Reg.	17.3.67
Chapman, J. S.	L.T. Reg.	17.3.67
Charles, D.	L.T. Reg.	17.3.67
Willcocks, H. C.	L.T. Reg.	17.3.67
Smith, R. C.	L.T. Reg.	17.3.67
Shiouxios, C. S.	L.T. Reg.	17.3.67
Chambers, A. G.	L.T. Reg.	17.3.67
Ward, L. R.	L.T. Reg.	17.3.67
Lewis, H. A.	L.T. Reg.	17.3.67
Wade, D. W.	L.T. Reg.	17.3.67
Barnes, E. D.	L.T. Reg.	17.3.67
Giles, E. W.	L.T. Reg.	17.3.67
Harpin, L. G.	L.T. Reg.	17.3.67
Bemley, R. A.	L.T. Reg.	17.3.67
Want, T. J.	L.T. Reg.	17.3.67
Sullivan, J.	L.T. Reg.	17.3.67
McTernan, J.	L.T. Reg.	17.3.67
Lee, E.	L.T. Reg.	17.3.67
Woolnough, D. J.	L.T. Reg.	17.3.67
Hobley, D. P. V.	L.T. Reg.	17.3.67
Wadlow, S. C.	L.T. Reg.	17.3.67
Vacani, D. P.	L.T. Reg.	17.3.67
Burridge, L. I.	L.T. Reg.	17.3.67
Gray, A. G.	L.T. Reg.	17.3.67
Palmer, J. H.	L.T. Reg.	17.3.67
Sheppard, H. A.	L.T. Reg.	17.3.67
Rowland, E. J.	L.T. Reg.	17.3.67
Salmon, D. E.	L.T. Reg.	17.3.67
Kingston, J. T.	L.T. Reg.	17.3.67
Mean, S.	L.T. Reg.	17.3.67
Harrington, A.	L.T. Reg.	17.3.67
Long, K. S.	L.T. Reg.	17.3.67
Warren, J. D.	L.T. Reg.	17.3.67
Baldock, P. K.	L.T. Reg.	17.3.67
Eade, J. C.	L.T. Reg.	17.3.67
Leonard, R. T.	L.T. Reg.	17.3.67
Veasey, J. L.	L.T. Reg.	17.3.67
Coldwell, A. H.	L.T. Reg.	17.3.67
Nixon, S. W.	L.T. Reg.	17.3.67
Powell, G. E.	L.T. Reg.	17.3.67
Dodd, A. J.	L.T. Reg.	17.3.67
Thame, B.	L.T. Reg.	17.3.67
Phillips, D.	L.T. Reg.	17.3.67
Davies, S. T.	L.T. Reg.	17.3.67
Oldacre, J. H.	L.T. Reg.	17.3.67
Cook, S. V.	L.T. Reg.	17.3.67
Hobbs, D. V.	L.T. Reg.	17.3.67
Morland, T. W.	L.T. Reg.	17.3.67
Robinson, D. E.	L.T. Reg.	17.3.67
Turner, J. G.	L.T. Reg.	17.3.67
Double, F. L.	L.T. Reg.	17.3.67
Hillier, G. R.	L.T. Reg.	17.3.67
Gwyer, C. A.	L.T. Reg.	17.3.67
Hearn, W. A.	L.T. Reg.	17.3.67
Gordon, C. E.	L.T. Reg.	17.3.67
Nathan, A. R.	L.T. Reg.	17.3.67
Wright, A. J.	L.T. Reg.	17.3.67
Pearl, J. E.	L.T. Reg.	17.3.67
Dell, A. J.	L.T. Reg.	17.3.67
Sales, J. W. A.	L.T. Reg.	17.3.67
Ellis, A. L.	L.T. Reg.	17.3.67
Rowan, L. M. H.	L.T. Reg.	17.3.67
Marshall, N.	L.T. Reg.	17.3.67
Wright, D. A.	L.T. Reg.	17.3.67
Sawyer, P. F.	L.T. Reg.	17.3.67
Sampson, J.	L.T. Reg.	17.3.67
Morgan, E. P.	L.T. Reg.	17.3.67
Ribbons, V. W.	L.T. Reg.	17.3.67

Promotions—*continued*

Name	Region, etc.	Date
Dwight, L. C.	L.T. Reg.	17.3.67
Coomes, W. E.	L.T. Reg.	17.3.67
Harvey, B. H.	L.T. Reg.	17.3.67
Sheldrick, B. G.	L.T. Reg.	17.3.67
Sturgis, D. V.	L.T. Reg.	17.3.67
Adams, G. T.	L.T. Reg.	17.3.67
Stockwell, D. F.	L.T. Reg.	17.3.67
Manktelow, E.	L.T. Reg.	17.3.67
Annesley, P.	L.T. Reg.	17.3.67
Hedges, B. N.	L.T. Reg.	17.3.67
Mallinder, D. E.	L.T. Reg.	17.3.67
Menzies, D. W.	L.T. Reg.	17.3.67
Stevens, P. H.	L.T. Reg.	17.3.67
Bennett, V. O.	L.T. Reg.	17.3.67
Beattie, A. S.	Scot.	14.3.67
Gillespie, R. R.	Scot.	14.3.67
Cohu, R. M.	S.W. Reg.	7.3.67
Burge, B. A.	S.W. Reg.	7.3.67
Sterry, H. J.	S.W. Reg.	7.3.67
Bush, P. G.	Mid. Reg.	1.3.67
Peirce, F. W.	L.T. Reg.	30.3.67
Laws, B. R.	L.T. Reg.	30.3.67
Edmonson, A.	N.I.	13.3.67
McAnce, J. J.	N.I.	6.3.67
Larkin, J. A.	L.T. Reg.	30.3.67
Hillier, G. J.	Eng. Dept.	30.3.67
Baldwin, B. J.	Eng. Dept.	30.3.67

Draughtsman to Assistant Executive Engineer

Name	Region, etc.	Date
Birbeck, R. H.	L.T. Reg.	17.3.67
Elston, R. E.	L.T. Reg.	17.3.67

Technical Officer to Inspector

Name	Region, etc.	Date
McKinstray, A. R.	Scot.	23.1.67

Senior Technician to Inspector

Name	Region, etc.	Date
Woods, H.	E. Reg.	6.2.67
Huggett, F.	E. Reg.	6.2.67
Hall, D.	N.W. Reg.	23.1.67
Hayward, L. C.	S.E. Reg.	29.3.67
Huckle, G. F. C.	Mid. Reg.	16.3.67

Technician I to Inspector

Name	Region, etc.	Date
Harris, W. G.	L.T. Reg.	21.2.67
Howe, A. M. L.	L.T. Reg.	21.2.67
Williams, H. E. J.	L.T. Reg.	21.2.67
Watson, A. G.	L.T. Reg.	21.2.67
Chapman, M.	L.T. Reg.	21.2.67
Johnson, E. G.	L.T. Reg.	21.2.67
Gaylor, K. W.	L.T. Reg.	21.2.67
Cross, J. W.	Mid. Reg.	3.2.67
Marsh, G. E.	S.W. Reg.	15.2.67
Humphries, P.	S.W. Reg.	15.2.67
Matthewson, J. S.	S.W. Reg.	15.2.67
Wilson, G. M.	Mid. Reg.	15.2.67
Noon, J. J.	L.P. Reg.	20.2.67
Cheeseman, T. J. P.	L.P. Reg.	20.2.67
Goold, G. R. W.	L.P. Reg.	20.2.67
Mayne, S. F.	L.P. Reg.	20.2.67
Keena, L. H.	L.P. Reg.	20.2.67
Durbin, L. S.	L.P. Reg.	20.2.67
Warner, R.	L.P. Reg.	20.2.67
Mackay, J.	S.W. Reg.	20.3.67
Chicken, J. W.	N.W. Reg.	24.2.67
Pullen, G. S.	L.P. Reg.	20.2.67
Lyford, L. M.	L.T. Reg.	20.3.67
Boswell, R. S.	L.P. Reg.	23.3.67
Shaw, H. C.	E. Reg.	29.3.67
Pike, K. J. E.	E. Reg.	29.3.67
Day, T. W.	Mid. Reg.	16.3.67

Principal Scientific Officer (Open Competition)

Name	Region, etc.	Date
Dyott, R. B.	Eng. Dept.	1.3.67

Senior Executive Engineer to Principal Scientific Officer

Name	Region, etc.	Date
Allnatt, J. W.	Eng. Dept.	23.2.67

Experimental Officer (Open Competition)

Name	Region, etc.	Date
Gerrard, G. A.	Eng. Dept.	13.2.67
McPherson, J. M.	Eng. Dept.	10.3.67

Scientific Officer (Open Competition)

Name	Region, etc.	Date
Deamer, J. M. (Miss)	Eng. Dept.	18.1.67
Ager, D. J.	Eng. Dept.	27.2.67

Assistant Experimental Officer (Open Competition)

Name	Region, etc.	Date
Robinson, P. A.	Eng. Dept.	26.1.67
Punchard, B. R.	Eng. Dept.	20.2.67
Marshall, J. F.	Eng. Dept.	10.3.67

Assistant (Scientific) (Open Competition)

Name	Region, etc.	Date
Ranasinghe, D. W.	Eng. Dept.	20.3.67

Assistant Regional Motor Transport Officer to Regional Motor Transport Officer

Name	Region, etc.	Date
North, H. E.	London Reg. to E. Reg.	30.1.67
Carruthers, W.	N.W. Reg. to N.E. Reg.	1.2.67

Promotions—*continued*

Technical Assistant to Assistant Regional Motor Transport Officer

Name	Region, etc.	Date
Pearce, V. I. C.	London Reg.	28.3.67

Technical Assistant to Motor Transport Officer III

Name	Region, etc.	Date
Crombie, D. B.	Eng. Dept.	28.3.67

Leading Draughtsman to Senior Draughtsman

Name	Region, etc.	Date
Gibson, B. A.	L.P. Reg. to Eng. Dept.	1.12.69

Draughtsman (Open Competition)

Name	Region, etc.	Date
Luff, C. D.	Eng. Dept.	3.1.67
Castell, L. J.	Eng. Dept.	20.1.67
Hockey, R. N.	Eng. Dept.	26.1.67
Howe, B.	Eng. Dept.	2.1.67
Monday, A. J. T.	Eng. Dept.	1.3.67

Executive Officer (Open Competition)

