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CONTENTS

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THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

Vol. 51 Part 1 APRIL 1958

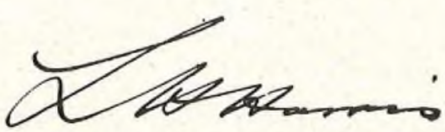
FOREWORD

This issue marks the beginning of the second half-century of the existence of our Journal. It has been published quarterly without a break since April 1908.

Quality of production has been high throughout and circulation has grown in line with the expansion of telecommunications. Its volumes record the history and progress of telecommunications engineering generally and in the Post Office in particular. Contemporary issues keep us in touch with developments and have proved of great value to the individual and to his work.

The authoritative nature of the Journal has been widely recognized and its circulation, which extends far beyond the members of the Institution of Post Office Electrical Engineers, both in the United Kingdom and overseas, is a measure of its educational and commercial worth.

Those responsible in the past can be proud of an achievement which augurs well for continuing success in the complex years to come.



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The Post Office Electrical Engineers' Journal

The history of the Journal is traced from the time of its introduction 50 years ago and details are given of some of the changes that have taken place.

INTRODUCTION

THE Institution of Post Office Electrical Engineers was formed in 1906 but it was not until April 1908 that the Institution's Journal, *The Post Office Electrical Engineers' Journal*, was first published, and it has been published quarterly since then without a break.

The affairs of the Journal are managed by a Board of Editors comprising a Chairman, a Managing Editor and two members, nominated by the Council of the Institution of Post Office Electrical Engineers, several co-opted members, two Assistant Editors and the Secretary-Treasurer.

Although the Journal is published for the Institution it is financially independent and, in fact, the Council of the Institution first sanctioned its publication on the definite understanding that it would be self-supporting, a condition that has been met except during and immediately following the First World War, when for five years grants of money from the Institution were necessary.

The report of Council for the year ending 31 March 1909 shows that the first year of publication of the Journal was a very successful one. It had been estimated that a minimum of 600 and a maximum of 2,000 copies of each issue might be sold and, so far as size was concerned, the utmost hoped for was a Journal of 64 pages with about four illustrations; in fact, for the four parts of the first volume the average number of pages in each part was 84, with nearly 30 illustrations, and 2,500 copies of the first part were printed and sold by the end of the year.

The subsequent history of the Journal can most conveniently be recorded by reviewing the changes in its format, contents and circulation.

FORMAT

The format of the Journal has undergone one radical change during the 50 years of publication. This was in 1927 when the size of the page was changed from royal octavo (about 10 in. by $6\frac{1}{4}$ in.) to demy quarto (slightly smaller than $11\frac{1}{4}$ in. by $8\frac{3}{4}$ in.), with two columns of type instead of one. There have, however, been a number of other quite important changes. Volumes 1 and 2 had a simple layout, but in Volume 3 a number of embellishments were added, notably headings interwoven with intricate designs (Fig. 1), and some of these were retained until Volume 26 (1933–34).

Increased production costs have necessitated the introduction of more-economical formats on several occasions. In October 1931 the size of type was reduced and the length of the columns was increased slightly, permitting 20 per cent more subject matter on each page. In 1934 further alterations were made and a smaller type was introduced for some features, such as District Notes. In 1951 the subject matter on each page was again increased, by about 15 per cent, by reducing the margins, the column width being changed from $3\frac{1}{8}$ in. to $3\frac{1}{2}$ in. and the length from 9 in. to $9\frac{3}{4}$ in.; a similar change had already been made to the Supplement, in July 1948.

Other alterations included changes in the design of the cover, and the three designs that have been used are reproduced in Fig. 2 to 4. The design in Fig. 2 continued to be used, with wider margins, when the size of the page was increased in 1927. In 1936 a synopsis was introduced at the beginning of each article, and the universal decimal classification of articles began in 1939.

The most recent changes are those introduced in this issue, which are intended to make the Journal easier to read and to improve its appearance, bringing it more into line with modern practice. Several changes of type face have been made, including a change in the type used for the main body of each article from Old Style (Roman) to Times. The headings of the articles have been rearranged and a number of other minor changes have been included. The change that first strikes the eye is that of the cover, which follows the modern trend towards simplicity and clean lines.

CONTENTS

The first volume was notable for including articles by five men who, in turn, held the post of Engineer-in-Chief to the British Post Office, and one who became Director-General of the Australian Posts and Telegraphs Department. The variety of subjects covered in the first volume can be seen by the titles appearing in its index, which include "The Design of Telephone and Telegraph Cables," "Common Battery Telephone Tranmission Systems," "Education and Training of Telegraph Engineers in France," "Pneumatic Tube Joints," "The Zones and the Trunk Lines" and "The Holding-Power of a Small Wall-Bracket." Features in the first issue which have been retained to this day were Notes and Comments, Institution Notes, and Staff Changes.

Since the Journal was first published it has been the policy of the Board of Editors that the Journal should contain articles recording developments in all aspects of telecommunications engineering and associated subjects, with particular reference to British Post Office practices, and that the size of the Journal should be limited only by the cost of production. As a result of this policy all the historic stages in the development of the Post Office engineering services since 1908 have been recorded in detail in the pages of the Journal, and when appropriate the Journal has been enlarged to do justice to the scope of these developments.

Thus, Volume 2 was notable in that Part 4 was greatly enlarged and included an article of over 50 pages describing in detail the 10,000-line common-battery exchange installed at Glasgow by the Peel-Conner Telephone Works, Ltd., who purchased 2,000 copies of that issue of the Journal. Volume 5 included a "double" number, Part 2, containing over 150 pages devoted mainly to automatic telephony and including a description of the Strowger automatic telephone exchange at Epsom, the first public automatic telephone exchange in the United Kingdom.

The end of the Second World War was marked by the publication of a special Victory Number in January 1946. That issue, which was larger than had been possible during the war, described some aspects of the work undertaken by Post Office engineers during the

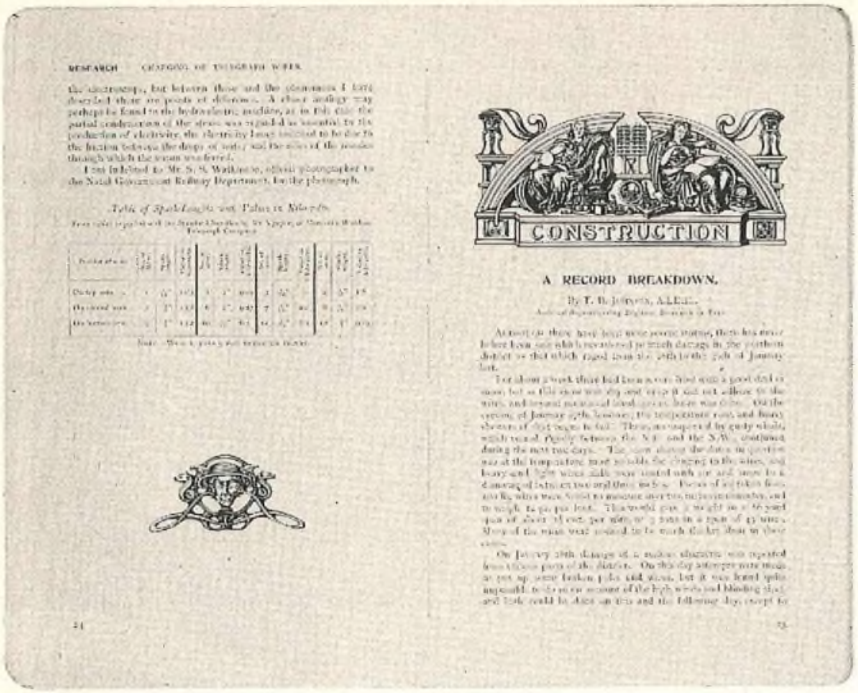

FIG. 1—PAGES 24 AND 25 OF VOLUME 3, PART 1, SHOWING INTRICATE DECORATIONS AT THE BEGINNING AND END OF ARTICLES

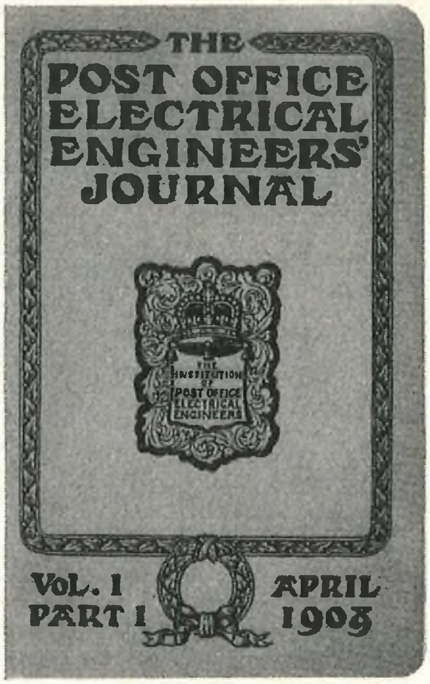

FIG. 2—COVER DESIGN FOR VOLUMES 1 TO 19 AND, WITH WIDER MARGINS, FOR VOLUMES 20 TO 26

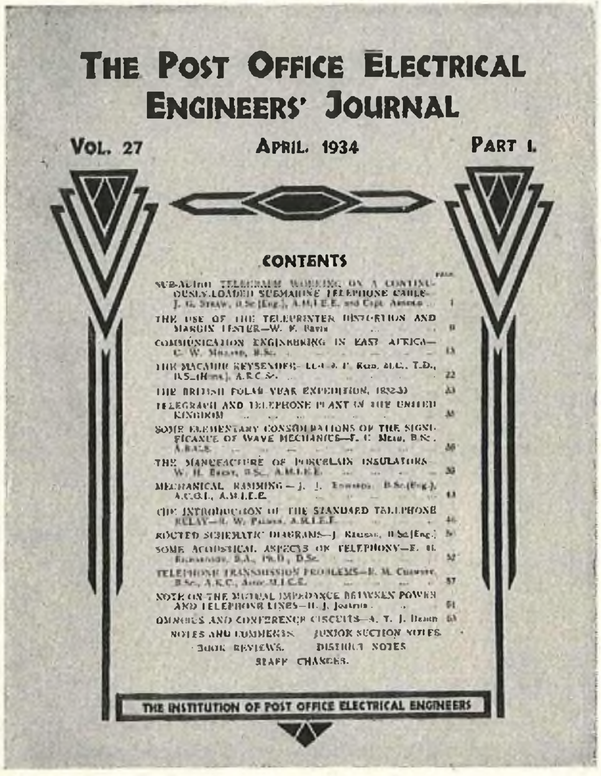

FIG. 3—COVER DESIGN FOR VOLUMES 27 TO 43

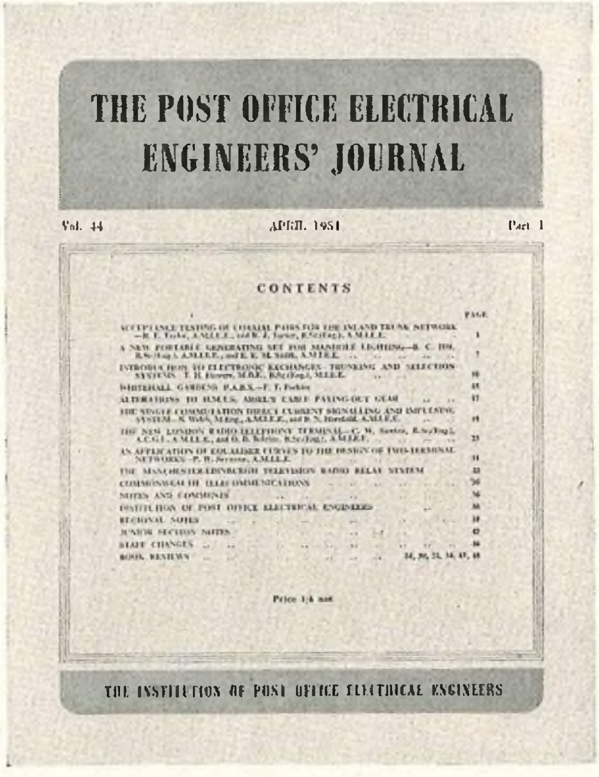

FIG. 4—COVER DESIGN FOR VOLUMES 44 TO 50

war in providing and maintaining communication services, particularly those for the armed forces and civil defence.

Then, in recent years, two special and very much enlarged numbers have been published. The first of these special numbers, the Jubilee Number, was published in October 1956 to celebrate the 50th anniversary of the foundation of the Institution of Post Office Electrical Engineers. It was about twice the normal size and contained articles tracing the history of the Institution from the time of its formation and describing the development of all phases of the engineering work of the Post

Office from the beginning of the century to the present day. The following issue, the Transatlantic Telephone Cable Number, was devoted entirely to articles describing all phases of the development, installation and testing of the transatlantic telephone cable system. It contained 188 pages, excluding the Supplement, and was about three times the normal size. With the Supplement it was about six times as large as the first number and was the largest ever published.

In July 1931 the Board of Editors embarked on a new venture in the shape of a Supplement to the Journal, containing model answers to the City and Guilds of London Institute examinations in telecommunications subjects. The Supplement was introduced with the needs of the younger readers mainly in mind, and it has proved to be very popular among them.

The expanding syllabus of the City and Guilds examinations has made it desirable to increase the size of the Supplement over the years and it now contains nearly 100 pages in each volume (four Supplements), compared with about 28 pages in the early years.