Name	Region, etc.	Date
Cary, C. R.	Eng. Dept.	19.1.67

Retirements and Resignations

Engineer in Chief

Name	Region, etc.	Date
Barron, D. A.	Eng. Dept.	5.4.67

Staff Engineer

Name	Region, etc.	Date
Franklin, R. H.	Eng. Dept.	9.2.67
Brockbank, R. A.	Eng. Dept.	13.3.67

Assistant Staff Engineer

Name	Region, etc.	Date
Pearson, A. W. C.	Eng. Dept.	9.2.67
Balcombe, F. G.	Eng. Dept.	8.3.67

Executive Engineer

Name	Region, etc.	Date
Griffin, S. J.	L.T. Reg.	31.1.67
Russel, J. H.	Scot.	16.1.67
Bartlett, B. B. *(Resigned)*	Mid. Reg.	31.12.66
Crompton, D. M. *(Resigned)*	Eng. Dept.	3.2.67
George, J. H.	E.T.E.	3.3.67
Smith, G. M.	L.T. Reg.	3.3.67
Broomfield, C. T.	Eng. Dept.	15.3.67
Baldwin, A. W. T.	L.T. Reg.	31.3.67
*Higgs, H. W.	Eng. Dept.	5.4.67
Coackley, R. *(Resigned)*	Eng. Dept.	23.3.67

Assistant Executive Engineer

Name	Region, etc.	Date
Thompson, C. F.	N.E. Reg.	8.2.67
Wilks, A. G.	Eng. Dept.	26.2.67
Smith, W. J.	E. Reg.	26.2.67
Lawrence, A. E.	S.E. Reg.	28.2.67
Cutts, W. J.	L.T. Reg.	28.2.67
Birrell, C. F.	Eng. Dept.	1.3.67
Bale, E. M.	W.B.C.	3.3.67
Wenman, H. E. A.	L.T. Reg.	3.3.67
Dickenson, I.	L.T. Reg.	5.3.67
Allerton, W. J. F.	E.T.E.	9.3.67
Northeast, S. G.	Mid. Reg.	11.3.67
Ellen, V. G.	L.T. Reg.	17.3.67
Sawyer, A. E.	L.T. Reg.	23.3.67
Williams, N. P.	S.W. Reg.	31.3.67
Bale, A. E. *(Resigned)*	Eng. Dept.	31.3.67
Hoy, W. *(Resigned)*	Eng. Dept.	31.3.67

Inspector

Name	Region, etc.	Date
Gatcum, A. W.	S.W. Reg.	10.2.67
Keys, P. H.	S.W. Reg.	5.3.67
Medford, R. C.	N.W. Reg.	31.3.67

Assistant (Scientific)

Name	Region, etc.	Date
Beken, J. D. *(Resigned)*	Eng. Dept.	10.3.67
Ani, I. N. *(Resigned)*	Eng. Dept.	31.3.67

Regional Motor Transport Officer

Name	Region, etc.	Date
Whitehurst, J. F.	N.E. Reg.	31.1.67

Leading Draughtsman

Name	Region, etc.	Date
Gemmell, A. G.	Eng. Dept.	1.1.67

Executive Officer

Name	Region, etc.	Date
Davis, G. E. (Miss)	Eng. Dept.	22.1.67

*Mr. H. W. Higgs is continuing as a disestablished officer in Eng. Dept.

Transfers

Telephone Manager II to Assistant Staff Engineer

Name	Region, etc.	Date
Lang, W. N. ..	E. Reg. to Eng. Dept.	9.1.67

Senior Executive Engineer

Name	Region, etc.	Date
Phillips, B.	Eng. Dept. to Ministry of Technology	1.1.67
Porter, J. E. ..	Libya to Mid. Reg. ..	19.1.67
Fudge, E. W. ..	Eng. Dept. to L.T. Reg.	16.1.67
Bellew, T. K. ..	Eng. Dept. to Jamaica	22.2.67
Halkes, G. R. H. ..	Eng. Dept. to L.T. Reg.	29.3.67
Foster, H. A. L. ..	Eng. Dept. to L.T. Reg.	20.3.67
Laver, K. S. ..	Eng. Dept. to L.T. Reg.	20.3.67

Executive Engineer

Name	Region, etc.	Date
Beeston, B.	L.T. Reg. to Nigeria ..	12.12.66
Matthew, J. D. ..	Eng. Dept. to Scot. ..	16.1.67
Peters, A.	Eng. Dept. to S.E. Reg.	23.1.67
Garside, R. ..	L.T. Reg. to Eng. Dept.	30.1.67
Goodwin, W. J. A. L.	E. Reg. to Ceylon ..	8.2.67
Redington, B. M. ..	Eng. Dept. to Mid. Reg.	6.3.67

Assistant Executive Engineer

Name	Region, etc.	Date
Petchey, R. F. ..	Eng. Dept. to S.W. Reg.	1.2.67

Transfers—*continued*

Name	Region, etc.	Date
Livingstone, D. W.	Eng. Dept. to Scot. ..	1.2.67
Clarke, J.	Eng. Dept. to Board of Trade	13.2.67
Maxwell, J. A. ..	Eng. Dept. to N.E. Reg.	13.3.67

Technical Assistant

Name	Region, etc.	Date
Jarrett, R. B. ..	Eng. Dept. to S.E. Reg.	13.2.67

Draughtsman

Name	Region, etc.	Date
Bailey, B. P. ..	Eng. Dept. to M.P.B.W.	9.1.67
Huxtable, A. G. ..	L.T. Reg. to Eng. Dept.	20.2.67

Executive Officer

Name	Region, etc.	Date
Brown, B. A. ..	Eng. Dept. to G.R.S.D.	1.2.67
Firth, J. H.	Eng. Dept. to Customs & Excise	1.11.66
Prescott, J. A. (Miss)	L.P. Reg. to Eng. Dept.	27.2.67

Deaths

Area Engineer

Name	Region, etc.	Date
Dunn, W. K. ..	N.W. Reg.	1.2.67

Assistant Executive Engineer

Name	Region, etc.	Date
Lockwood, C. ..	N.E. Reg.	3.2.67
Stubbs, D. L. ..	N.W. Reg.	25.2.67
Saunders, W. E. ..	Scot.	1.3.67
Johnston, J. A. ..	N.E. Reg.	7.3.67
Kinch, H. R. ..	E. Reg.	24.3.67

Inspector

Name	Region, etc.	Date
Kearney, J.† ..	Scot.	5.9.66

Draughtsman

Name	Region, etc.	Date
Robinson, A. D. ..	Eng. Dept.	26.1.67

†It is regretted that in the April 1967 issue Mr. J. Kearney was shown as having resigned.

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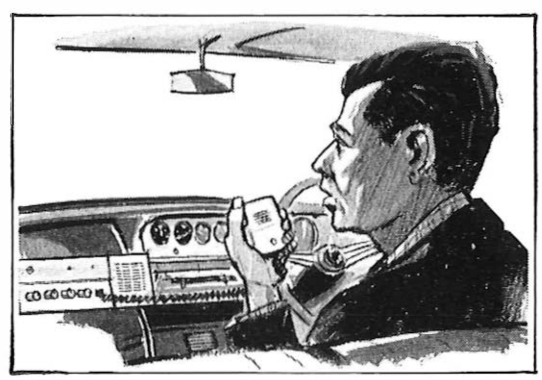

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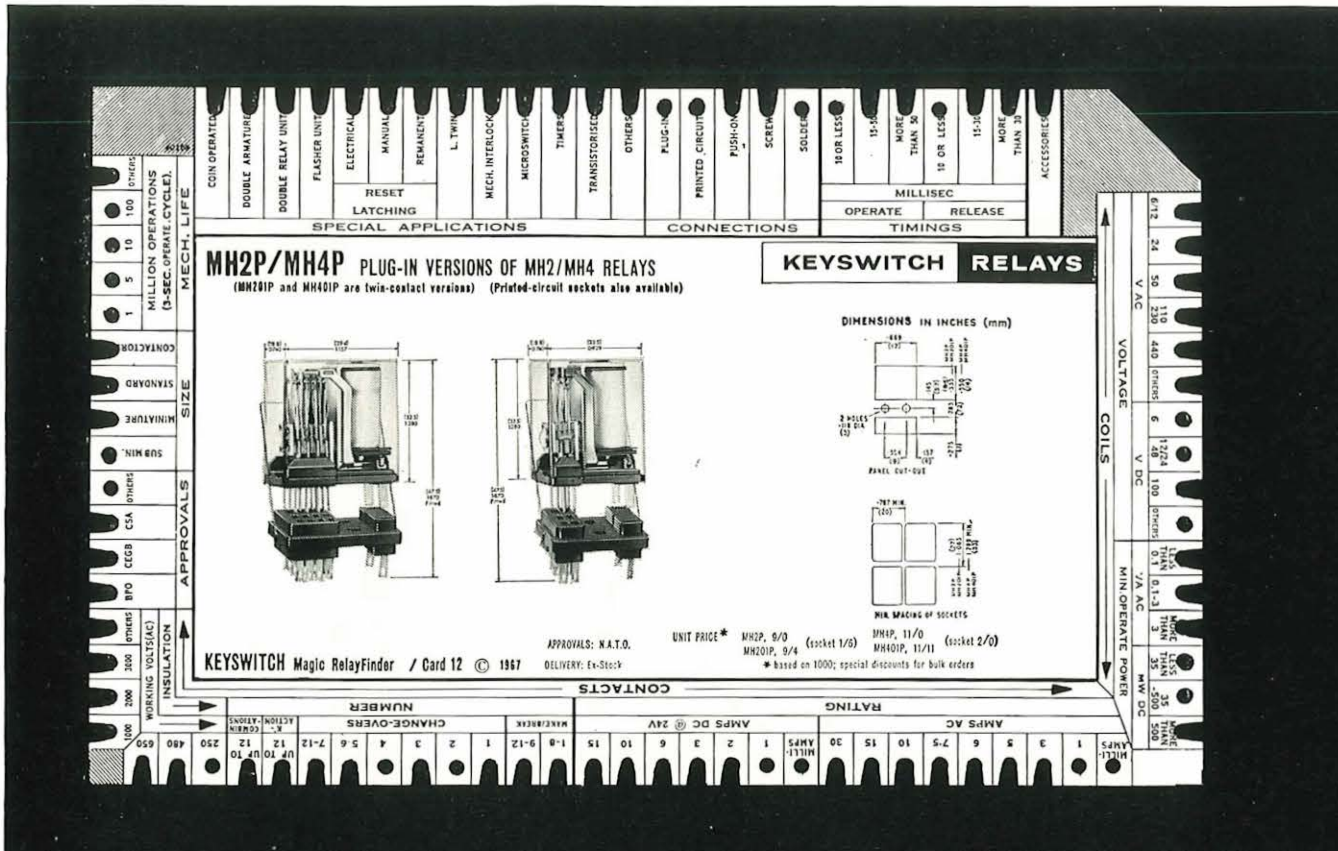
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DOUBLE RELAY UNIT
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ELECTRICAL
MANUAL
REMANENT
RESET
LATCHING
L. TWIN
MECH. INTERLOCK
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TIMERS
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PLUG-IN
PRINTED CIRCUIT
PUSH-ON
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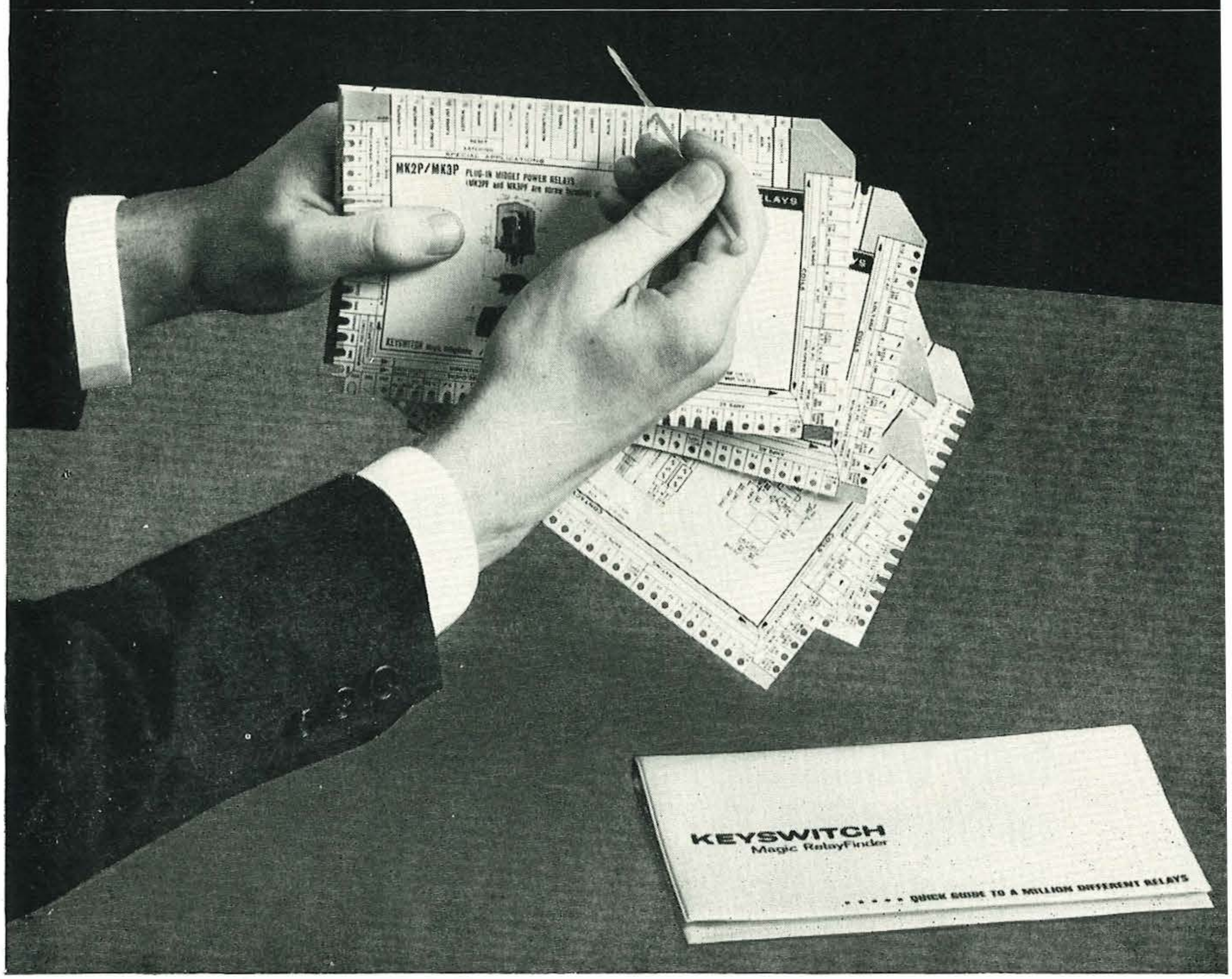
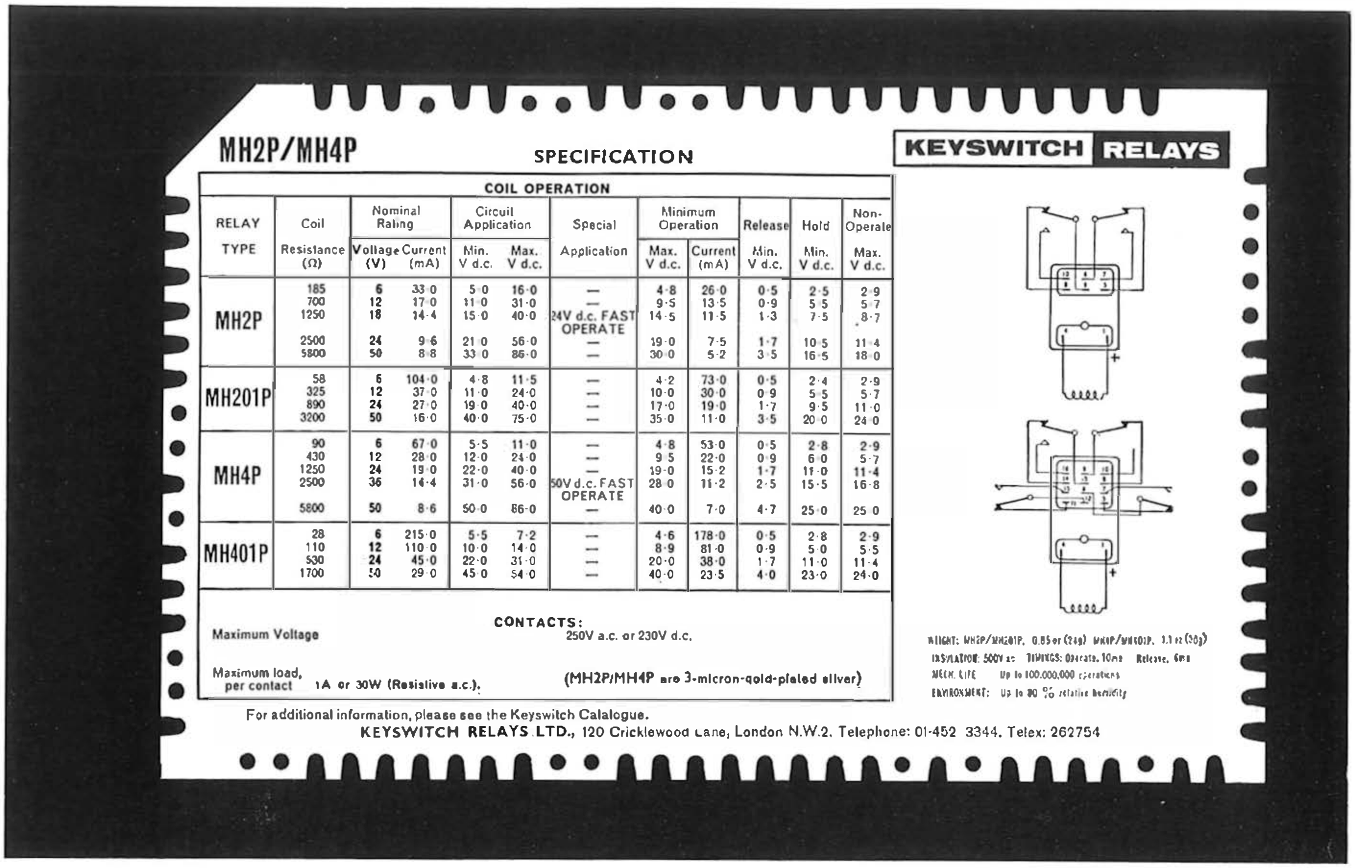
SOLDER
MILLISEC
OPERATE
RELEASE
ACCESSORIES
MILLION OPERATIONS (3-SEC. OPERATE CYCLE)
MECH. LIFE
CONTACTOR
STANDARD
MINIATURE
SUB MIN.
SIZE
BPO
CEGB
CSA
OTHERS
APPROVALS
WORKING VOLTS(AC)
INSULATION
VOLTAGE
COILS
V AC
V DC
MIN.OPERATE POWER
DIMENSIONS IN INCHES (mm)
PANEL CUT-OUT
MIN. SPACING OF SOCKETS
KEYSWITCH Magic RelayFinder / Card 12 © 1967
APPROVALS: N.A.T.O.
DELIVERY: Ex-Stock
UNIT PRICE* MH2P, 9/0 (socket 1/6) MH201P, 9/4
MH4P, 11/0 MH401P, 11/11 (socket 2/0)
* based on 1000; special discounts for bulk orders
CONTACTS
NUMBER
RATING
CHANGE-OVERS
AMPS DC @ 24V
AMPS AC


MK2P/MK3P PLUG-IN MIDGET POWER RELAYS
KEYSWITCH
Magic RelayFinder
QUICK GUIDE TO A MILLION DIFFERENT RELAYS



MH2P/MH4P

SPECIFICATION

KEYSWITCH RELAYS

COIL OPERATION

RELAY TYPE	Coil Resistance (Ω)	Nominal Rating Voltage (V)	Nominal Rating Current (mA)	Circuit Application Min. V d.c.	Circuit Application Max. V d.c.	Special Application	Minimum Operation Max. V d.c.	Minimum Operation Current (mA)	Release Min. V d.c.	Hold Min. V d.c.	Non-Operate Max. V d.c.
MH2P	185	6	33·0	5·0	16·0	—	4·8	26·0	0·5	2·5	2·9
	700	12	17·0	11·0	31·0	—	9·5	13·5	0·9	5·5	5·7
	1250	18	14·4	15·0	40·0	24V d.c. FAST OPERATE	14·5	11·5	1·3	7·5	8·7
	2500	24	9·6	21·0	56·0	—	19·0	7·5	1·7	10·5	11·4
	5800	50	8·8	33·0	86·0	—	30·0	5·2	3·5	16·5	18·0
MH201P	58	6	104·0	4·8	11·5	—	4·2	73·0	0·5	2·4	2·9
	325	12	37·0	11·0	24·0	—	10·0	30·0	0·9	5·5	5·7
	890	24	27·0	19·0	40·0	—	17·0	19·0	1·7	9·5	11·0
	3200	50	16·0	40·0	75·0	—	35·0	11·0	3·5	20·0	24·0
MH4P	90	6	67·0	5·5	11·0	—	4·8	53·0	0·5	2·8	2·9
	430	12	28·0	12·0	24·0	—	9·5	22·0	0·9	6·0	5·7
	1250	24	19·0	22·0	40·0	—	19·0	15·2	1·7	11·0	11·4
	2500	36	14·4	31·0	56·0	50V d.c. FAST OPERATE	28·0	11·2	2·5	15·5	16·8
	5800	50	8·6	50·0	86·0	—	40·0	7·0	4·7	25·0	25·0
MH401P	28	6	215·0	5·5	7·2	—	4·6	178·0	0·5	2·8	2·9
	110	12	110·0	10·0	14·0	—	8·9	81·0	0·9	5·0	5·5
	530	24	45·0	22·0	31·0	—	20·0	38·0	1·7	11·0	11·4
	1700	50	29·0	45·0	54·0	—	40·0	23·5	4·0	23·0	24·0

CONTACTS:

Maximum Voltage 250V a.c. or 230V d.c.