Because of alterations in the format of the Journal and Supplement the changes in the number of pages published are not a direct indication of the changes in the amount of subject matter. The changes in the total contents of the Journal can, however, be seen in Fig. 5, which shows the contents of each volume relative to the contents of Volume 1. It will be seen that, except during the two world wars, the size of the Journal has increased progressively and the present Journal is itself twice the size of the early Journals and in addition it includes a Supplement equal in size to the early Journals.

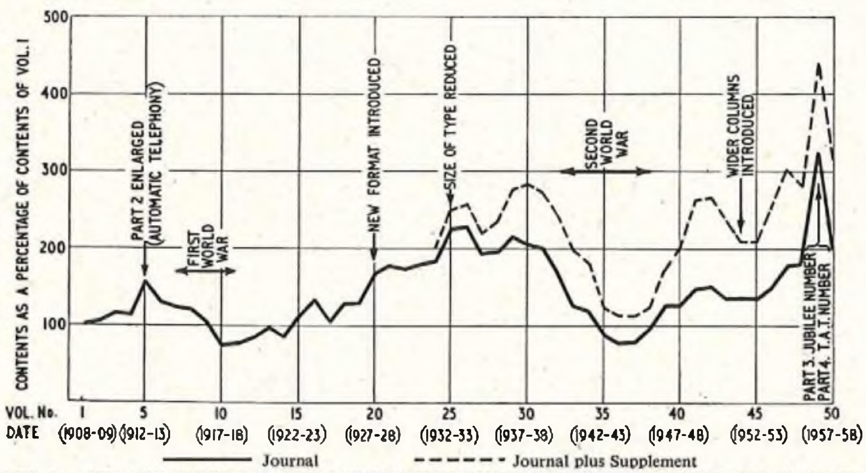

FIG. 5—AVERAGE CONTENTS PER PART OF EACH VOLUME, EXPRESSED AS A PERCENTAGE OF THE AVERAGE CONTENTS PER PART OF VOLUME 1

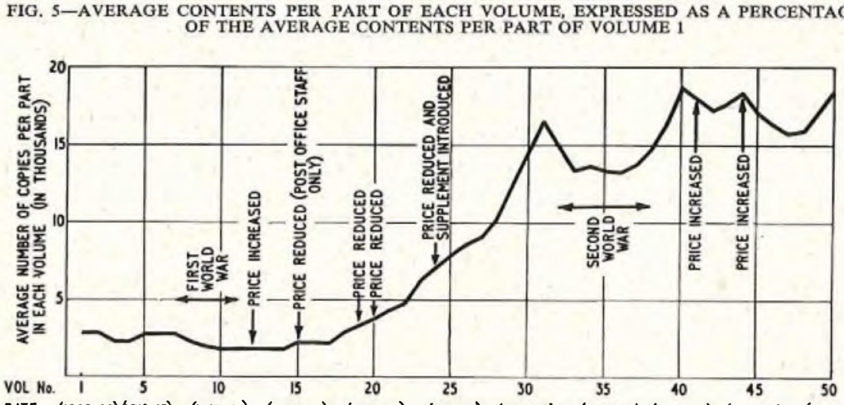

FIG. 6—AVERAGE NUMBER OF COPIES PER PART OF EACH VOLUME

CIRCULATION

The circulation of the Journal during the years has been affected both by restrictions imposed by the two wars and by changes in price. Referring to Fig. 6 it will be seen that during the first few years the circulation did not change appreciably, but during the First World War it fell somewhat. After the war the reduced circulation and increased cost of production necessitated increasing the price in October 1919 from 1s. to 2s. per copy for sales outside the Post Office, and then in April 1920 to 2s. to members of the Post Office.

The report on Volume 14 (1921–22) shows that for the first time in six years the Journal was again making a profit, which was due mainly to a fall in the cost of printing and an increase in the revenue from advertisements. As a consequence, the price to Post Office subscribers was reduced to 1s. 6d. The reduction in price stimulated sales but it was not until Volume 18 (1925–26), of which nearly 3,000 copies of each issue were printed, that the circulation exceeded the pre-war figure and it was possible for Volume 19 to reduce the price to 1s. 6d. per copy for sales outside the Post Office.

When the format was changed radically, in 1927, the saving in the cost of production allowed the price for a complete volume of four parts to be reduced to 5s. From then on the circulation rose steadily to over 6,000 copies of each issue, permitting a further reduction of price to 1s. per copy in 1931. At the same time, the Supplement was introduced and further stimulated the increase in circulation.

The period between the introduction of the new format and the beginning of the Second World War was one of great expansion for the Journal, the circulation increasing more than fourfold. The number of copies printed reached a peak for Volume 31 (1938–39), when an average of 16,575 copies of each part were printed.

The outbreak of war again saw a change in the fortunes of the Journal. Circulation fell, reaching 13,350 copies of each part in 1943–44, and restrictions in the use of paper and other factors resulted in the size of the Journal being progressively reduced, as shown in Fig. 5. The exigencies of war also resulted in delays in publication. Financial worries were few because the reduced cost of publication, due to the smaller size, more than offset the fall in revenue and quite substantial profits were made.

The end of the war did not see the end of the Journal's troubles; labour difficulties at the printer's works, delays in obtaining paper supplies when required, railway delays and power cuts made it difficult to publish the Journal on time. Nevertheless, circulation rose again, reaching the record total of an average of 18,575 copies of each part of Volume 40 (1947–48). Higher printing charges and increased cost of paper raised the cost of production and resulted, in 1946–47, in a large loss being incurred on the year's operations, which had to be met from the balance accumulated during the war. As a result the price had to be increased in April 1948 from 1s. to 1s. 6d. per copy. The circulation fell and before it had fully recovered it was necessary to increase the price again—to 2s. 6d. per copy for subscribers outside the Post Office, in October 1951, and to 2s. for Post Office subscribers in July 1952—an increase that was necessary in spite of the introduction of the more economic format in 1951 and a reduction in the contents of the Journal. Consequently, the number of copies printed fell progressively, reaching an average of 15,625 copies of each part for Volume 47 (1954–55). Since then the circulation has increased but has not quite reached the record level of Volume 40, the number of copies printed of Volume 50 being an average of 18,400 copies of each part, but sales are still rising and the number of copies printed of Part 4 of Volume 50 was 19,000.

The Board of Editors' report on Volume 6 (1913–14) records that even in those early days the Journal had " . . . an extensive international circulation . . ." It is difficult to establish precisely how wide the international circulation now is because the ultimate destination of copies sold to booksellers and agencies abroad is not fully known. The total distribution of the Journal can at present be divided approximately into the following main categories:

(*a*)	Institution members	6,500
(*b*)	Members of the Associate Section of the Institution having annual subscriptions	2,100
(*c*)	Post Office staff other than (*a*) and (*b*)	6,700
(*d*)	Publisher's sales	2,400
(*e*)	Agents in telecommunications contractors' works in United Kingdom	400
(*f*)	Booksellers and book agencies, other than those included in (*d*)	300
(*g*)	Complimentary and exchanged copies	150
(*h*)	Casual sales ($\frac{2}{3}$ U.K.; $\frac{1}{3}$ abroad)	450

Although some copies in categories (*f*), (*g*) and (*h*) go abroad the bulk of the overseas sales are by the publisher, and it is of interest that a recent review showed that the publisher's sales abroad were distributed as shown in Table 1.

TABLE 1

Destination	Copies to each destination
Australia	201–300
South Africa	101–200
Japan, Malaya, U.S.A., New Zealand	51–100
Holland, South America, India	41–50
Germany, Italy, U.S.S.R., Canada, Poland	31–40
France, Hungary, Sweden, West Indies	21–30
Denmark, Ceylon, China, Northern Rhodesia, Czechoslovakia, Nigeria, Norway	11–20
Hong Kong, Malta, West Africa, Yugoslavia, Gibraltar, Portugal, Finland, East Africa, Switzerland, Spain, Belgium, Cyprus, Pakistan, Egypt	5–10

ACKNOWLEDGEMENTS

The Journal has now been published quarterly, without a break, for 50 years. During that time the amount of material included in each issue has trebled, but the price has only risen to two-and-a-half times the original price (only twice the original price to members of the Post Office); the circulation has increased sevenfold and is now world wide; and all the important developments in Post Office telecommunications equipment and practices have been recorded. This success would have been impossible without the authors of the thousands of articles that have now been published; the printer, Sanders Phillips & Co., Ltd.; The Engravers Guild, Ltd., who prepare the blocks for illustrations; the publishers, Birch & Whittington (Proprietors Dorling & Co. (Epsom), Ltd.); the many local agents who undertake the distribution of the Journal; and the advertisers whose faithful support has helped the Journal to weather its financial crises. To all these people the Board of Editors offers very sincere thanks for their help in bringing the Journal from its modest beginning to the success that it enjoys to-day.

Reference

LEIGH, H. The Production of the Post Office Electrical Engineers' Journal. *P.O.E.E.J.*, Vol. 34, p. 126, Oct. 1941.

W. A. H. and E. D.

High-Power Radio-Frequency Broad-Band Transformers

E. R. BROAD, B.A.†

U.D.C. 621.372.414 : 621.396.679.4

The design of wide-band transformers composed of simple transmission line elements and capable of handling radio-frequency power of the order of 20 kW is discussed. Examples are given of devices matching 75-ohm coaxial cable to balanced-pair transmission lines with a standing-wave ratio of less than 1·3 over the band 4–28 Mc/s.

INTRODUCTION

THE transfer of large amounts of radio-frequency power from the transmitters to the aerial arrays at high-frequency radio transmitting stations presents a number of problems. The power transmission system should, ideally, introduce negligible loss, permit the maximum flexibility in transmitter-to-aerial connexions, provide the proper standard of safety for operating staff and discourage undesirable modes of propagation. If, as is now the case at all Post Office radio stations, aerials of the rhombic type capable of operating satisfactorily over band-widths of 2 to 1, or more, are gradually superseding the single-frequency arrays it is, additionally, essential for the feeder systems to be wide-band.

None of the systems at present in use fully meets all these requirements. The simplest of all systems employs the open-wire transmission line, nominally of 600 ohms characteristic impedance and balanced to earth, from the transmitter output terminals to the aerial and has been extensively used for many years. Low loss can be achieved economically and it is well suited for direct connexion to most aperiodic aerial systems, but in all other respects it leaves much to be desired.

The coaxial feeder of nominal 75 ohms impedance and unbalanced to earth has also been widely used. It is several times more costly to install than an open-wire system of equivalent performance and is not well suited for direct connexion to most high-frequency aerial systems, particularly when wide-band operation is required.

On the other hand, a coaxial system has obvious attractions from the aspects of safety and aerial switching, and a moderately successful attempt to produce a solution along these lines was introduced into the Rugby B Station[1] by using a balanced-to-earth system throughout but using twin coaxial feeders of nominally 200 ohms impedance for distribution within the transmitter building.

There is, however, little doubt that the most satisfactory solution of all would be found in a combination of the unbalanced coaxial system for radio-frequency power transmission and switching within the building and the balanced 2-wire system for covering the sometimes considerable distances out to the aerials. All that is needed is the means of connecting the two together over a sufficiently wide band of frequencies.

There is therefore a need for a transformer device capable of handling radio-frequency power of 20 kW or more and of matching coaxial feeders, of characteristic impedance of the order of 50–75 ohms, to open-wire lines of the balanced-to-earth type and of characteristic impedances of 500–700 ohms.

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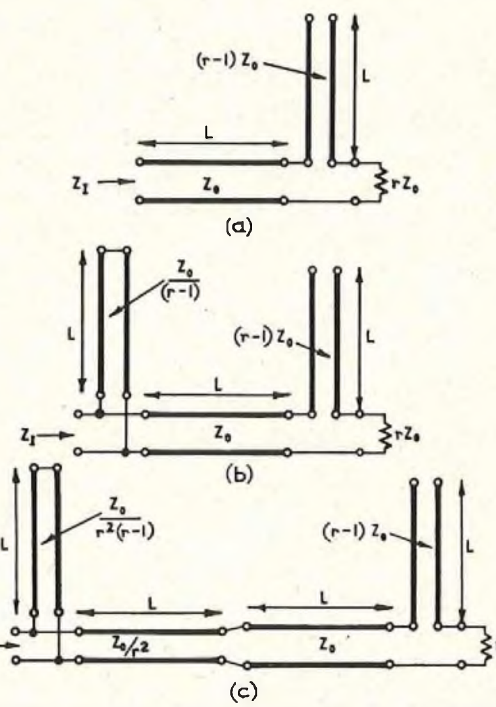
So far, conventional wound transformers using ferrite cores have been designed for this purpose for handling up to 5 kW of radio-frequency power. The problems of transmitting higher powers than this are believed to be formidable. A brief description is given in this article of "transmission-line" transformers which can readily be designed to transmit the higher radio-frequency power. They are also designed to pass the wide frequency band of 4–28 Mc/s and to give a satisfactory input impedance over this band.

TRANSMISSION-LINE TRANSFORMERS

The complete transmission-line transformers may be regarded as consisting of several components, each fulfilling a definite function. These will be described in turn before showing how they are coalesced into the several forms of the device so far investigated. First, the manner in which the quarter-wavelength transformer may be developed into a device operating over a broad band of frequencies is described. Then one simple solution to the problem of interconnecting balanced and unbalanced impedances is examined. Finally, a description is given of a method of obtaining an impedance change of 4 : 1.

Quarter-Wavelength Transformer

It is well known that a length of transmission line one quarter-wavelength long can act as a transformer. The input and load impedances Z_I, Z_L are related to



(*a*) Quarter-wave-line transformer with series compensating line at the high-impedance end
(*b*) Quarter-wave-line transformer with series compensating line at the high-impedance end and shunt compensating line at the low-impedance end
(*c*) Two quarter-wave-line transformers in tandem with series compensating line at high-impedance end and shunt compensating line at the low-impedance end

FIG. 1—TRANSMISSION-LINE TRANSFORMERS

the characteristic impedance, Z_0, of the line by the simple formula

$$Z_I Z_L = Z_0^2$$

For transmission lines used at radio frequencies, Z_0 can be regarded as a pure resistance. If Z_L is a pure resistance and equal to rZ_0, then Z_I is equal to Z_0/r and the line acts as a transformer of impedance ratio r^2.

But this is only true for isolated discrete frequencies at which the line is an odd number of quarter-wavelengths long. Over small bands of frequency centred on these frequencies the line continues to act as a transformer of approximate ratio r^2. However, by connecting suitable "stub" lines[2] at the ends of the transmission line (see Fig. 1) it can be made to operate over wide frequency bands.

If the load Z_L is larger than Z_0 (i.e. $r > 1$), an open-circuited stub line of characteristic impedance $(r - 1)Z_0$ is connected in series with the load. If, also, this line is made equal in electrical length to the main transmission line, the resistance component of the input impedance Z_I remains constant and equal to Z_0/r whatever the frequency. Approximate correction of the reactance component of the input impedance can be secured by connecting a stub line of equal electrical length in parallel with the input terminals. This shunt compensating line must be short-circuited at its far end and be of characteristic impedance $Z_0/(r - 1)$. The theory of this method is presented in the appendix to this article.

It happens that the attainable transformer ratio may be increased by using another quarter-wavelength line, the characteristic impedance of which is made equal to Z_0/r^2, in tandem with the first. The shunt compensating line is omitted at the end of the first line and is connected to the input terminals, but now has a characteristic impedance of $Z_0/r^2(r - 1)$ (see Fig. 1(*c*)). The resistance component of the input impedance is approximately equal to Z_0/r^3 but is no longer independent of frequency. However, reckoned against a line of impedance Z_0/r^3 the input impedance can have a standing-wave ratio (s.w.r.) of less than about $r : 1$ over a wide frequency band.

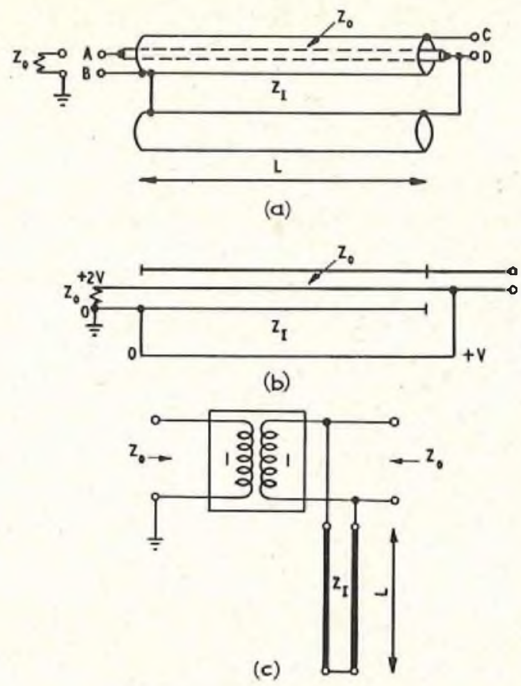
This procedure may be repeated and as many as six tandem lines employed, resulting in an impedance ratio between input and output terminals of r^{12}. In this way an impedance ratio of 8 : 1 may be obtained for an s.w.r. of about 1·2 over a frequency band of 4–28 Mc/s.

Slight adjustment of the values away from those indicated by this simple theory can result in s.w.r. of the order of $\frac{1}{2}(1 + r)$, or in the example quoted above 1·1 : 1. This adjustment is indicated in the appendix.

Balance-to-Unbalance Transformer

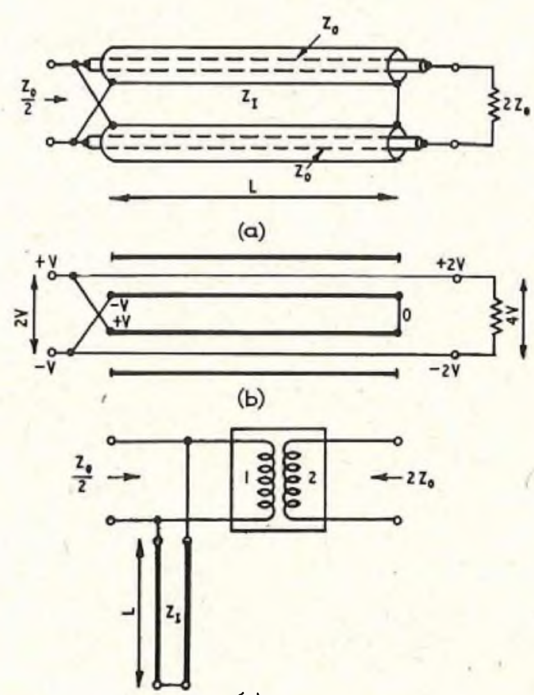
Devices that act as transformers between balanced and unbalanced impedances at high frequency have been given the abridged name of "baluns." The most simple of these devices[3] has a 1 : 1 impedance ratio. It will only operate satisfactorily by itself over a small frequency band about that frequency at which its length is one quarter-wavelength. However, when used in conjunction with a quarter-wavelength transformer of the type described above, broad-band operation can be secured.

The balun consists essentially of two conducting tubes of equal diameter set up as an open-wire transmission line. One end of this line is short-circuited and is regarded as the neutral or "earthed" point. At the other end one tube is connected to a third conductor placed within the other tube to form a coaxial line, as shown in Fig. 2(*a*). At the frequency for which the open-wire line is one quarter-wavelength long, if an "unbalanced to earth" load equal to the characteristic impedance of the coaxial line is connected to terminals A and B, it appears at terminals C and D as a balanced load of equal impedance. Alternatively, a balanced load connected to C and D appears as an unbalanced load at terminals A and B.



(*a*) Simple balun
(*b*) Voltage distribution on balun
(*c*) Equivalent circuit of simple balun

FIG. 2—BALANCED-TO-UNBALANCED TRANSFORMER



(*a*) The 4 : 1 transformer
(*b*) Voltage distribution on 4 : 1 transformer
(*c*) Equivalent circuit of 4 : 1 transformer

FIG. 3—THE 4 : 1 TRANSFORMER

The voltages with respect to earth at the terminals are shown in Fig. 2(*b*). The voltage across the coaxial line throughout its length is $2V$, but the outside conductor is V volts below earth at the open end.

The device may be regarded as an ideal 1 : 1 transformer with the short-circuited transmission line connected in shunt across the balanced terminals, as in Fig. 2(*c*). It can be seen therefore that the device can be made broad-band in operation only if the reactance of this line can be nullified or usefully employed.

The 4 : 1 Transformer

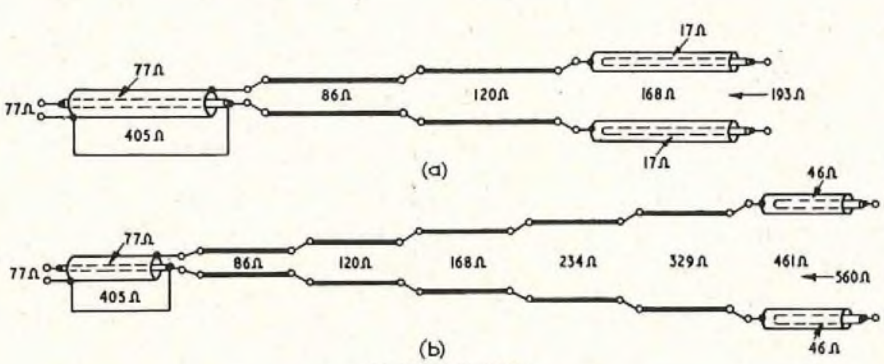
Another simple line transformer[2] which can be employed between balanced circuits to give a 4 : 1 step up in impedance at a single frequency is shown in Fig. 3(*a*). It consists of two coaxial lines connected in series at one end and parallel at the other. The outer conductors may be connected to earth only at the high-impedance end. They form a short-circuited transmission line in shunt across the low-impedance terminals as in the balun above. At frequencies at which this line resonates so as to present a high impedance across the terminals, the transformer will function satisfactorily. Alternatively, the reactance of this loop may be nullified or usefully employed to give broad-band operation.

PRACTICAL DESIGNS OF TRANSFORMER

By bringing together the three simple devices outlined above to form a composite balanced-to-unbalanced transformer, it is theoretically possible to obtain almost any desired impedance ratio in a transformer working over a fairly wide frequency band. There are, however, severe practical limitations, particularly when the transmission of powers of the order of 20 kW is desired.

Because of the voltages and currents involved and because, also, of the mechanical difficulties the characteristic impedance of the coaxial compensating lines is limited to values between about 15 and 150 ohms. For the usual values of terminating impedance between 50 and 75 ohms, therefore, the minimum realizable value of r is about 1·2 and values of s.w.r. below about 1·1 are not to be expected.

In the same way there are limits to the characteristic impedances for which balanced pair lines may be conveniently constructed. A few of the designs intended for the transmission of up to 20 kW of radio-frequency power that have so far been investigated are briefly described in the following sections.



(*a*) 75/200-ohm balun
(*b*) 75/600-ohm balun

FIG. 4—LONG-TYPE BALUNS

75/200 Balun: Long Type

This transformer is designed to operate between coaxial lines of approximately 75-ohm unbalanced and 200-ohm balanced impedances and consists of two component parts. The first, at the 75-ohm unbalanced end, is a 1 : 1 balanced-to-unbalanced transformer unit as already described. The shunt transmission line of this unit becomes the reactance compensating line at the low-impedance end of a tandem quarter-wavelength transformer of the type previously described, consisting of three sections of ascending characteristic impedance. The conductors of the final section are hollow and contain an inner conductor providing the open-circuited series-connected compensating line required at this end. The complete transformer is shown in outline in Fig. 4(*a*).

The impedances of the quarter-wavelength sections are rather low for easy realization in balanced-pair lines, the more so because of the high power involved. The 168-ohm section of the tandem line is constructed from four 1 in. diameter copper tubes in square formation[4] of 6⅜ in. side, with four $\frac{9}{16}$ in. diameter tubes inside them to form the series compensating line. Connexions to the load are made from two adjacent inner conductors in parallel at each terminal.

The other two tandem sections are also of 4-wire square construction but with diagonally-opposed conductors[4] of ¾ in. diameter connected in parallel, the sides of the squares being 2¼ and 4 inches, respectively, for the 86-ohm and 120-ohm lines.

The balun, together with the feeder connected to it, has an outer conductor of 3¼ in. diameter. To secure a perfect balance the second conductor must also be of this size but this would require a spacing of about 4 ft to give the impedance of 405 ohms required by the transformer design. By permitting an unbalance of the order of 5 per cent, however, the spacing can be reduced to 16½ in. and the "balancing" conductor to ⅜ in. diameter.

With tandem lines approximately 15 ft long and the balun line 14 ft long the input s.w.r. of the transformer does not exceed 1·2 between 3·2 Mc/s and 28 Mc/s.

75/600 Balun: Long Type

By withdrawing the inner conductor at the high-impedance end of the transformer described above and adding three more tandem lines, together with the necessary series compensating lines, a new transformer matching approximately 75 ohms unbalanced to 600 ohms balanced is formed.

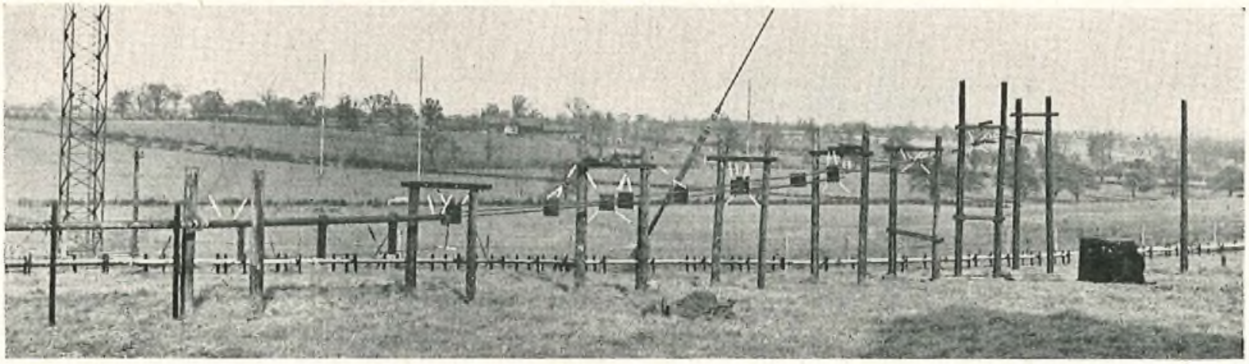
This transformer is shown in outline in Fig. 4(*b*). The final tandem line of 461 ohms is constructed from ¾ in. diameter copper tubes spaced nearly 17 in. apart. Within these tubes are placed inner conductors of $\frac{5}{16}$ in. diameter to form the series compensating lines of 46 ohms characteristic impedance.