Maximum load, per contact 1A or 30W (Resistive a.c.). (MH2P/MH4P are 3-micron-gold-plated silver)

WEIGHT: MH2P/MH201P, 0.85 oz (24g) MH4P/MH401P, 1.1 oz (30g)
INSULATION: 500V a.c. TIMINGS: Operate, 10ms Release, 6ms
MECH. LIFE Up to 100,000,000 operations
ENVIRONMENT: Up to 90 % relative humidity

For additional information, please see the Keyswitch Catalogue.
KEYSWITCH RELAYS LTD., 120 Cricklewood Lane, London N.W.2. Telephone: 01-452 3344. Telex: 262754

the great relay muddle is over!

Anybody who ever needed a relay is only too familiar with The Great Relay Muddle. Finding the right relay has usually been strictly *needle-in-haystack*. There are so many different parameters involved in even the simplest type, you hardly knew where to start looking or when to stop.

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Each of these unique new cards carries the basic printed matter you'd find on the product data-sheet for a different Keyswitch relay model, *plus* information-retrieval coding that gives you quick access to over a million different relay configurations. A few jabs of the needle into the holes corresponding to whichever parameters concern you most, and up come just the specs, price, delivery and other data you need.

FREE

A Keyswitch Magic RelayFinder is yours free on request—including data-cards, needle, handy wallet and the automatic service that up-dates your data-cards as new and advanced Keyswitch relays are introduced. So ask for yours today, and put The Great Relay Muddle out of your life forever.

Keyswitch Magic RelayFinder

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Keyswitch Relays Ltd · 120 Cricklewood Lane · London NW2
Telephone: 01-452 3344 · Telex: 262754

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Marconi Instruments type 6600 Microwave Sweep Oscillator is a versatile and economical system for microwave measurements in the frequency range 250 MHz to 40 GHz. Emphasis has been placed on flexibility of controls and stability of output, and the single knob function selector in conjunction with a carefully organised group of front panel controls provides for ease of operation. The power supply is particularly noted for low noise and high stability. An extensive selection of interchangeable plug-in oscillators provide for the wide range of frequencies covered.

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Features include:—

- ✱ Stability.
- ✱ Plug-in Economy.
- ✱ Feedback Levelling with optional Diode Levelling.
- ✱ Wide Band Modulation Capabilities.
- ✱ Calibrated Symmetrical Sweep.

Sanders Sweep Oscillator type 6600 is manufactured under licence from MICRO-POWER Inc. Long Island City, U.S.A. Marconi Instruments Ltd, Sanders Division are the exclusive representatives for MICRO-POWER in the U.K. and non-exclusive representatives for the rest of the world (excluding U.S.A., Canada, Mexico, and France).

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Gunnels Wood Road, Stevenage, England.
Telephone: Stevenage 2311. Telex: 82159.
'An English Electric Company'

Sanders

Eddystone

Eddystone Radio specialize in the manufacture of communications receivers and have, over the years, gained a high worldwide reputation for the excellence of their products. The diverse range of models offered falls into various categories and naturally there are variations in the capabilities of one receiver compared to another, according to frequency range, price class and the applications envisaged, with the advantage that most requirements can be met.

The total frequency coverage encompassed is extremely wide—no less than 10 kHz at one end (in the 850/4) and 870 MHz at the other (in the 990S). Some receivers use valves, others transistors, and a high engineering standard is maintained throughout. Other common features are good performance, robust construction and reliability.

A typical example is the Eddystone 990S receiver, which is a recently introduced model for VHF/UHF operation. It can be used separately or as a complete panoramic receiver, in which form it is illustrated here.

Eddystone EPR29 panoramic receiver

A combination of the 990S receiver and the EP17R display unit, with the necessary accessories. The receiver is transistorized and gives high performance from 230 MHz to 870 MHz, divided into two ranges, with clear direct-reading scales. FM, video and AM modes of operation are catered for. The display unit operates on the IF output of the receiver and has a maximum scan of one MHz, with excellent resolution and other characteristics. The whole forms a versatile, compact equipment having many applications.

Comprehensive information from your Eddystone distributor or from: Eddystone Radio Limited, Eddystone Works, Alvechurch Road, Birmingham 31. Telephone Priory 2231. Telex 33708.

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The DENSO Anti-Corrosion Service will offer you expert advice on most corrosion problems, based on years of practical experience in all industries.

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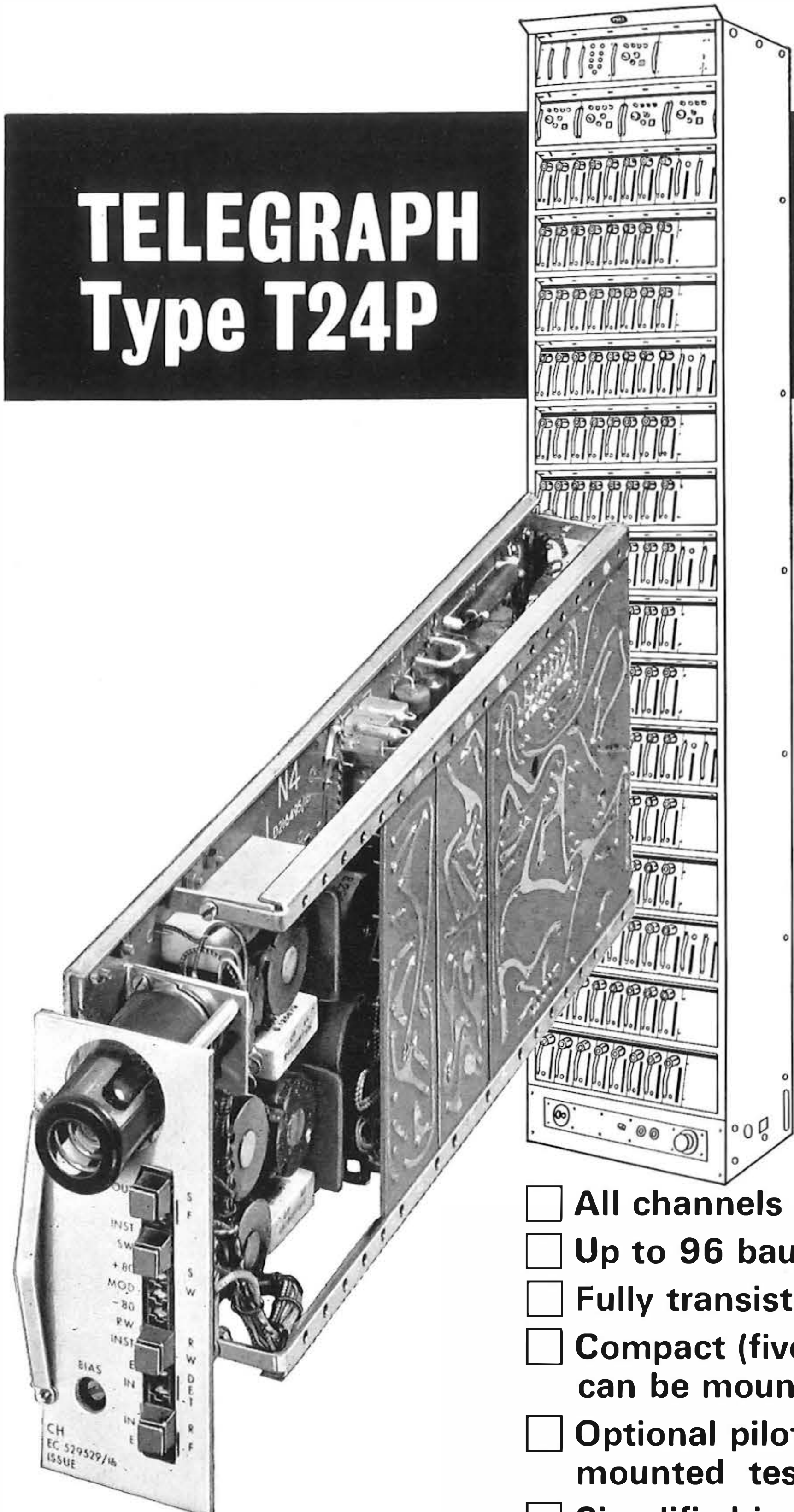

TMC Type T24P equipment embodies the latest design and construction techniques and is suitable for the provision of data or telegraph circuits.
The use of 62 Type equipment practice and the direct modulation of each channel allows the system to be readily extended by plug-in units from 1-24 channels, thus offering great flexibility of operation.
Write now for full details of TMC Type T24P equipment. It can be installed with confident expectation of years of trouble free service and increasing utilisation.

- ☐ **All channels directly modulated**
- ☐ **Up to 96 bauds low distortion working**
- ☐ **Fully transistorised**
- ☐ **Compact (five 24-channel terminals can be mounted on a 9 foot rack)**
- ☐ **Optional pilot control and rack mounted test equipment**
- ☐ **Simplified installation and maintenance**

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TMC is a registered trade mark
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The only portable Data Transmission test set

at £115

This portable test set has been designed to simplify the locating of faults in data transmission systems, modems or data link equipment. Developed under contract to the British Post Office, this equipment is being marketed commercially with their approval.