Photographs of an experimental set-up of this transformer for power tests are shown in Fig. 5.

The input s.w.r. of this unit is not worse than 1·24 over the frequency band of 3·0 Mc/s to 29 Mc/s.

75/200 Balun: Short Type

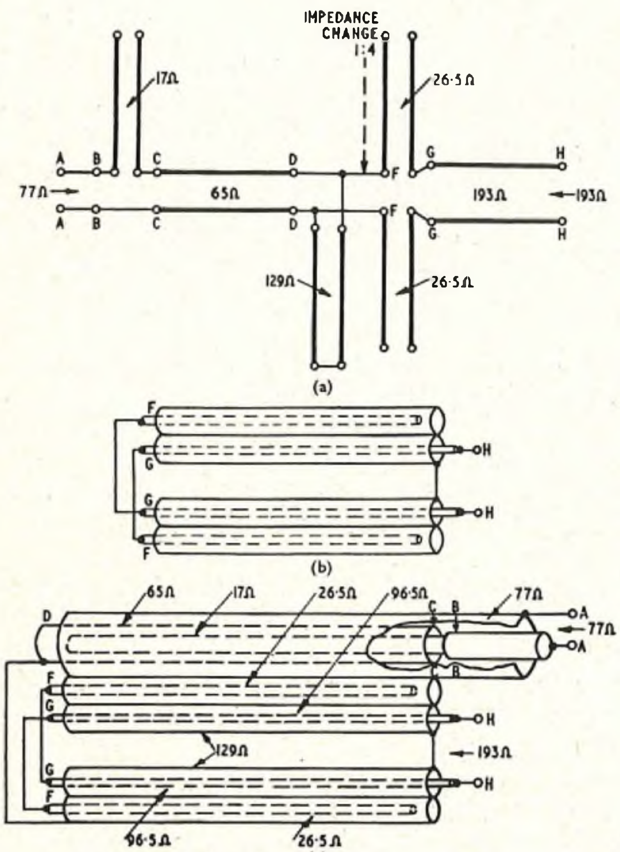
Both the transformers described above, although simple in conception, are very long and inconvenient to



View from low-impedance end

View from high-impedance end

FIG. 5—EXPERIMENTAL 75/600-OHM BALUN AT ONGAR RADIO STATION



(c)

(*a*) Circuit diagram
(*b*) Series compensating lines and 4 : 1 transformer
(*c*) Practical realization of balun

FIG. 6—SHORT-TYPE 75/200-OHM BALUN

build. This disadvantage has been overcome by making use of the 4 : 1 transformer previously described; in the case of the 75/200-ohm unit the length is reduced to one quarter that of the long type.

In essence the short type of balun consists of a single-section compensated quarter-wavelength transformer stepping down from 75 to 50 ohms approximately, followed by a balun device and a 4 : 1 transformer. The whole has been compressed into one unit 15 ft long by coalescing the short-circuited open-wire lines of the two component transformers and using them as the shunt compensating line of the 75/50-ohm transformer.

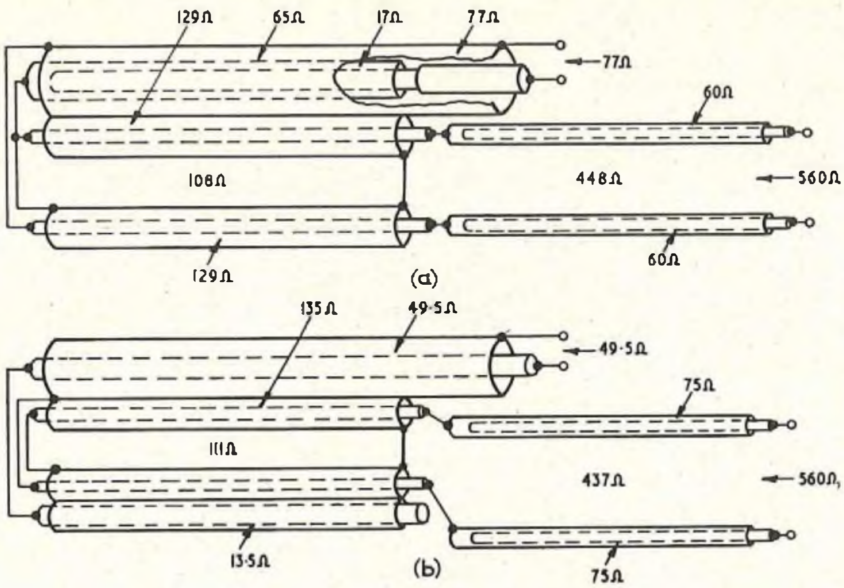
In order to reduce the impedance of the shunt compensating line, the quarter-wavelength transformer has been double-compensated at the low-impedance end (Fig. 6(*a*)). In effect the transformer is over-compensated by the shunt line and a series open-circuited line added to give the necessary correction.

For ease of construction, this "series" compensation is added to the 4 : 1 transformer as in Fig. 6(*b*) and appears as two open-circuited lines of double the impedance. To these four coaxial lines is added a fifth comprising the line CD of Fig. 6(*a*). Connected in suitable fashion, see Fig. 6(*c*), it provides the balun action of Fig. 2. Within the inner conductor of this fifth coaxial line is inserted a further conductor to form the series compensating line BC.

The input s.w.r. of this transformer, as shown in Fig. 8(*a*), is not worse than 1·2 over the frequency band 4 Mc/s to 27·5 Mc/s.

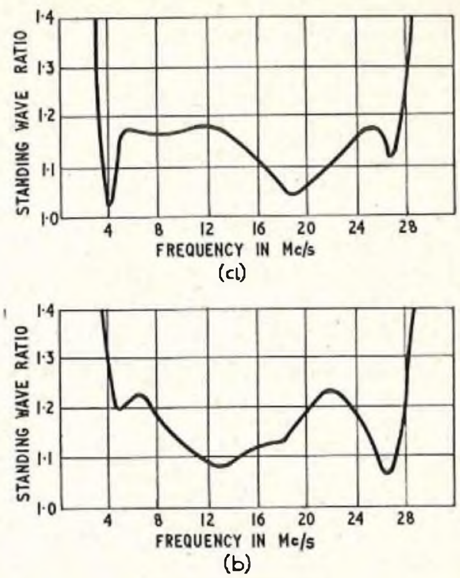
75/600 Balun: Short Type

The 75/600 transformer may be reduced in length in the ratio 3·5 : 1 by using the 4 : 1 transformer. The constituent elements are again a compensated quarter-



(*a*) Practical realization of 75/600-ohm balun
(*b*) Practical realization of 50/600-ohm balun

FIG. 7—75/600-OHM AND 50/600-OHM BALUNS MATCHING TO OPEN-WIRE LINES



(*a*) 75/200-ohm balun
(*b*) 75/600-ohm balun

FIG. 8—INPUT STANDING-WAVE RATIO OF SHORT-TYPE 75/200-OHM AND 75/600-OHM BALUNS

wavelength transformer 75/50 ohms, a balun section, a 4 : 1 transformer and a further 2-section compensated quarter-wavelength transformer to 560 ohms. Except for the second tandem section of the latter, together with its internally constructed series compensating lines, the whole transformer is compressed into a single length of 15 ft by coalescing the shunt-connected short-circuited lines.

Each quarter-wavelength transformer has simple single compensation at each end. Where the two transformers effectively connect together, the shunt compensating lines become one of lower impedance, and that is the common line of the balun and 4 : 1 transformer. The first tandem line of the second quarter-wavelength transformer is an integral part of the 4 : 1 transformer so that the latter's impedance ratio is effectively increased.

The construction is shown diagrammatically in Fig. 7(*a*). The performance is generally better than an input standing wave ratio of 1·25 but it rises to 1·3 at 4 Mc/s and 28 Mc/s (see Fig. 8(*b*)).

50/600 Balun

It seems obvious from the foregoing that a 50/600 transformer could be made. But it is necessary to have recourse to double-type compensation at the low-impedance end in order to keep the impedance, and thus the separation of the two sides of the transformer, small.

Fig. 7(*b*) shows diagrammatically the arrangement of such a transformer. The performance of such a device over the band 4 Mc/s to 28 Mc/s is of the same order as that already described.

CONCLUSION

All the devices outlined are comparatively simple to construct and can transmit powers of 20 kW in the frequency range 4 Mc/s to 28 Mc/s. Unbalanced impedances of 50 or 75 ohms are matched to balanced impedances of 200 or 600 ohms.

Development of these devices should do much to rationalize and simplify the interconnexion of aerials and transmitters at short-wave radio transmitting stations and so enable the advantageous features of both coaxial and open-wire feeders to be used to the maximum extent.

APPENDIX

THE COMPENSATED QUARTER-WAVE TRANSFORMER

A loss-free open-circuited transmission line of characteristic impedance aZ_0 has an input impedance of $-jaZ_0 \cot\theta$ and the length of the line, l, is equal to $\lambda\theta/2\pi$. To such a line is connected in series a resistance equal to rZ_0. Then the impedance of the combination Z_L may be written as:

$$Z_L = Z_0(r - ja\cot\theta) \quad \ldots\ldots(1)$$

If this combination constitutes the load connected to a loss-free line of characteristic impedance Z_0 and of the same electrical length as the first line, the input impedance measured at the other end of the line will be given by:

$$Z_S = Z_0\frac{(Z_L\cot\theta + j\,Z_0)}{(Z_0\cot\theta + j\,Z_L)} \quad \ldots\ldots(2)$$

Substituting in expression (2) from (1) and rearranging the result:

$$\frac{Z_S}{Z_0} = \frac{r\cot\theta + j(1 - a\cot^2\theta)}{(1 + a)\cot\theta + jr} \quad \ldots\ldots(3)$$

At radio frequencies Z_0 can be regarded as a pure resistance, hence, on separating the resistance component R_S and reactance component X_S of the impedance Z_S, R_S may be expressed as:

$$\frac{R_S}{Z_0} = \frac{r(1 + \cot^2\theta)}{r^2 + (1 + a)^2\cot^2\theta} \quad \ldots\ldots(4)$$

Thus if $r = (1 + a)$ the value of R_S is independent of θ and equal to Z_0/r. Since θ is the only frequency-dependent term, the nput resistance under these conditions is therefore constant with frequency.

Algebraic manipulation will also show that X_S is equal to $(-a\cot\theta)\,R_S$ for $(1 + a) = r$, that is to say that in general X_S is both finite and frequency-dependent. To obtain an ideal network matching a resistance rZ_0 to a resistance Z_0/r it is therefore necessary to add a device in series of reactance $(+\,a\cot\theta)Z_0/r$. No simple device giving such a reactance exists. Approximate compensation of the reactance component can be obtained by connecting in shunt with the input terminals a short-circuited transmission line of characteristic impedance Z_0/a and of the same electrical length as the other two lines.

Let $\frac{1}{Z_S} = Y_S = G_S + jB_S$, and $Y_0 = \frac{1}{Z_0}$

$$\frac{G_S}{rY_0} = \frac{1}{(1 + a^2 \cot^2 \theta)} \quad \text{.........(5)}$$

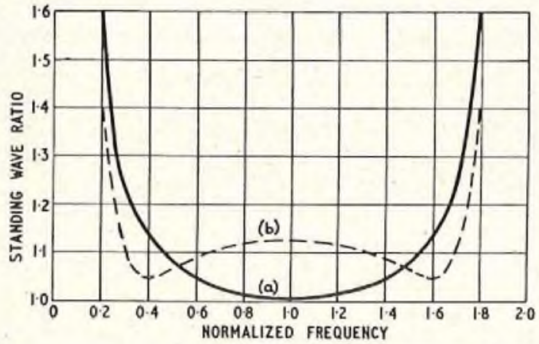
$$\frac{B_S}{rY_0} = \frac{a \cot \theta}{(1 + a^2 \cot^2 \theta)} \quad \text{.........(6)}$$

The susceptance B_O of the shunt compensating line may be written in similar terms as:

$$\frac{B_O}{rY_0} = \frac{-a \cot \theta}{(1 + a)} \quad \text{.........(7)}$$

The residual susceptance B remaining on connexion of this line is found to be given by:

$$\frac{B}{rY_0} = \frac{a^2 \cot \theta \,(1 - a \cot^2 \theta)}{(1 + a)(1 + a^2 \cot^2 \theta)} \quad \text{.........(8)}$$



Standing-wave ratio of quarter-wave transformer with series compensating line at the high-impedance end and shunt compensating line at the low-impedance end.

Curve (a) 80/125 ohms
Curve (b) 90/125 ohms

FIG. 9—STANDING-WAVE RATIO OF COMPENSATED QUARTER-WAVE TRANSFORMER

Equation (8) shows that for $\cot \theta = 0$ and $\cot^2 \theta = 1/a$ the susceptance falls to zero. At the same time, equation (5) indicates that the standing-wave ratio at the input of the device is given as unity and $(1 + a)$ respectively. (Reckoned against a transmission line of impedance Z_0/r.)

For example, if $a = 0{\cdot}25$, $r = 1{\cdot}25$, $r^2 = 1{\cdot}5625$, a line of 100 ohms impedance will act as a matching device between 80 ohms and 125 ohms if compensating lines of 400 and 25 ohms are used giving unity s.w.r. at mid-band ($\cot \theta = 0$) where the lines are $\lambda/4$ long, and an s.w.r. of 1·25 at frequencies where the lines are approximately $3\lambda/40$ and $17\lambda/40$ long ($\cot \theta = 2$) (i.e. at 4·8 Mc/s and 27·2 Mc/s if the lines are $\lambda/4$ long at 16 Mc/s).

The full line curve of Fig. 9 shows the variation of s.w.r. of the example quoted above. If the same device is used to match 90 ohms and 125 ohms, the s.w.r./frequency behaviour becomes that shown by the dotted curve of Fig. 9. The frequency scale is shown in terms of the mid-band frequency, i.e. the frequency at which the lines are one quarter-wavelength long.

It may be inferred that optimum wide-band behaviour results from some adjustment of the values of r and a and that the simple theory given above serves only as a guide. In general, it appears that standing-wave ratios of the order of $\frac{1}{2}(1 + r)$ can be obtained using values of a somewhat greater than $(r - 1)$.

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[2]BERNT, W. The Transmission of Energy to the Aerials of Short-Wave Transmitting Stations. Part II, *Telefunken-Zeitung*, Vol. 27, pp. 163–171.

[3]British Patent 438,506.

[4]GRAZIADEI, H. A Practically Frequency-independent Transition between a High-Frequency Coaxial Cable and a Balanced-Pair Transmission Line. Fernmeldetechnische Zeitschrift, Vol. 6, pp. 311–319.

Book Reviews

"Definitions and Formulæ for Students. Radio and Television Engineering." Fourth edition. A. T. Starr, M.A., Ph.D., M.I.E.E. Pitman & Sons, Ltd. 65 pp. 50 ill. 2s. (Size 4 in. × 5¼ in.).

For many years past Sir Isaac Pitman & Sons, Ltd., have published a series of pocket-size reference books each covering the working theoretical background of one of the applied sciences. Dr. A. T. Starr, well known in the telecommunications field in this country and an acknowledged authority on network analysis, is the author of one of the works in this series, on the terms and formulæ used in Radio and Television Engineering. The book was first published in 1935 and this, its fourth edition, has just appeared, 22 years later.

It is an assorted collection of information. Section 1 of the book, comprising the first 38 plates, gives the definitions of about 400 terms and abbreviations in use in the science of telecommunications. Selecting this list must have been a tedious job. Some of the items have been taken from the Glossary of the British Standards Institution; others are statements of terminology in current use. Some surprising errors have, however, remained in the booklet, surviving even to this fourth edition. For example, although m.k.s. units are recommended by the author he lapses into c.g.s. units on occasion, as on page 47. The term "transitional coupling," if ever it was in common use in this country, has long been replaced by "critical coupling." "Demodulation," on page 12, is given the definition that is normally that of "Modulation Suppression." Any student who used this book to obtain the precise meanings of Appleton layer, Heavyside layer or D, E, or F layers would finish in mental confusion, as the heights given to define them are not mutually consistent.

Section II of the booklet is titled "Formulæ and Circuits." There are many standard formulæ, such as the one for coil inductance in terms of former diameter and length and the number of turns; there are simple outlines of a few of the classic circuits, e.g. the various valve oscillators and the simplified form of a negative feedback amplifier. The standard formulæ expressing the performance of such circuits are quoted.

This booklet is very cheap indeed by present standards. It is difficult however to see just what function it can perform satisfactorily except perhaps as a useful memory jogger for those who are out of touch. It is much too sketchy to be a reference source for serious students and it is too elementary for engineers, who would expect to have access to standard works. It is insufficiently practical to help the laboratory technician or practical designer.

C. F. F.

"Transmission Téléphonique, Theorie des Lignes." R. Croze and L. Simon. Editions Eyrolles. 416 pp. 156 ill. 3,960 fr. (approx. £4).

The authors are well-known members of the French Posts, Telegraphs and Telephones Administration, and the work is based upon courses in line transmission given at the French Higher National School of Telecommunications. The book is divided into two parts, the first dealing with line transmission in all aspects and the second with crosstalk in its many aspects.

Starting with an introductory chapter describing the bandwidth and other requirements for the transmission of various types of signals from telegraphy to television, there follow two chapters dealing with the primary and secondary parameters of all types of lines. These chapters contain much useful material on the change of the parameters with temperature not often collected together for such easy access. The next chapter, on loading, is fairly conventional but a comprehensive treatment is given.

A separate chapter is devoted wholly to the coaxial pair

(*Continued on p. 15*)

The Post Office Type 10 Relay

B. H. E. ROGERS†

U.D.C. 621.318.56

The Post Office 3,000-type relay has acquired a reputation for service reliability and maintenance economy, but when used in circuits where the rate of operations is high there is a likelihood of early misoperation due to mechanical wear. For such applications a new relay, the Type 10, has been designed with the object of obtaining a mechanical life of 100,000,000 operations while retaining the basic characteristics of the 3,000-type relay.

INTRODUCTION

SINCE the Post Office 3,000-type relay was introduced some 25 years ago, it has acquired a reputation for service reliability and maintenance economy. Experience has shown, however, that when such relays are used for pulse repetition, distribution, storage or counting where the rate of operations required is high, mechanical wear resulting in early misoperation occurs. In this context mechanical wear is taken as the number of operations the relay performs without readjustment before block clearance is lost on at least one spring under conditions of no load on the contacts. Electrical contact wear is a separate problem which can be solved satisfactorily by suitable spark quenching, the purely mechanical wear on unloaded contacts being negligible.

Because mechanical wear of relay parts increases the frequency of relay readjustment and eventual replacement of parts, redesign has been undertaken with the object of obtaining a mechanical life of 100,000,000 operations while retaining the basic characteristics, mounting arrangements and design data associated with the 3,000-type relay. In the redesign it was borne in mind that if a long-life relay electrically and functionally equivalent to the 3,000-type could be produced at no greater cost, there would be advantages in standardizing it.

BASIS OF NEW DESIGN

Change of mechanical adjustment of a 3,000-type relay results from wear between lifting pins and studs and at the knife-edge; also from hammering of the residual screw or stud on the pole face and of the armature back-stop on the yoke. Laboratory tests with modified parts showed that wear at these points could be much reduced and would result in a satisfactory life from the relay. To this end the following alterations have been made:

(*a*) Spring-set lifting pins and studs are replaced by a lifting comb of synthetic resin-bonded paper bearing directly on the metal of the armature, the keramot lifting studs being omitted. Typical combs are shown in Fig. 1.

(*b*) The radii of the yoke knife-edge and armature are increased to give an improved seating surface.

(*c*) Diameters of the armature back-stop and residual screw are increased and each is given a slightly-domed striking surface to reduce the indentation on the yoke and pole face. The residual-screw thread has the same pitch as on the 3,000-type relay in order to give the same movement per turn for adjustment purposes. The residual-screw locking-nut has the same dimension across flats as on the 3,000-type relay. Residual studs are not used as a finer control can be obtained from a screw adjustment.

FIG 1—TYPICAL COMBS

(*d*) The buffer block has been lengthened to position the steps nearer the contacts (Fig. 2). On the 3,000-type relay, flexing of the spring between the contacts and the spring lug reduces the effective block clearance. Forward positioning of the block steps reduces the amount of flexing and consequently increases the block clearance. A minimum clearance of 0·005 in. is specified.

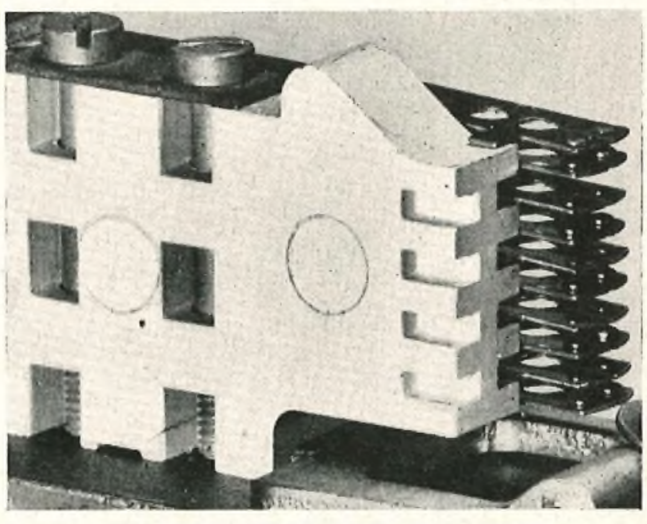

FIG. 2—THE 5-MAKE-CONTACT BUFFER BLOCK

CONTACT BOUNCE

Although relays to this construction conform closely to the 3,000-type relay design data and maintenance techniques, their contact-bounce characteristics are in general inferior to those of their 3,000-type equivalents, a feature which could in some cases reduce the reliability of circuit operation.

The increase of contact bounce in comb-operated relays arises from the reduction of friction and consequent greater freedom of the springs to oscillate; with the

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reduced mechanical damping thus given, the tendency for armature rebound on release is increased and is a further cause of contact bounce. The effect of armature rebound is most noticeable on slugged relays, where the decay of magnetic flux is slow compared with that of the armature load, which varies in discrete steps. When the relay is released the armature is restored to normal by the spring load but tends to re-operate, due to the flux remaining in the iron circuit. In certain light-load conditions it is possible for complete re-operation to occur before the armature finally releases.

In these circumstances it was decided to limit the scope of the new design to plain-coil relays (i.e. relays without slugs or timing requirements) for immediate use, as modifications may be required before comb-operated spring-sets can be satisfactorily used on slugged relays. With pulse repetition relays using K (make-before-break) contacts the design referred to gives rise to excessive contact bounce and the application of comb operation to such relays is the subject of a separate investigation.

TYPE 10 RELAY

The long-life relay described has been coded as Type 10/. ., the figure 10 indicating a relay generally similar to the 3,000-type relay but with the modifications, comb operation and other features, already mentioned. It is available with a range of spring-sets built up from the following contact units: 1 make plus 1 break; 2 makes; 3 makes; 2 change-overs; and 3 change-overs. All springs are nickel-silver, 12 mils thick, and the standard

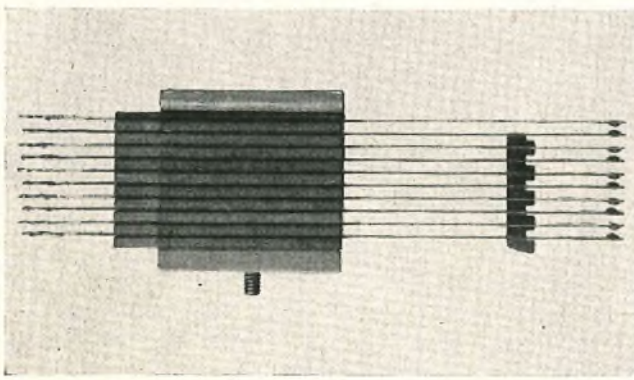

FIG. 3—THE 5-MAKE-CONTACT SPRING-SET

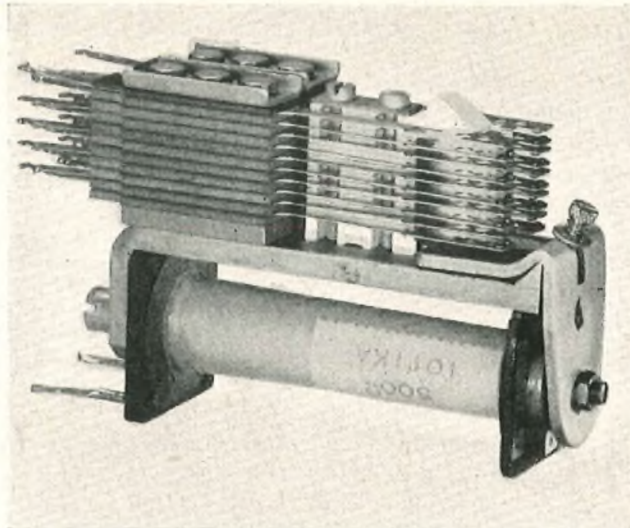

FIG. 4—THE 10-MAKE-CONTACT RELAY

contact material is silver, although platinum may be used in special cases. In the interests of rationalization, spare springs are accepted providing they do not carry platinum contacts. Plain coils only are used and because of the acceptance of spare springs, new designs will only be introduced where the projected use is large.

The width of the spring-set separators has been increased slightly to ensure that the relay will withstand a 1,000-volt 50 c/s test voltage between the contact springs and the relay frame. This qualifies the relay for 250-volt working and it can safely be used, with suitable spark-quenching, for switching light current at this voltage. The introduction of this feature considerably widens its field of use. A special relay in this series for which there is no equivalent in the 3,000-type range is one fitted with two 5-make spring-set assemblies giving 10 make-contact actions. Such a spring-set is illustrated in Fig. 3 and the complete relay in Fig. 4.

The Type 10 relay will normally be used where the number of relay operations is expected to exceed 500,000 per year. Such an application has arisen on some of the register-translators being developed for subscriber trunk dialling, in which the 10-make-contact version of the relay is to be extensively employed.

Book Review

"Transmission Téléphonique, Theorie des Lignes,"—

continued from p. 13

and its properties. The use of coaxial cables is now so widespread that the separate treatment of this type of cable is welcomed. The first part of the book is concluded by a consideration of the mis-terminated line and reflections, and contains a small amount of information on pulse transmission. This latter is too short to be anything more than an introduction, and the book could be improved by more information on this interesting but complicated subject. Possibly this is due to the wide frequency band required for the French 819 television standard, which is generally relayed over radio links.