The tester is of simplified design and is intended for use by field engineers. It comprises a transmitter and receiver of d.c.signals in which the transmitter generates simple test patterns at any one of five rates, and the receiver measures the bias distortion of the received test signals, displaying the results on a sensitive centre-zero meter which is suitably calibrated. Switch keys are provided on the tester for controlling the interchange circuits of the modem under test, with indicator lamps to show the relevant response.

If you would like further details of this unique test set contact:

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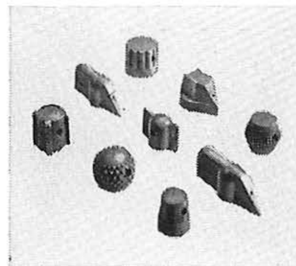
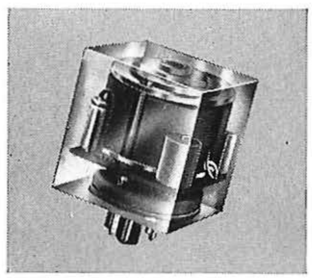
TREND ELECTRONICS LTD.

St. John's Works, Tylers Green,
Nr. High Wycombe, Bucks.
Telephone: Tylers Green 322.

WHITELEY

ELECTRICAL RADIO CO., LTD.





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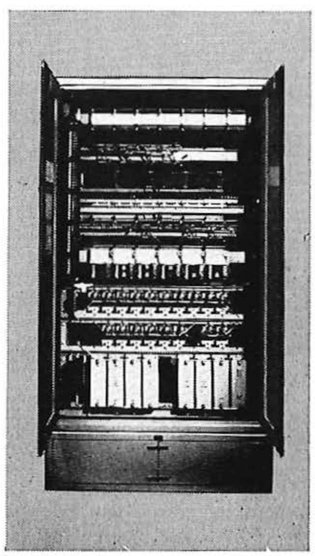

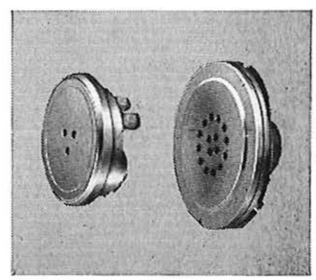

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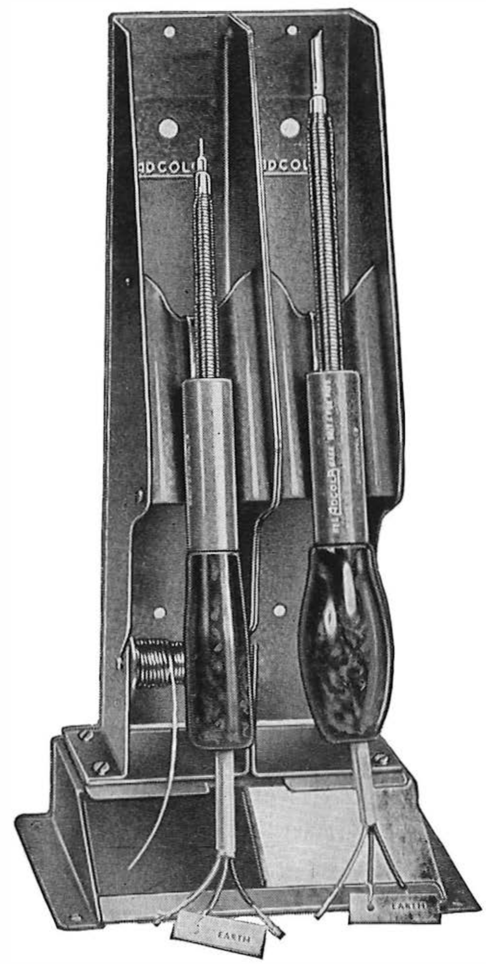

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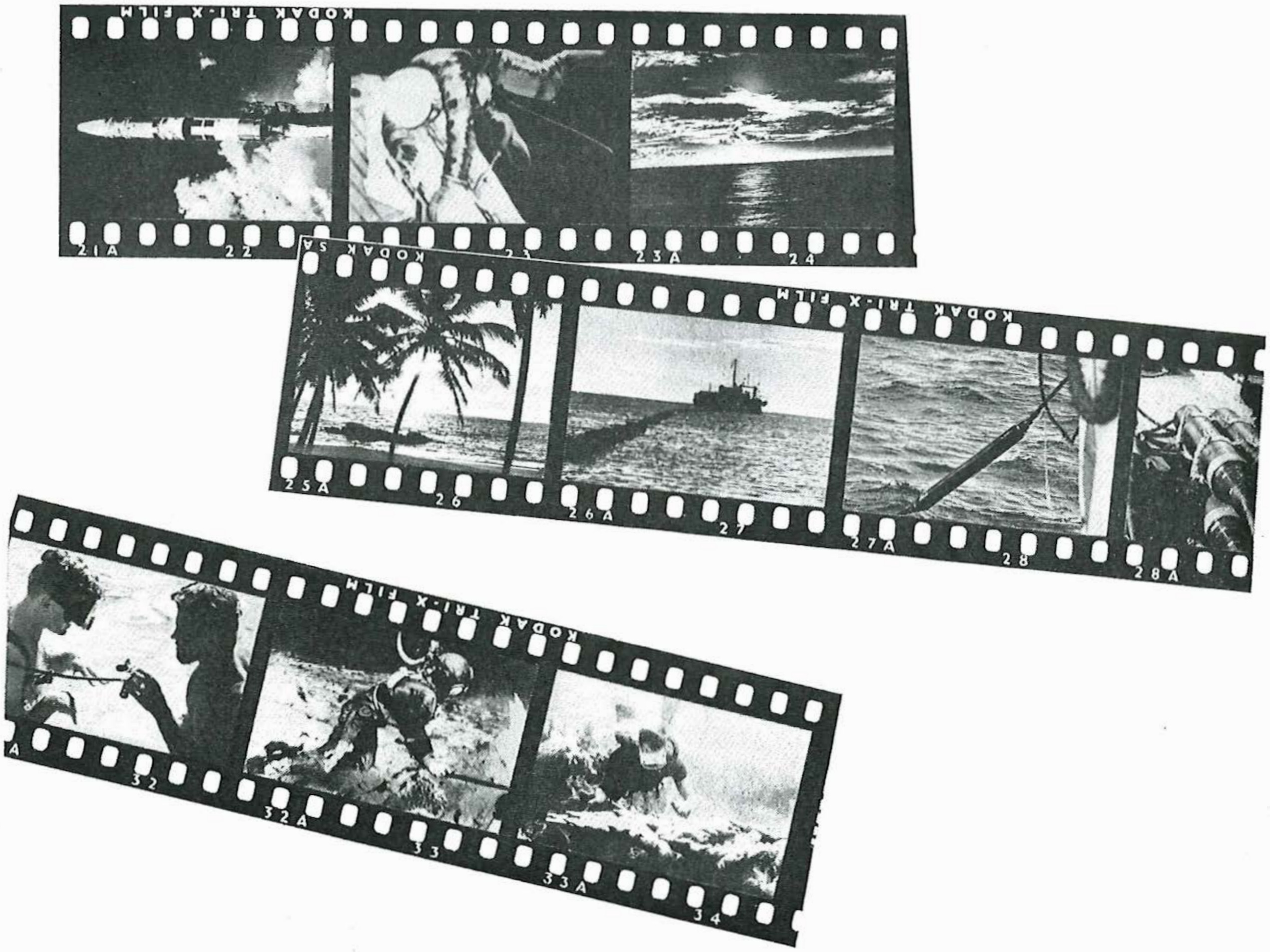

The demands of space exploration have taken STC to the bottom of the ocean

An STC submarine cable system is supplying a vital link in the United States Space Exploration Project.

The link, 760 miles long, carries communications between the Eastern Test Range Base, at Cape Kennedy, and Grand Turk Island in the Bahamas. Intermediate shore stations are located at Grand Bahama Island and San Salvador.

By the aid of amplification units, or repeaters, laid every 10 miles, the cable will carry 270 simultaneous telephone conversations—or high speed data equivalent—between Cape Kennedy and Grand Bahama Island. And to link Grand Bahama Island, San Salvador and Grand Turk, the repeaters will be laid every 30 miles to provide an 80 channel capacity for these sections.

Equipment for the project—repeaters, multiplexing terminal equipment, equalisers and cable—were designed and manufactured by STC factories in the U.K.

Once again, an STC activity becomes the focal point of international attention.

Standard Telephones and Cables Limited, Submarine Cable Division, Southampton New Docks, West Bay Road, Southampton, Hants. Telephone: Southampton 74751.

Submarine Repeater Division, Basildon, Essex. Telephone: Basildon 3040. Telex: 99101.

STC

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You can pick out the new Deltaphone with your eyes closed

So compact and lightweight is the new Deltaphone, you can lift it with one hand. Easily.

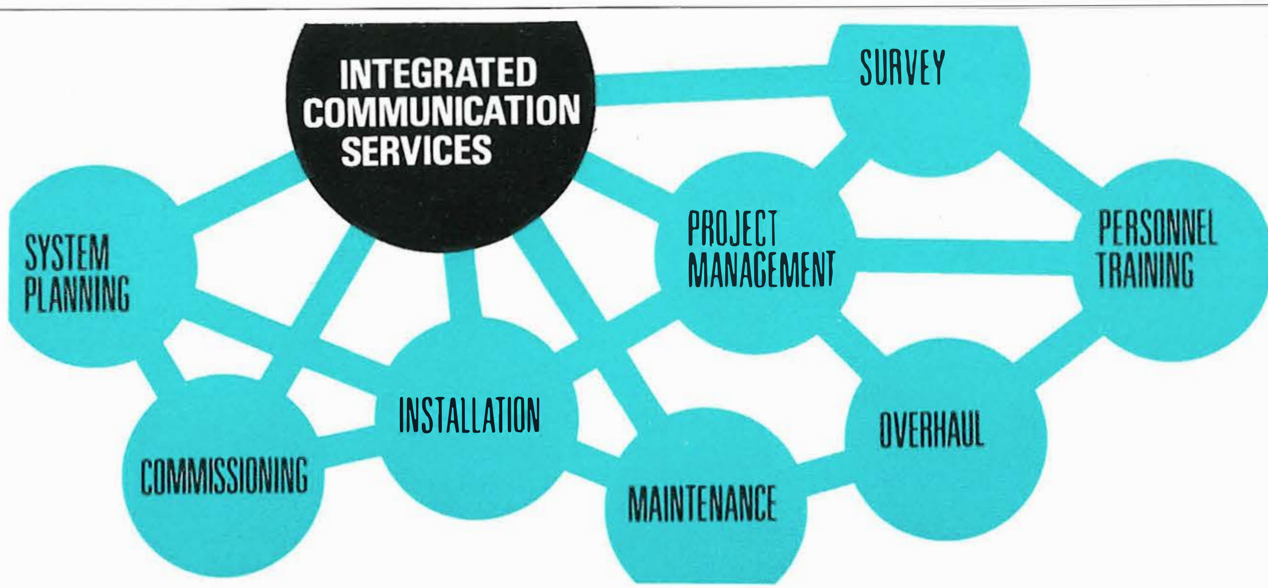
At 4·3 inches (109 mm), the body is only slightly wider than the dial. And the handset is less than half the weight of the more conventional variety—just 4 ounces (120 gms)!