The second part of the book deals with the subject of crosstalk and in addition to a thorough theoretical treatment contains good practical descriptions of methods of combating this complex problem. Chapter X, dealing with crosstalk between coaxial cables, is very well done since this subject is not widely dealt with in present-day literature. The book concludes with a description of cable-balancing methods and a number of annexes.

It is perhaps unfortunate for English readers that the text is in French as the book can be well recommended. It gathers together in one volume a very comprehensive description of line transmission theory and practice. The subject matter is up to date and the reviewer is not aware of any English textbook that covers the subject so well in a single volume.

It would make a very good textbook for C. & G. Telecommunications (Principles) V and Line Transmission II courses, but in view of the language this would not be practical. However, it should find a place as a reference book in all offices where line transmission is dealt with seriously. J. R.

Aluminium in Telecommunications Cables*

R. C. MILDNER, M.Sc., M.I.E.E., and Miss B. F. THORNE, B.Sc., A.Inst.P.†

U.D.C. 669.71:621.315.2

The comparatively low cost of aluminium has for a long time justified its use in cables, though the new techniques required for its processing and the unknown factors involved in its service performance have stood in the way of its adoption. Recently these difficulties have been largely surmounted and aluminium is now being used for both land and submarine telecommunications cables. The use of aluminium as a conductor, as a sheath, as a screen and for armouring is discussed, and details of some specific applications are given.

INTRODUCTION

THE more important conventional materials used in the manufacture of cables for telecommunications purposes comprise the following: copper for the electrical conductors, dry paper and air for the insulation, lead for the watertight covering and for electrical screening, bituminized hessian for corrosion protection and steel for mechanical protection (sometimes also for electromagnetic screening). Within the last decade or so new materials, namely aluminium and plastics, have been introduced to an increasing extent into the cable industry, to secure either technical or economic advantages. Although these two materials are sometimes complementary, at other times the design requirements associated with their use are conflicting. A correct appreciation of the interplay between these two concurrent developments is essential to a rapid stabilization of the most economical and satisfactory cable designs. Although the low cost of aluminium has for a long time justified its use in cables, the new techniques required for its processing, and the unknown factors involved in its service performance, have stood in the way of its adoption. A particular drawback has been the difficulty of jointing aluminium in its various forms compared with the relatively easy methods available for copper and lead. In recent times, however, these difficulties have been largely surmounted and aluminium has entered the field of telecommunications cables in many different applications both for land and submarine use. In view of the increasing cost and scarcity of both copper and lead, aluminium is assured of a continuing and, indeed, of an increasing field of application.

ALUMINIUM AS A CONDUCTOR

In power applications, the efficiency of power transmission is determined by the resistance of the conductors, and this in turn is related to the resistivity. Although the resistivity of aluminium is nearly 65 per cent greater than that of copper, the low price of this light material often makes its substitution for copper an economic proposition. Owing to the unequal current distribution which occurs in conductors at the higher frequencies involved in communications, the efficiency of transmission tends to be proportional to the square root of resistivity. At first sight, this fact would seem to suggest that in communications cables conditions are even more favourable to the use of aluminium than in power cables. However, in most cases the cost of the conductors is only a small proportion of the total material cost of the cable, and the enhanced size of the conductors leads to an increased overall size and to a greatly increased cost of the other component materials. This factor can be doubly important in the case of plastic-insulated cables, where the cost of the synthetic insulation is higher than that of the natural material which it supplants. In spite of these difficulties, there are already numbers of experimental applications for aluminium conductors, and the indications are that these usages will become established and will increase.[1]

The other physical properties of aluminium do not greatly hinder its use. It is only in exceptional and rare cases that the high thermal expansion coefficient is a hindrance. The natural oxide film formed on aluminium in air does not affect the electrical performance of the conductors, and as moisture must not be allowed to come into contact with the wires, there are no corrosion hazards under normal conditions. Under certain fault conditions in which water has entered the cable, some difficulty has been experienced with small-gauge conductors, because they have been quickly corroded through so that anomalous resistances have been established which have interfered with accurate fault location.

The problems of jointing these conductors in the factory and in the field have called for new or modified techniques, and these will be considered in a later section.

ALUMINIUM AS A WATERTIGHT SHEATH

On a cost per unit volume basis, aluminium has a clear case for consideration as an alternative to lead for sheathing cables. Although the cases where aluminium has been adopted are by no means inconsiderable, the change-over has not been universal because of the difficulties described below.[2,3]

There are three basic methods of providing a watertight covering in aluminium, and these are listed in the order of importance which they have achieved to date. It is not suggested that this order will be maintained in the future.

(*a*) The cable core can be inserted in an oversize extruded tube of aluminium which is then drawn-down, rolled or swaged so that it becomes a close fit on the cable core.[4]

(*b*) A tube is formed by folding a longitudinal aluminium strip around the cable core and by seaming the edges by cold pressure welding, by argon arc welding or by induction heating.

(*c*) An aluminium sheath may be extruded directly over the cable core.[5,6]

Discussing the first of the above methods, the cablemakers of this country are not usually fabricators of aluminium, and consequently they have to obtain their supplies of aluminium tube from the established aluminium suppliers. Apart from the high cost of forming into tube, which brings the semi-processed

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material cost to a figure which is from two to five times that of the raw material, the process has to stand the cost of the necessary drums and their transport to and from the aluminium supplier's plant. Many of the cable-makers' competitors on the Continent are more happily placed—because they are also suppliers of extruded sections in aluminium and operate the large presses necessary to produce the long lengths of tube required. Although many cable-makers have developed ingenious procedures to make the operation of sheathing semi-continuous, it yet involves considerable manhandling and remains intrinsically an expensive operation.

With the second method mentioned above, the semi-processed material in the form of strip is somewhat less expensive and transportation costs are considerably lower. On the other hand, the seaming process is essentially hazardous and any interruption of it is liable to initiate a fault. Although the seamed tube can be tested to detect faults and the chances of a faulty sheath passing into service can be substantially eliminated, the cost of the finished cable is increased by the re-processing involved in rectifying such faults.

Experimental work on direct extrusion of aluminium over cable has proceeded intensively since the war, and this work has been based on some preliminary experience gained in Germany just prior to the Second World War. At least five distinct designs of press have been tried, but it is still too early to say that complete success has been achieved. It is our impression that the more successful attempts were made in Germany. The most difficult problem still to be solved is the overheating of the cable core due to the high temperatures necessary to extrude aluminium satisfactorily. When this problem has been solved with paper-insulated cables it will remain to be tackled with cables covered with thermo-plastic materials.

Aluminium sheaths are sometimes compared unfavourably with lead sheaths in respect of stiffness. It is our impression that this is not very important with the smaller cables up to diameters of, say, 1 in. In fact, their very stiffness is often advantageous since it allows cables generally to be supported with fewer cleats and air-spaced coaxial cables to withstand crushing more satisfactorily. With the larger sizes, the stiffness of aluminium is burdensome when the cable has to be installed in a confined space. Work-hardening induced by the shrinking process does not help matters, but even super-purity material, which is initially soft, does not compare too well with the established lead-alloy sheaths. To avoid these difficulties, a number of designers have adopted a corrugated aluminium sheath.[7] One ingenious process based on this principle uses wall-thickness about one-half of those used on cylindrical sheaths. The major disadvantage of this solution lies in the increased diameter of the cable, and this can be prohibitive in certain cases where the cable has to be drawn into ducts.

Aluminium sheaths have one outstanding advantage over lead sheaths, namely, their ability to withstand severe vibration without damage.

The major factor which has retarded the general adoption of aluminium sheaths for line communications cable has been uncertainty as to their behaviour in service under corrosive conditions. In this respect the experience gained with power and radio-frequency cables over a number of years offers a clear lead. For underground cable, whether it be for direct burial or installation in ducts, the sheath must be provided with complete corrosion protection. In the early days, plant limitations precluded the application of extruded plastic sheaths to any but the smallest sizes of cable, and p.v.c. followed by hessian tapes were widely used for corrosion protection. More recently, developments in the application of plastics have enabled extruded sheaths to be applied to all sizes up to 3 in. outside diameter and in many cases such a sheath is cheaper than a taped covering, as well as being more reliable.

For cable installed above ground, the position is not so clear-cut, although many engineers recommend bare sheaths where they are not subjected to severe industrial and coastal atmospheres. Although we realize that the bulk of cable will stand up well to normal atmospheric conditions, we have encountered a number of cases of pinholing of sheaths and recommend that all sheaths should be provided with protective coverings. Our experience has been gained with pressurized, air-spaced, radio-frequency cables where the puncturing of a sheath is detected immediately by a loss of gas pressure in the system. In this matter, experience with overhead lines is not pertinent because there the presence of isolated pitting does not affect the service performance.

In the case of a high-grade cable, or of a cable providing an essential service, the cost of full protective covering can be tolerated but there are many marginal cases where the extra cost prevents the use of aluminium. We consider that there is an urgent need for a light and inexpensive protective covering, preferably applied simultaneously with the extrusion of the tube and not impaired by the sinking process. This would serve to protect the tube during transport and storage out of doors, and provide the additional margin of safety required with cable installed in air. We have found coverings which appear to meet the technical requirements, but we have not been able to devise a method of applying them without an additional process. Here is a requirement which must be placed squarely on the tube suppliers.

What improvements do we look for to increase the use of aluminium as a sheath?

The draw-down process suffers to some extent from the inability of tube suppliers to provide tube in which billet joints and stop marks are of the same high quality as the normal run of tube. Consequently, the lengths of tube available for use are limited to something less than can be produced from a single billet. We have evidence that in this matter certain continental producers are ahead of this country and are able to use tube in lengths which incorporate a considerable number of billet joints.

It seems certain that the maximum use of aluminium will be achieved only when direct extrusion over cable core is feasible. It is up to the aluminium suppliers in this country to provide every help to the cable industry and to the manufacturers of extrusion presses in order to hasten the date when that becomes possible. Otherwise the initiative will lie with our competitors overseas.

ALUMINIUM AS A SCREEN

In addition to the watertight sheaths, aluminium tapes, applied helically or longitudinally over the cable, are also used sometimes in balanced cable to provide a measure of screening between the cable conductors and the electric and magnetic fields outside the cable. These tapes may be used, for example, in all-plastic cables where immersion in water does not affect their operation, or in paper-insulated cable which is provided with a plastic sheath capable of reducing the rate of moisture diffusion to an adequately low level.

The electrical requirements for such screens vary considerably from design to design. In certain cases, they serve merely as an electrostatic screen and any continuous metallic covering will serve; in such cases even metallized paper can be used—say a 0·0005 in. aluminium foil glued to a 0·0025 in. paper.

If a good magnetic screen is required, the aluminium sheath or the longitudinal tape screen is usually adequate at high frequencies, but the tape screen may require additional iron screening at low frequencies. The helically-applied tapes are not very efficient magnetic screens and are particularly poor at high frequencies. There are two reasons for this. The helical path followed by the tape is inefficient so that the direct-current resistance is high; it also introduces reactance into the screen circuit and this prevents the appropriate screening currents being induced at high frequencies.

In other cases the screen is intended to act as a low-impedance path for neighbouring lightning strokes or as a return path for other earth currents, and must be capable of carrying heavy currents without overheating. Here the direct-current resistance is a good criterion of performance and the aluminium sheath compares very favourably with the equivalent lead sheath.

The mechanical requirements for these screens are not onerous, because tapes are not normally used where high flexibility is required. The helically lapped tapes are intended to slip when the cable is bent, but some creasing and cracking may be experienced if the thicknesses are less than, say, 0·004 in. Longitudinally applied tapes are usually corrugated for cable diameters above, say, ½ in., but this depends upon the particular conditions of use.

ALUMINIUM AS AN ARMOUR

Paradoxically, the most important contribution made by aluminium in the field of armouring lies in removing the necessity for such armouring. The aluminium sheath is so much harder and tougher than the lead sheath that in many cases one can dispense with wire or tape armour.

The use of aluminium-alloy armour for submarine communications cables has been investigated from time to time, but so far appears to be uneconomic. For deep-sea cable, the requirements of high tensile strength and small size are best met by the use of high-tensile steel wire, whilst for shore ends resistance to abrasion is important and great weight is in fact advantageous; consequently, medium-strength steel remains the obvious choice. If the economic position changes, or if applications requiring low electrical resistance or non-magnetic armour arise, then the new practice of covering each individual armour wire with p.v.c. will help to make acceptable the choice of aluminium alloy.

THE JOINTING OF ALUMINIUM

The jointing of aluminium is considered here only in its relation to telecommunications cables, and certain techniques applicable only to large aluminium conductors are excluded.

Wire

Wire joints have been largely confined to three methods: cold pressure welding, ultrasonic soldering, and arc welding on a variation of the Post Office twist joints used with copper conductors. In addition to joints between aluminium conductors, it is often necessary—especially with subscribers' distribution and minor trunk cables—to joint aluminium to copper conductors. The first two methods mentioned above are suitable for both these applications.

Cold pressure welding may be used in several ways, the simplest of which is to make a butt joint between the two conductors, using a hand tool. As a variation on this, the two wires may be twisted together and the tips of the twist pressure welded, or a specially prepared sleeve may be crimped over the wires to form a compression joint. For cold pressure welding to be effective, strict cleanliness of the wires is absolutely essential. This is not always possible in the field, especially within the limited space of a manhole. For this reason cold pressure welding has not so far made much headway in field jointing.

In ultrasonic soldering, the aluminium wires are pretinned on site by dipping into a solder bath, which is vibrated ultrasonically to break up the oxide film. The wires may then be soldered conventionally. In a method used by the British Post Office, the wires are first twisted together over about 1 in. and the tip of the twist is dipped into the vibrating solder bath. This method requires the provision of an ultrasonic generator run from a 230-volt supply and therefore is inconvenient for field use.

Arc welding has also been used by the Post Office[8] for jointing the tips of the twisted aluminium wires. The method is simple and easy to apply and may be used in the field. A 24-volt battery of secondary cells, such as is normally used for lighting jointing chambers, is used for the power supply. A pair of conventional pliers, connected to the negative terminal of the battery, is used to grip the twisted wires near the tip. The positive terminal is connected to a carbon rod which is brought momentarily into contact with the tip of the wires; the passage of the high current melts the ends of the wires and produces a blob of aluminium at the tip. The carbon rod is enclosed in an insulating holder which effectively shields the jointer's eyes from the intense light of the welding arc.

Tape

The jointing of aluminium tape is usually required only in the factory. The only practicable methods available at present are cold pressure welding and resistance spot welding—both of them skilled processes requiring great cleanliness for success. Conventional soldering, using one of the aluminium fluxes available, is not successful as the tape tends to be unduly weakened by the high temperatures involved.

Tube

When aluminium is used as a tube to provide a watertight sheath over a cable, it is essential that this watertightness shall not be impaired by the joints. In applications such as this the jointing difficulties are increased when plastic materials are used for the insulation, because the highest temperatures which they can withstand are very much lower than the temperatures required for plumbing.

Although many and various fluxes are available which are alleged to render the plumbing of aluminium no more complicated than that of lead, it is our experience that all such fluxes suffer inherent disadvantages. They are excessively corrosive and no telephone administration welcomes the use of a corrosive flux on telephone cables, especially as it is almost impossible to ensure that all traces of the flux are removed after jointing. Furthermore, the plumbed joints themselves constitute a corrosion hazard due to possible bi-metallic contacts and must therefore be kept dry.

Mechanical joints seem to offer the most promising method to date, but they will probably never be acceptable for long carrier telephone lines because of the fear that they may become noisy with time due to the formation of the oxide film. This effect might be increased by vibration due to traffic, for example. They have, however, been used extensively in radio-frequency feeders and similar cables where the lengths involved are relatively short so that the number of joints and terminations is limited. The mechanical joints we favour rely on the principle of forcing a stepped steel ring to bite into the aluminium surfaces under pressure from a screwed cap. They tend to be awkward to assemble and their success depends upon accurate dimensioning of both cable sheath and ring. Probably the neatest solution would be to apply cold pressure welding techniques to the jointing of a tube, if that became possible. Until some such method is evolved aluminium will not be an attractive substitute for conventional constructions in long-distance carrier telephone cables.

SPECIFIC APPLICATIONS

Land Lines

Probably the most interesting application in this field is an experimental cable recently installed by the British Post Office between Dover and Deal.[8] This cable is of conventional star-quad construction in which 20 lb copper conductors (0·036 in. diameter) are replaced by 0·044 in. diameter aluminium conductors having the same d.c. resistance. The main and spur cables contain 54 and 28 pairs, respectively. The cables are paper insulated and two open helical lappings of 0·002 in. aluminium tape are applied over the cores. This tape is included to stabilize the capacity of the cores to earth and to facilitate the testing of the polythene sheath which is extruded overall (Fig. 1).

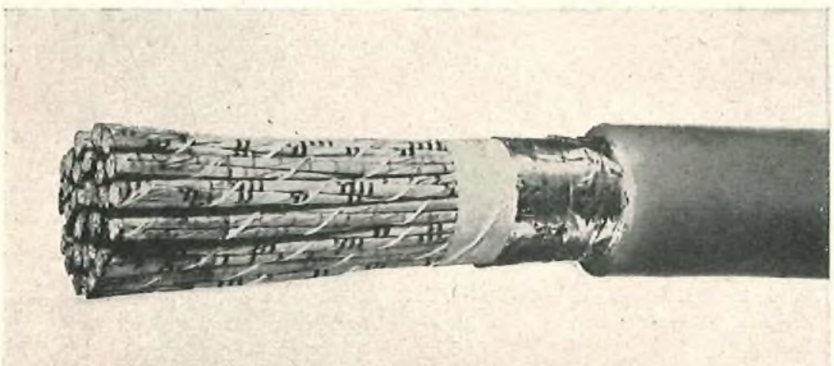

FIG. 1—EXPERIMENTAL CABLE WITH ALUMINIUM CONDUCTORS, PAPER INSULATED, LAID BY THE BRITISH POST OFFICE BETWEEN DOVER AND DEAL

An interesting comparison between the weights and costs of materials in the experimental cable and in a conventional copper lead cable is shown in Tables 1 and 2. It is seen that the experimental aluminium cable is only about one-third the weight of the corresponding copper/lead cable, and costs about 30 per cent less; the prices of materials quoted are those current in early 1955. It should be noted that production costs are likely to differ for the two types, and this may affect the result slightly.

TABLE 1

Weight of Components in a 1 ft Length of Cable

54 pr/0·044 in. Experimental Cable			Standard 54 pr/20 lb P.C.Q.T. Copper-Paper-Lead Cable		
	Weight Grams	% of Total Weight		Weight Grams	% of Total Weight
Polythene sheath	96·6	41·3	Lead sheath	462·0	67·8
Aluminium sheath	6·8	2·9			
Aluminium wire	89·1	38·1	Copper wire	190·2	27·9
Paper and cotton	41·5	17·7	Paper and cotton	29·0	4·3
Total	234·0	100·0	Total	681·2	100·0

Relative weights 1 : 2·9

TABLE 2

Relative Cost of Cable Components (Materials Only)

54 pr/0·044 in. Experimental Cable		Standard 54 pr/20 lb P.C.Q.T. Copper-Paper-Lead Cable	
Polythene	60	Lead	61
Aluminium screen	3		
Aluminium wire	35	Copper wire	100*
Paper and cotton	14	Paper and cotton	10
	112		171

* Arbitrarily assigned as 100 for purpose of comparison
Ratio of values = 1 : 1·52

In addition to this Post Office experiment, 14-pair and 28-pair carrier quad cables with aluminium conductors insulated with polythene have been tried out experimentally for the armed services. The conductor size is 0·064 in., equivalent in d.c. resistance to 40 lb copper conductors. Two helical aluminium tapes are used for screening. These cables can be handled in half-mile lengths on drums and weigh about 50 per cent of a conventional armoured cable of lead, copper and paper.

In America, aluminium has been used extensively to replace lead as the outer screen and sheath in certain types of paper-insulated cables. This development started during the last war when lead was both scarce and expensive. The best known applications are probably those of Alpeth, Stalpeth, and P.A.S.P., in which aluminium is used in various combinations with steel and polythene. In these cables, the aluminium is usually applied as a thick longitudinal tape with overlapping seam in order to make the best use of it as an electromagnetic, as well as an electrostatic screen. To give larger cables sufficient flexibility so that they can be bent, the tape is transversely corrugated before application. As the tape is not in itself watertight, some form of overall sheath is required. One way of providing this (Alpeth)[9] was to flood the aluminium screen in a plastic (polyisobutylene) cement and then to extrude an overall sheath of polythene (Fig. 2); thus, the aluminium tape is very effectively protected from corrosion. In the Stalpeth[10] construction, a corrugated steel (terneplate) sheath with a longitudinal soldered seam was applied over the aluminium screen and the overall polythene sheath was extruded without the polyisobutylene cement. In the P.A.S.P. construction the aluminium screen was applied over a polythene-sheathed core and was then protected by steel and polythene as in the Stalpeth

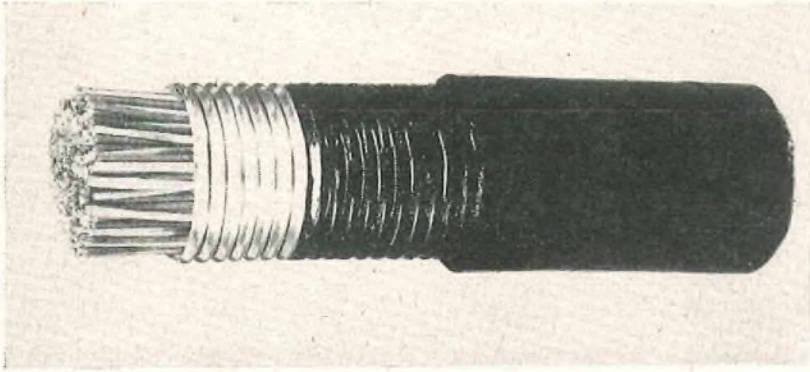

FIG. 2—ALPETH CABLE, MANUFACTURED IN AMERICA, SHOWING CORRUGATED ALUMINIUM LAYER, PLASTIC CEMENT AND POLYTHENE SHEATH

construction. The object in all these designs is either to eliminate, or reduce to an acceptable low value, the rate of moisture permeation into the paper insulation.

Submarine Cables

Aluminium has been used as the return conductor on the new lightweight, armourless, submarine coaxial cable[11] at present under development with the British Post Office: it is applied in the form of long-lay helical tapes 0·015 in. thick. In this design the tensile member is a steel strand inside the inner conductor which is a tube of copper tape. The insulation is solid polythene. Corrosion protection, in the form of a fabric tape impregnated with barium chromate, is provided over the aluminium and there is a thin polythene sheath overall.

Although in this particular design the aluminium is not required to contribute to mechanical strength, designs have been considered in which the tapes could be of hard aluminium alloy of tensile strength sufficient to support the cable.

Radio-frequency Cables

In radio-frequency cables, aluminium has made a more important contribution than in any other field of telecommunications. In the form of a seamless tube over an air-spaced centre conductor, it is well known in its application to radio and television feeders both in this country and abroad. In Germany and the U.S.A., styroflex is used in helical lappings to support the centre conductor inside the tube. In this country, polythene or polytetrafluorethylene, in the form of a helix cut from a thick-walled tube and wrapped around the conductor edge-on, is used in our own helical membrane cable (Fig. 3). Similar constructions, using a wrapped polythene tape, have more recently been developed in Germany and in this country.

The outstanding advantage of aluminium in many of these applications is its lightness, especially for very-high-power feeders. The Germans have produced a feeder having a diameter of 6½ in. over the aluminium sheath: the largest produced to date in this country is the 3⅛ in. diameter feeder (coded HM 10) manufactured by our own company. Previous feeders of equivalent power-handling capacity have been of the built-up type and are both costly and time-consuming to erect. In order to avoid the slipping which may occur with an extruded corrosion protection, HM 10 cable is given several coats of p.v.c. paint after erection. In this way it is possible to protect the cleats as well as the cable at clamping points.

Accessories

Aluminium accessories in the form of connectors, mechanical joints and cleats for radio-frequency cables are very well known. Less well known are the aluminium

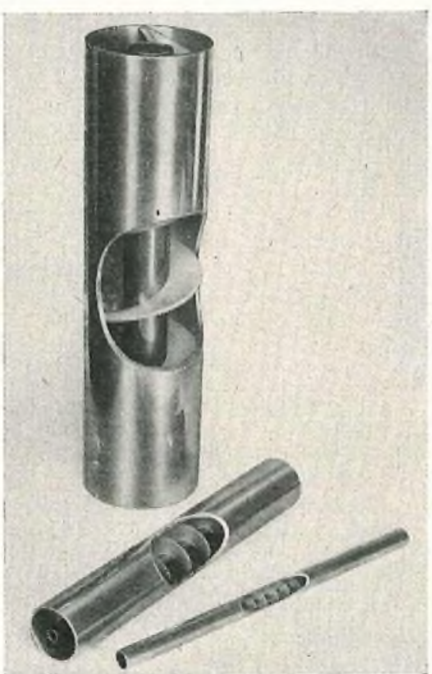

FIG. 3—HELICAL MEMBRANE CABLES WITH ALUMINIUM SHEATH AND POLYTHENE INSULATION, SHOWING RANGE OF SIZES FROM 3·125 IN. OUTSIDE DIAMETER TO 0·475 IN. OUTSIDE DIAMETER

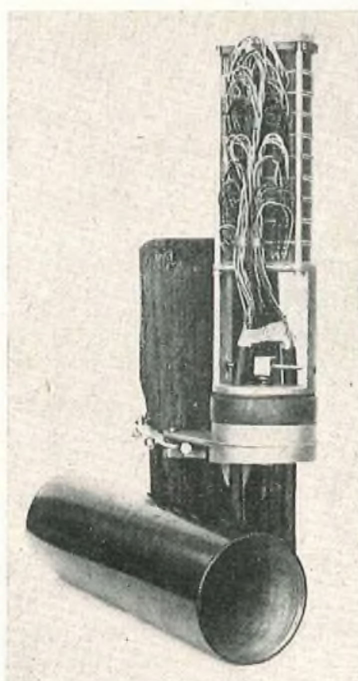

FIG. 4—ALUMINIUM LOADING COIL CASE AND FITTINGS FOR POLE MOUNTING

jointing and loading cases designed for use with either conventional plastic telephone cables or cables containing aluminium. Both our company and the Sterling Cable Company supply jointing cases in aluminium, ours being fabricated from aluminium tube and those by Sterling being special castings. Previous materials used have been either iron or brass. The boxes are of the expanding-plug type used by the British Post Office[12] and may be either buried direct in the ground or pole-mounted for use with aerial cables.