When a call comes through on the Deltaphone, listen. It doesn't ring. It warbles discreetly. At any volume level you choose.

When it's silent, the Deltaphone still attracts attention. By its looks.

And high technical specifications match its elegant appearance. With the added attraction of restrained colours to choose from and optional dial illumination, the Deltaphone makes the ideal choice—wherever functional elegance is essential.

Standard Telephones and Cables Limited, Telephone Switching Group, Oakleigh Road, New Southgate, London, N.11.



Today, the many complex aspects of a communication problem can be dealt with under one roof.

By the Installation & Maintenance Services Division of the STC Transmission Group.

Backed by the world-wide resources of ITT, this Division offers world-wide capability in the provision of *integrated* communication systems.

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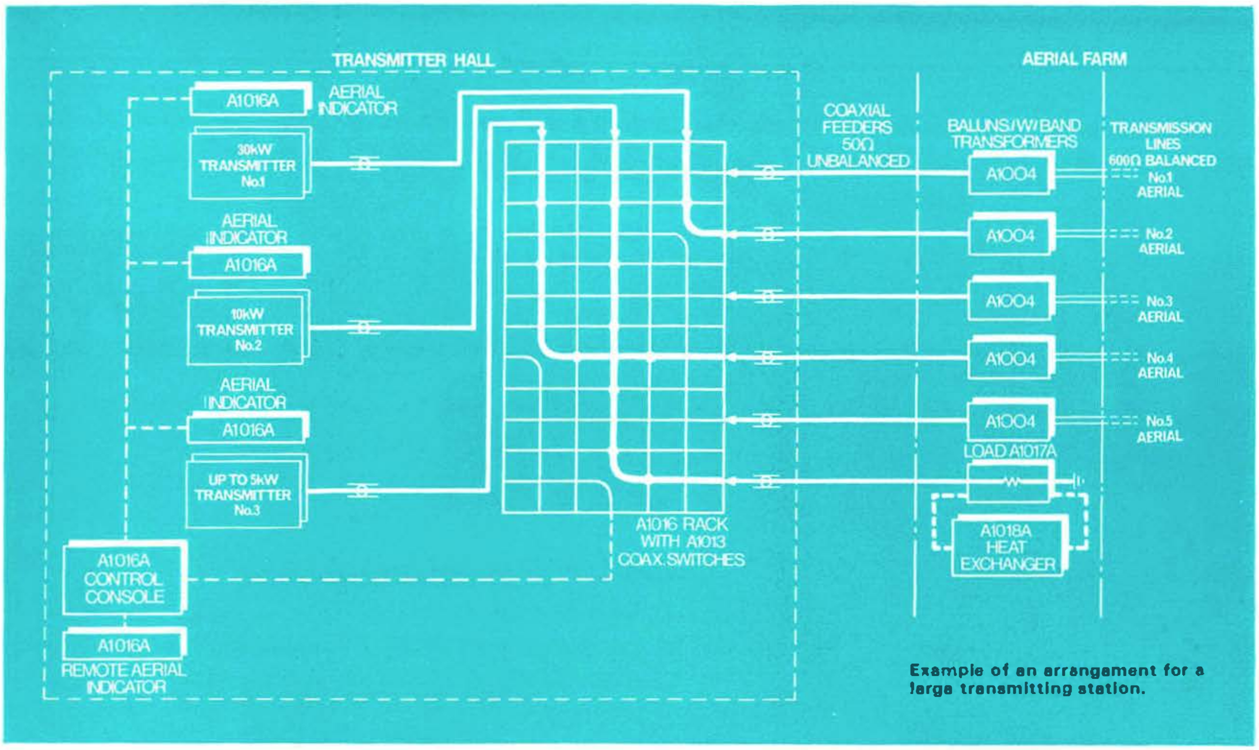


Coaxial Crossbar Switch Type A.1013B


Wideband Matching Unit (Balun) Type A.1004


5kW Wideband Aerial Matching Transformer Type A.1003

Aerial Ancillaries for STANFAST* transmitter systems

STANFAST* automatic tuning and supervisory techniques enable the modern transmitting station to be operated with a minimum of attendance. The aerial systems for use with these stations must, of necessity, embody components designed specifically for this form of operation. STC can supply a complete range of aerial ancillaries for this purpose.

- 5kW and 10kW wideband aerial matching transformers A.1003 and A.1012
- 20/30kW baluns A.1004
- Coaxial crossbar switch A.1013
- 2 and 4-way coaxial switches A.1014-A and A.1015-A
- Crossbar aerial exchange A.1016-A comprising switching rack, crossbar switches, control console and lamp indicators.

STANFAST* The STC concept of automated radio stations.

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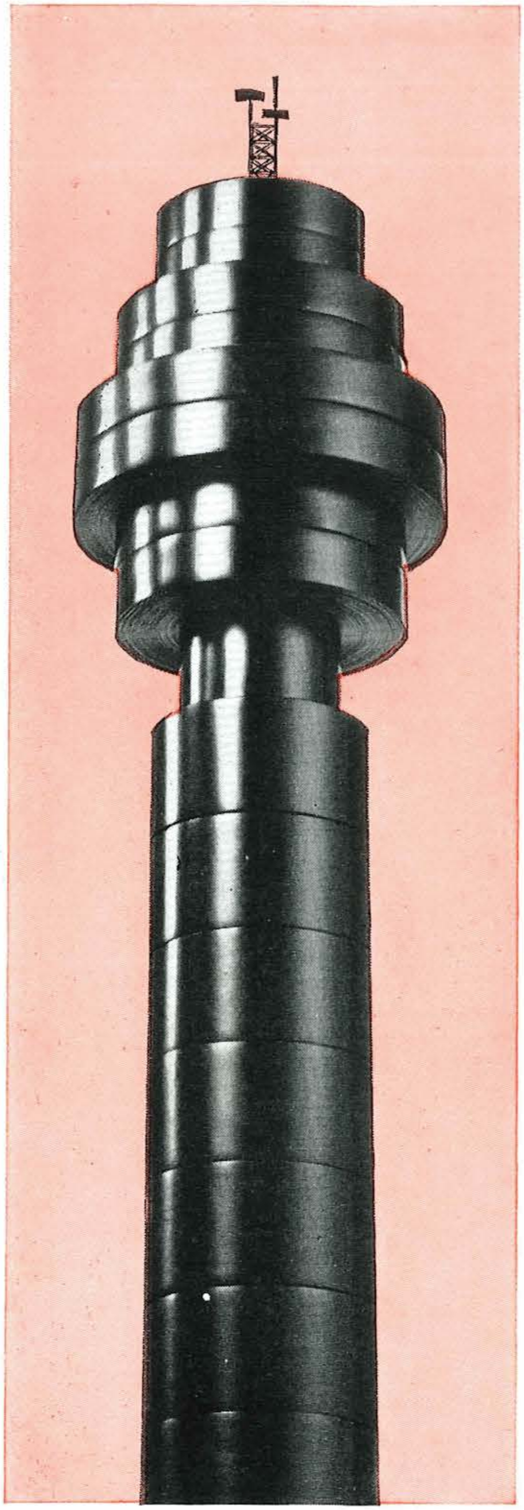
For further details, write, phone or telex Standard Telephones and Cables Limited, Radio Division, Oakleigh Road, New Southgate, London N.11. Telephone: ENTerprise 1234. Telex: 261912.



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ELECTRICAL TAPES TOWER

...above all other insulating tapes

Today's insulating techniques demand something better than ordinary general purpose insulating materials for cable wrapping and splicing, overwrapping junction boxes and similar applications. And something better means 'SELLOTAPE' POLYTHENE ELECTRICAL 1409. This outstanding 'Sellotape' product has many advantages:

- Clean to handle—it remains flexible even at low temperatures meaning easy application in any conditions.
- Plasticiser-free film and special long ageing adhesive prevent the tape from drying out and going brittle.
- Conformable, elastic film base ensures a moisture, chemical and oil proof seal.
- Compatible with polythene sheathed wires and cables.
- Available in a range of colours to B.S. 2746.

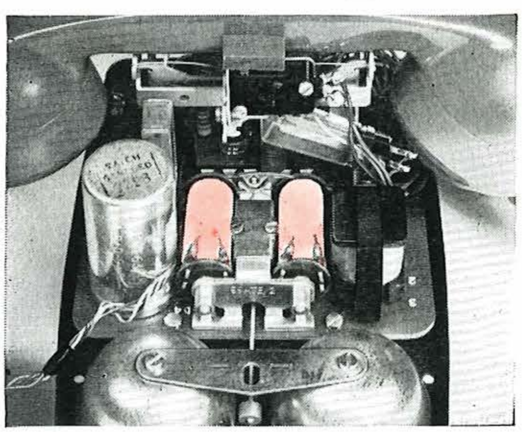
...above all other component finishing tapes

'SELLOTAPE' CREPED PAPER THERMOSETTING 2701 is today's finest product for finishing wire wound components, such as the ringer coil illustrated below.

Designed, like the handset, for life-time service, 2701 is a low cost, high grade product employing a specially purified paper coated with a thermosetting adhesive.

The tape is suitable for all impregnated components; since it withstands processing temperatures of 180°C and has good solvent resistance.

To find out more write for a copy of the 16-page 'Sellotape' booklet 'Electrical Taping' or discuss your requirements with one of the 'Sellotape' team of electrical tape specialists.



Sellotape products – a plus on every production line

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G.E.C. of England

G.E.C. (Telecommunications) Ltd., of Coventry, England is a world leader in the field of telecommunications. This large industrial complex, backed by the vast resources of its parent, The General Electric Co. Ltd. of England including a virile research and development organisation, is fully capable of undertaking complete contracts, including the manufacture and installation of a comprehensive range of telecommunications equipment, surveying, planning, maintenance, and the training of personnel.

International capability in telecommunications

G.E.C. can demonstrate the proven ability to undertake complete contracts on a 'turnkey' basis for the supply of completely integrated national telecommunication networks in many different parts of the world.

Transmission equipment with world-wide acceptance

One of the major contributions made by G.E.C. to the advancement of the world's communications has been in the field of transmission equipment. In particular, the introduction of semiconductored microwave radio equipment is an advance of fundamental importance. This equipment, with its inherent advantages of greatly improved reliability, lower maintenance cost and substantially reduced power consumption, enables the many advantages of solid-state techniques to be fully exploited.

Advanced design in 6000 MHz equipment

G.E.C. SHF broadband radio equipments Types SPO 5558 A and B are examples of the range of microwave equipments available. Both equipments are semiconductored, except for a travelling wave amplifier output stage providing a 10 watt output, and operate in the frequency band 5925 — 6425 MHz. The equipments conform to CCIR recommendations. The Type A version of the equipment can provide up to 1800 high quality speech circuits or 405, 525 or 625 — line high definition television in colour with one sound channel, or monochrome with up to four sound channels. The Type B version can provide up to 960 high quality speech circuits or 405, 525 or 625 — line colour or monochrome television with one sound channel. Both equipments are designed specifically for high-capacity, high-density long haul applications. One of the recent examples of the application of G.E.C. 6000 MHz equipment is described overleaf, followed by a specification summary.

G.E.C.

Takes telecommunications into tomorrow

G.E.C. (Telecommunications) Ltd.,
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G.E.C. of England

brings latest techniques to 6000 MHz equipment

Specification summary

S.H.F. Semiconductored Broadband Radio Relay Equipment SPO 5558 A & B

Radio Characteristics

Operating Frequencies:
5925 MHz — 6425 MHz
(C.C.I.R. recommended).

Transmitter Output:
10 watts nominal.

Transmitter Input:
0.3 volt r.m.s. (70 MHz).

Receiver Bandwidth:
± 20 MHz at 3db points.

Receiver Output:
0.5 volt r.m.s. (70 MHz).

I.F. Input and Output Impedances:
75 ohms.

Baseband Characteristics

(i) Telephony

Capacity:
(A) Up to 1800 channels.
(B) Up to 960 channels.

Baseband Frequency:
(A) 300 kHz to 8248 kHz.
(B) 60 kHz to 4028 kHz.

Continuity Pilot:
(A) 9023 kHz (B) 8500 kHz.

Gain Stability:
± 0.2 db over one day.
± 0.5 db over one month.

Pre-emphasis:
To C.C.I.R. Recommendations.

Mean Deviation:
(A) 140 kHz r.m.s. at channel test level.
(B) 200 kHz r.m.s. at channel test level.

(ii) Television

Capacity:
(A) One high definition TV colour + one sound channel or TV monochrome + four sound channels.
(B) One high definition TV colour + one sound channel or TV monochrome + one sound channel.

Video Input and Output Impedances:
75 ohms.

Video Input Level:
Nominal 1 volt peak-to-peak
(Adjustable ± 3 db relative to nominal).

Video Output Level:
Nominal 1 volt peak-to-peak
(Adjustable ± 3 db relative to nominal).

Pre-emphasis:
To C.C.I.R. Recommendations.

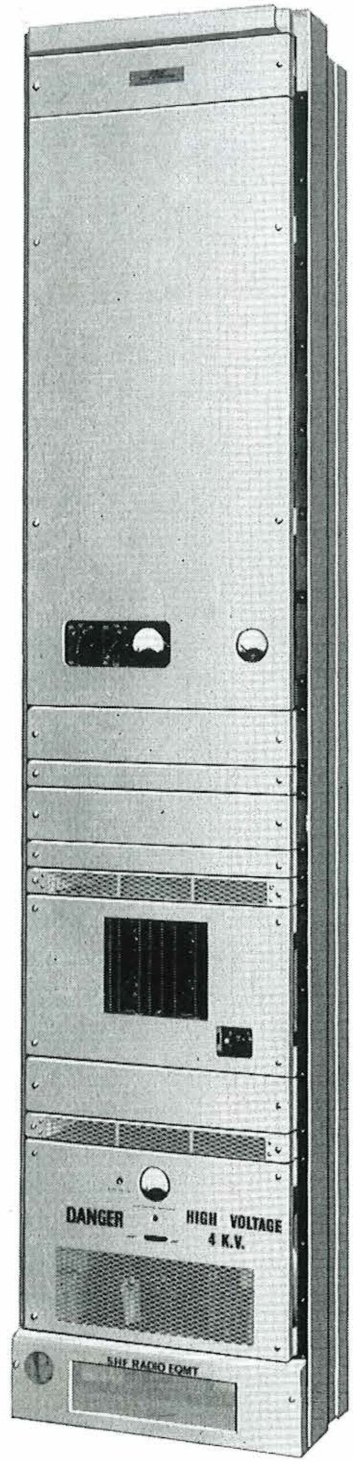
Sound Channel

Sub-carrier Frequencies:
(A) 7.00 MHz, 7.36 MHz, 7.74 MHz and 8.14 MHz. (B) 7.5 MHz.

Power Requirements

Supplies:
24 volts d.c. In-built d.c. voltage regulators cater for supply variations of 21.8 volts to 28.15 volts.

Equipment Consumptions:
SHF Radio Rack, comprising SHF transmitter/receiver, meter unit, associated power units and a 24V/AC inverter.
(A) 13 amps (B) 12 amps. Each pair duplicated modulators 2.5 amps.
Each pair duplicated demodulators 1.5 amps.



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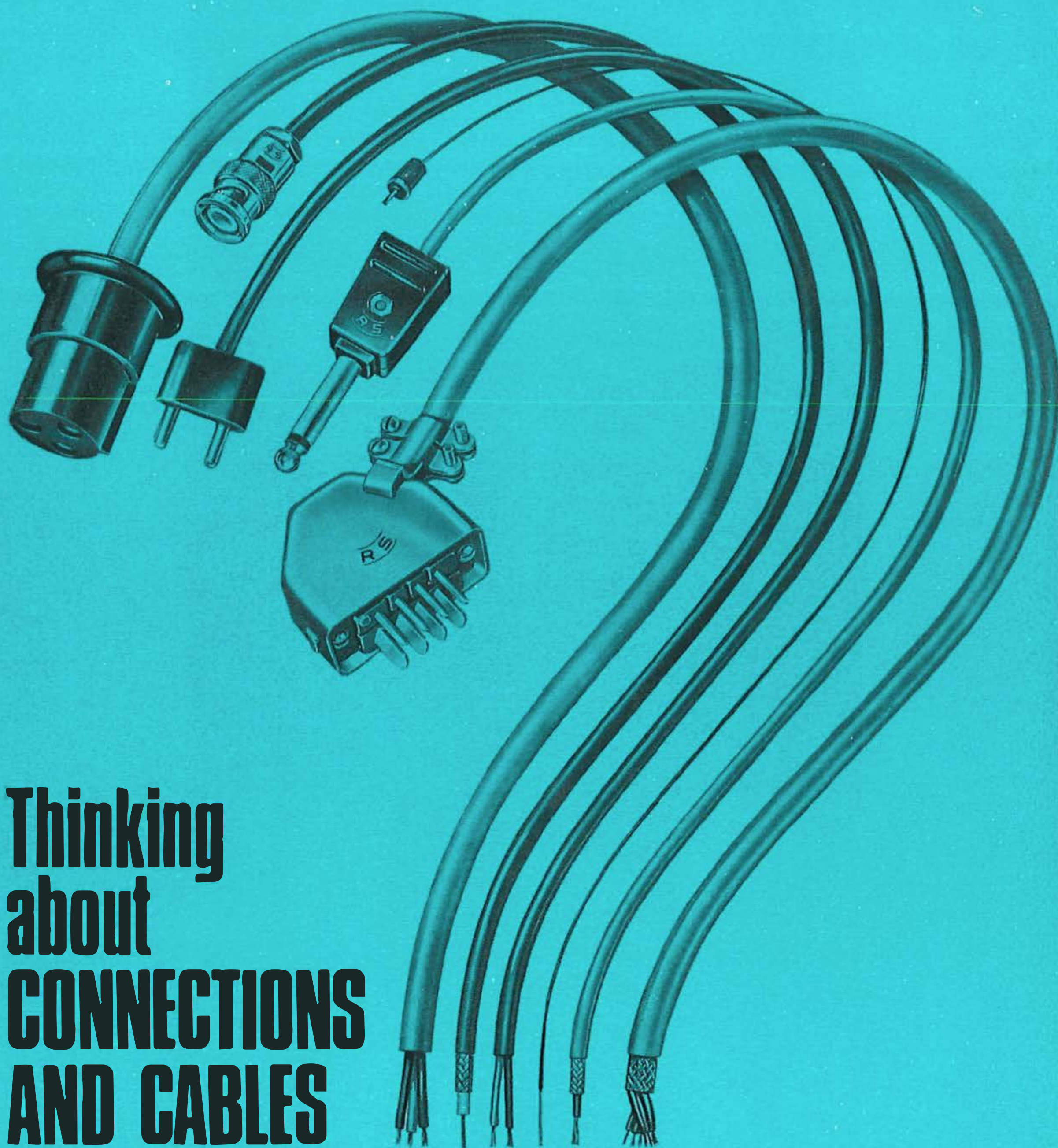

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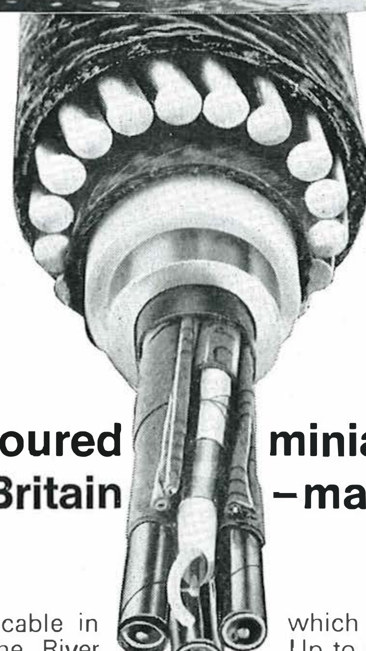

The first armoured miniature coaxial cable to be installed in Britain –made by Pirelli General

The first armoured miniature coaxial cable in the U.K., was laid recently across the River Tamar in the vicinity of the new road bridge. It was manufactured by Pirelli General and forms part of a 54 mile telecommunications link between Plymouth and Truro which has been installed by the Pirelli Construction Company, except for the river crossing which was handled by the General Post Office. Up to 960 conversations can be held over each two tubes, of only .174 inch diameter and the performance is well within CCITT limits for this type of circuit. This installation follows the first of these links (Salisbury-Bournemouth) which was completed in record time by the Pirelli Construction Company.

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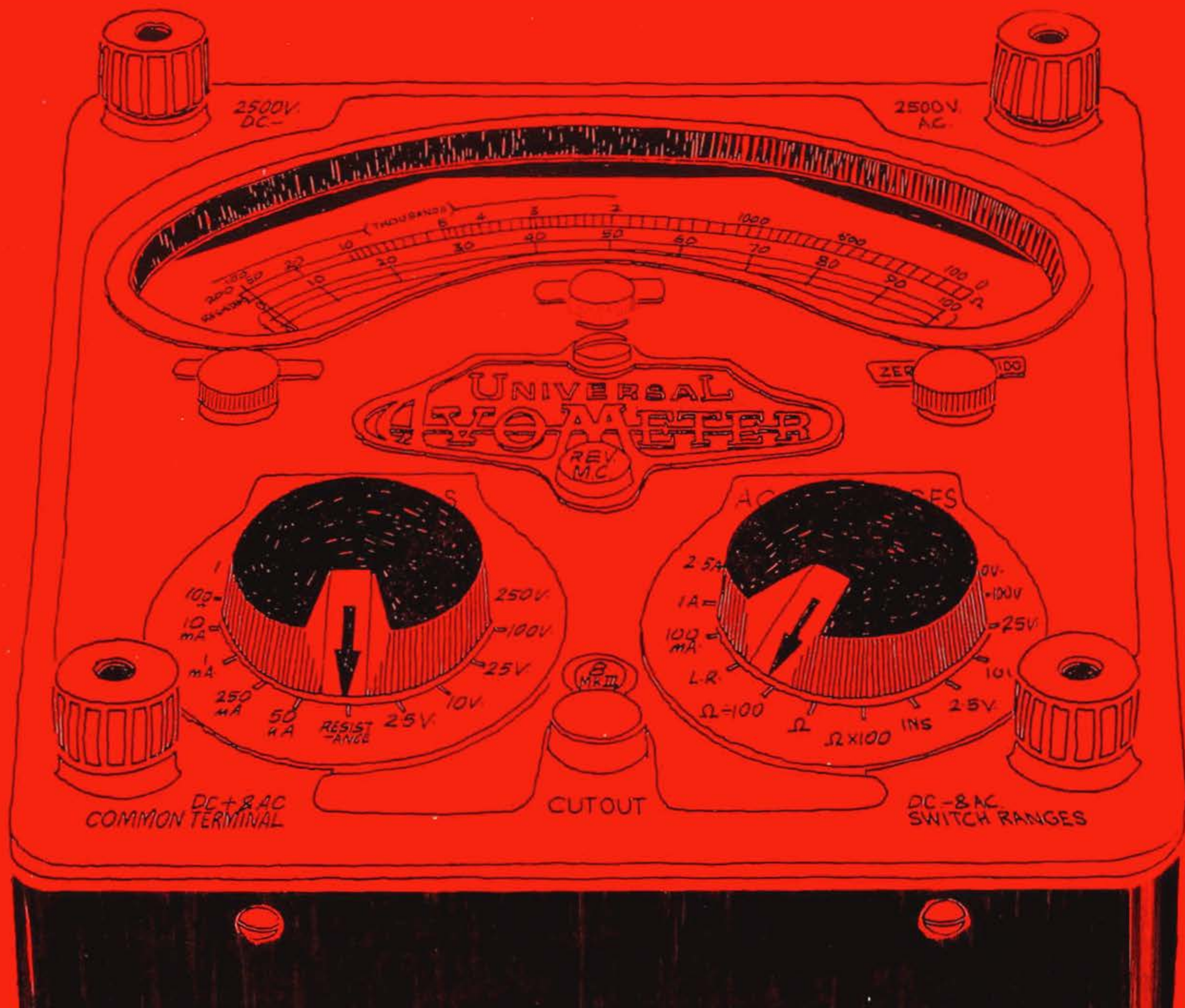

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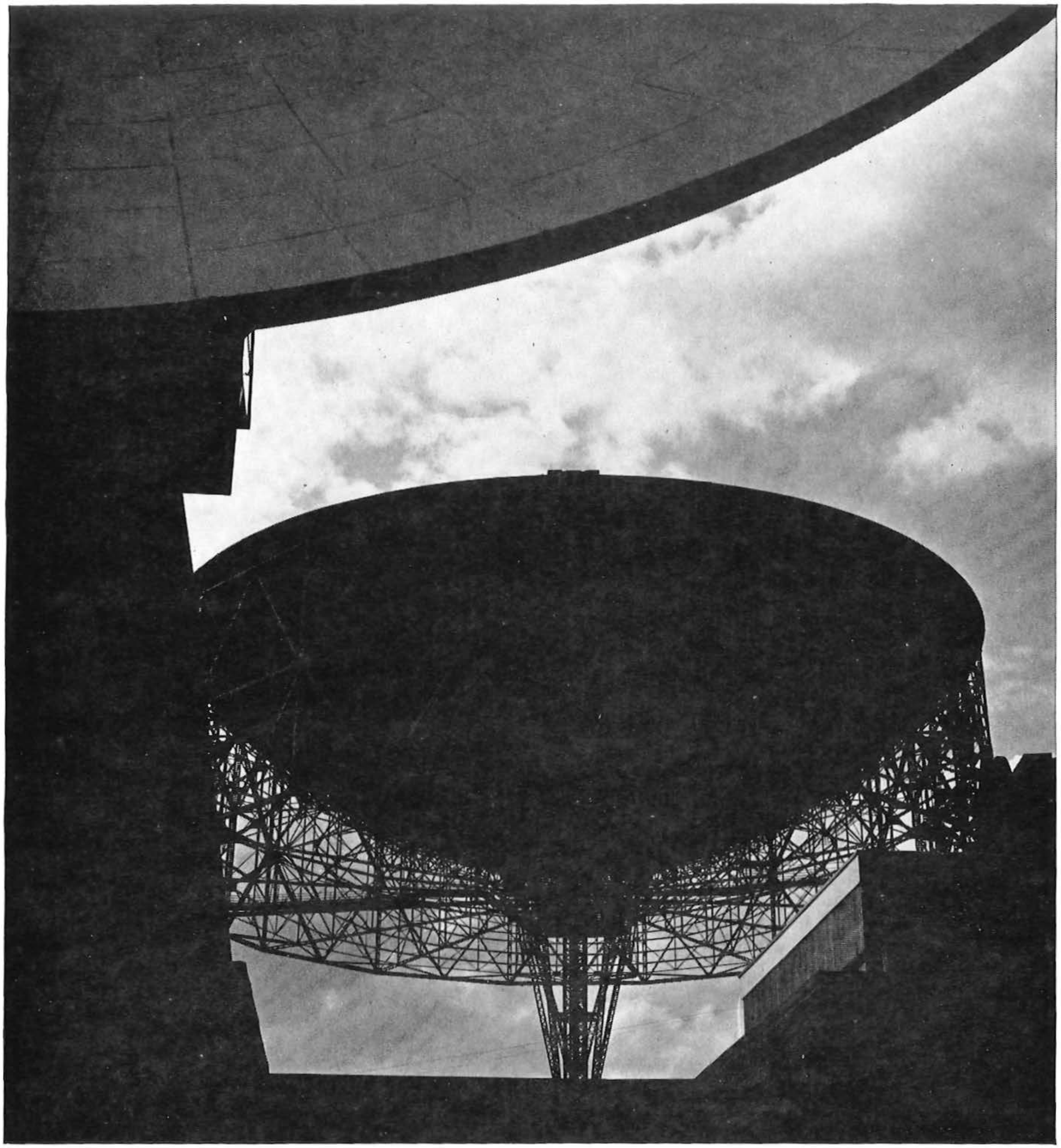
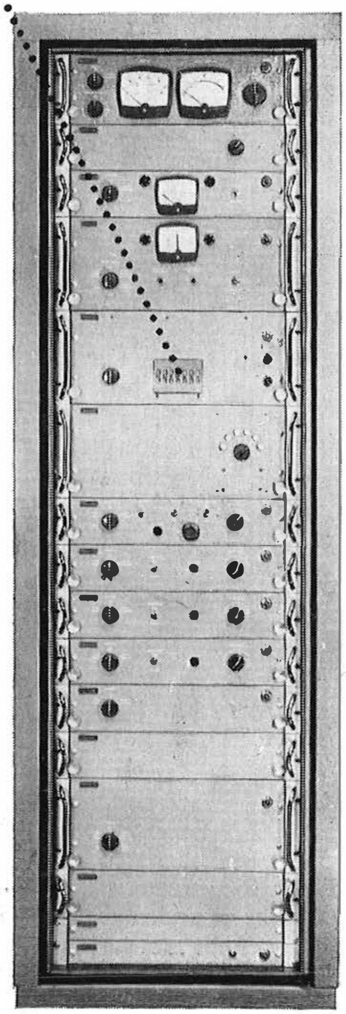


The British Post Office has selected the Plessey PVR800 Series HF receiver

for split-second automatic tuning to any one of millions of frequencies

The Plessey PVR800 provides the BPO with international point to point ISB radio services. The receivers have been re-engineered to conform with BPO Rack 51 practice.



Immediate and automatic tuning of the Plessey PVR800 Series receiver follows the selection of a new frequency on the synthesizer.
The receiver tunes to any one of 2.5 million frequencies between 3 and 27.5 Mc/s. Also six of these frequencies can be preselected on a memory unit and chosen by the turn of a single switch.

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The Plessey PVR800 Series brochure No. 6033 provides full details; please write for a copy to the address below.

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