Loading-coil cases have also been designed on the same principle and used for a loaded voice-frequency telegraph aerial cable installed recently. These are pole-mounted by means of cast aluminium brackets, which also serve as the lower pressure plates for the expanding-plug assembly. The tops of the aluminium covers are argon-arc welded and the entire cover is protected by a coating of about 0·03 in. of black polythene. The brackets are left unprotected as they are sufficiently massive to stand a small amount of corrosion. All bolts and loose parts (e.g., compound-filling plugs) are cadmium plated and passivated. A typical assembly is illustrated in Fig. 4.

CONCLUSION

It is of interest to survey briefly the field of telecommunication cables and to forecast roughly where aluminium is likely to make its most important contribution in the future. It is fairly certain that it will be used more extensively for conductors than it has been in the past, especially for local cables (e.g., subscribers' distribution, etc.), which account for many thousands of tons of copper and lead annually. It is in this type of link that aluminium will probably make its most important contribution, where it is effectively protected from corrosion and where its jointing problems have been solved in practice. For broadband carrier telephony over air-spaced coaxial cable, aluminium is likely to remain unattractive as a sheathing material until a simple non-mechanical joint has been developed and a completely effective corrosion protection has been found. In specialized fields, such as those of radio and television feeders and high-power transmitters, aluminium will certainly continue to play a very important part largely as an efficient sheathing material but in some abnormal situations perhaps even as a centre conductor as well.

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Book Reviews

"Electricity in Building." A. L. Osborne. B. T. Batsford, Ltd. 160 pp. 91 ill. 25s.

This book is about the provision of electrical services in domestic and commercial buildings and buildings for light industry, written by an architect "in conjunction with the British Electrical Development Association" for the benefit of other architects and builders. After treating electrical supply, distribution, wiring and control gear and their relationship to the structure of a building in just over half the book, the author goes on to chapters on lighting, heating and water heating. The treatment of heating gives the false impression that this is now primarily an electrical service. Omission of means more primitive than electricity for lighting is, of course, no loss and this clear, concise chapter makes a valuable introduction for an engineer. Similar chapters on lifts and forced ventilation would have improved the book. As the author says: ". . . . improved systems are not likely to be developed until structural engineer, architect and electrical engineer become more closely aware of each other's requirements and problems."

The author is careful not to advocate "do-it-yourself" but much of the information will be valuable to members of that school who will probably find the book in the local library. For them there are pitfalls such as the statement that: "A person can receive an electric shock only when he is in effective contact with earth . . . .".

No one should be in doubt about the telephone: "It is always advisable to discuss the matter with the telephone engineers at an early stage of the design when their services are required within a building".

The publisher has made a good job except for the title which suggests the use of electric tools for building construction. Paper, print and illustrations are first rate.

I.P.O.E.E. Library No. 2478. D. J. H.

"The Theory of Networks in Electrical Communication." F. E. Rogers, A.M.I.E.E. Macdonald & Co., Ltd. 560 pp. Illustrated. 65s.

The writing of books about network theory is now becoming so popular, particularly in America, that it might almost be classed an occupational hazard for those concerned with the subject. Much of the credit for this situation is no doubt due to the inspired lectures and publications of Professor Guillemin at the Massachusetts Institute of Technology, which have done so much to spread a deeper understanding of networks from the standpoint of the theory of functions of a complex variable. Most of the recent books to appear have all had very much the same content and the general level has been quite high.

It is therefore rather disappointing to find the latest book, by Mr. Rogers, falling short of this standard. Intended for students in the final year of a degree course the book deals

(*Continued on p. 28*)

The Jointing of Polythene-Insulated Coaxial Cables

G. HALEY, B.Sc.(Eng.), A.M.I.E.E., and J. E. H. COSIER†

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Special equipment and techniques have been developed for making joints in polythene-insulated coaxial cables to meet the very rigorous requirements of joints in submarine cables. This article describes the method adopted for making brazed butt joints in the centre conductor of coaxial cable, and the equipment developed and techniques adopted for making the moulded polythene joint in the insulation of the cable core. The quality of the joints made is illustrated by reference to the specification requirements that were satisfactorily met in joints made in the British section of the transatlantic telephone cable.

INTRODUCTION

ALTHOUGH a limited number of polythene cables had been in use since 1940, the advent of such cables, largely as submarine coaxial cables, began on a large scale with the cross-Channel D-day installations. Since then there has been a rapid development in the use of these cables, concurrently with the introduction of submerged repeaters in many of them.

The need for highly reliable jointing methods was accentuated by the relatively high voltages applied to cables containing repeaters, and much of the work described in this article has been carried out with these requirements in view.

In all branches of engineering, a basic ideal is that any joint shall be at least as good as the parent material. In the manufacture of polythene cables the insulant is extruded over the conductor at a temperature above its softening point and jointing involves means for replacing in a completed cable the section of insulation necessarily removed during the conductor-jointing operations. The method normally adopted for replacing the insulation is basically one of making an injection moulding over the conductor joint in such a manner that the moulding unites with the original cable insulation to form a homogeneous structure.

Earlier Methods of Jointing

With the earlier polythene cables, jointing methods had largely followed those which proved satisfactory for the previous cable insulants (gutta-percha, paragutta, etc.). Such joints consisted of sheets of material built up in layers over the conductor and the tapered ends of the core insulation. These sheets were bonded together and to the core insulation by the application of heated tools. Conductor joints were generally soft soldered. Several excellent methods of making these joints have been developed and many such joints are in service in telegraph and telephone cables throughout the world.

The quality of hand made joints is entirely dependent on the craft of the jointer and there are inherent difficulties when polythene is used, due to the oxidation of the material and the general difficulty of controlling molten polythene. Additionally, such joints frequently contain many air spaces, which render them most unsuitable for submarine repeatered cables carrying high d.c. operating voltages.

Injection moulding was introduced to overcome these difficulties and an immediate and very real improvement resulted. The earlier machines for this work, however, were found to have serious limitations, as it proved difficult to obtain a completely homogeneous structure in the joint and the designs of the moulds were such that joints were liable to contain air inclusions, or voids. The physical dimensions of the machines were also a serious handicap in many applications.

The introduction of harder grades of polythene necessitated higher working temperatures and injection pressures, which resulted in charring of the polythene and excessive "flashing" of material between the faces of the mould. A wide range of polythene cables is now in existence and many variables occur in the diameter, grade of polythene, plasticizer and anti-oxidant employed, the method of application, and make up of the conductor; all of which demand some variation of the jointing techniques.

A machine which it is believed will meet most current and many future requirements has been developed and is described in this article.

JOINTING OF CONDUCTORS

Past experience has shown that many soft-soldered and scarfed joints part during laying or recovery operations, continuity across such joints being provided by a helically applied lapping of fine copper wire soldered to the conductor only at the ends of the helix (known as a safety wire). Experiments showed that brazed butt joints would give breaking strains of at least 95 per cent of that of the unjointed conductors, with very good elongation and having the ability to withstand a far greater amount of bending, at very small radii, than would ever be experienced in practice. Also a brazed joint can be made much more quickly without the use of corrosive fluxes and with only localized heating. This is important, as the cable insulant is readily damaged by the application of excessive heat to the conductor joint.

By the use of resistance heating, the jointing process can be reduced to a simple operation, resulting in joints of highly uniform quality. The unit to perform

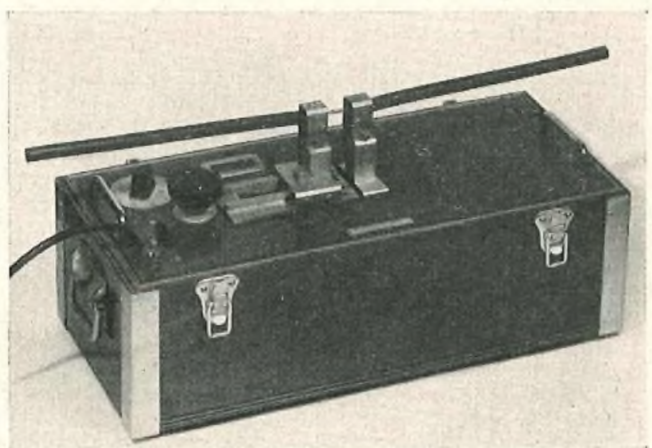


FIG. 1—BRAZING UNIT

† The authors are, respectively, Senior Executive Engineer, Factories Dept. (formerly Executive Engineer Post Office Research Station), and Assistant Engineer, Post Office Research Station.

this brazing operation (Fig. 1) was, in common with the other items to be described later, designed to be as light as possible, portable and sufficiently robust to withstand the rigours of marine and field conditions. The conductor to be heated is held between two clamps connected to the opposite ends of the low-voltage secondary winding of a transformer. When the ends of the conductor are brought in contact and the transformer energized, a very heavy current flows and the conductors are rapidly heated. The primary winding of the transformer is tapped, and a tapping to give a suitable heating current for the work can be selected by a heavy-duty rotary switch. Currents of the order of 4,000 amp have been measured in the secondary circuit during the jointing of heavy conductors.

A range of accurately aligned jaws are provided to grip the conductor and make connexion to the secondary winding of the transformer. One jaw is movable on a machined slide by means of a lead-screw, and so permits different lengths of joint to be made. These jaws also act as thermal shunts to control the flow of heat along the conductor. It has been found that if the temperature of the conductor rises unduly during the brazing operation, softening of the polythene at the cable ends will occur and this in turn is a known cause of voids in the joint. For heavier conductors, where the protracted heating times and higher thermal conductivity of the conductor make this difficulty serious, cooling water is circulated through the jaws.

The conductors are brazed together using a silver phosphorous brazing alloy which has the important advantage of requiring no flux for copper-to-copper joints. The melting range of the brazing alloy is 625–780°C and in practice it is only necessary to use a temperature slightly in excess of 780°C for a very short time to produce a completely satisfactory joint of good brazing-alloy penetration.

The cable-core ends are prepared in the following stages:

(*a*) Removal of the polythene. For this operation a small pipe cutter of the three-wheel type is used. By this means the polythene can be cut without damage to the conductor.

(*b*) Removal of filling compounds. In some of the earlier cables, Chatterton's compound was used to fill the interstices between the conductor and tapes, and experience has shown that this should be cleaned off before brazing, by means of a solvent such as Xylene.

(*c*) If the conductor is of composite construction, i.e. taped or stranded, the complete conductor of each cable end is, in turn, held between the brazing jaws so that a preformed sleeve of brazing alloy may be melted into the interstices of the conductor. The conductors are then cut through at the centre of the solidified zone and each end is then ready for jointing in the same way as a solid conductor.

(*d*) The conductor ends are filed square, accurately aligned in the jaws and pressed together with a suitable insert of brazing alloy between them. The passage of the heating current fuses the alloy and unites the conductors. The correct amount of brazing alloy to give maximum strength and minimum increase of conductor diameter is determined for each conductor size. Preformed pieces of brazing alloy are prepared from 0·005 in. or 0·010 in. sheet.

Discoloration, caused by slight oxidization of the conductor, is inevitable but experience has shown that the practice of removing such discoloration by abrasive methods tends to leave loosely adhering particles which migrate into the moulding during the later stages of the jointing work. These can cause the final moulding to fall below the very high standards of cleanliness and freedom from foreign matter which are required.

In certain cases it is necessary to ensure that, should water enter the cable at any point, any tendency for it to travel along the interface of conductor and insulation shall be arrested. For example, it is desirable to guard against this possibility occurring along the cable in the vicinity of a submerged repeater. This is achieved by brazing the ends of the conductors into a copper castellated ferrule. When polythene is moulded over this a hydraulic seal is formed similar in principle to the cable gland used on submerged repeaters. The use of such a ferrule is illustrated later, in Fig. 5(*c*), when considering typical joint profiles, in the section dealing with the moulds.

Ferrules are also used on stranded conductors of large effective diameter, and in some cases the castellations on the ferrule may be omitted.

DESIGN REQUIREMENTS OF A MOULDING MACHINE

It has been found that, in general, a satisfactory injection moulding machine for polythene must have the following features:

(*a*) A heating section in which a charge of polythene is heated to a suitable temperature ready for injection into the mould.

(*b*) A mould in which the cable to be jointed is held, with the conductor under tension, so that the polythene may be replaced. It is necessary that the ends of the existing polythene insulation shall be softened by preheating the mould prior to injection of the replacement polythene. The extent of the heated zone is controlled by the circulation of cooling water in the ends of the mould, together with air cooling by means of fins.

(*c*) An injection-ram system to force the heated polythene into the mould. A hydraulic ram and hand pump have proved to be a convenient way of performing this function.

Electrical control gear for the heaters, and temperature indicators are important auxiliaries, while a water-circulating pump and header tank are desirable to permit operation away from piped water supplies.

While the size of the individual items is fixed, the arrangement of units is capable of variation, and consideration of the envisaged uses of the machine showed that a design should provide:

(*i*) Individual units of such size and weight that they can be handled in any circumstances by two men. The severe requirements of jointing work on cable ships influence this feature—jointing equipment sometimes has to be loaded into open boats and used on exposed beach positions. At the same time robust construction is essential.

(*ii*) A machine capable of making joints in cable held within a few inches of the floor with not more than 24 in. of cable available to the machine. (The earlier types of shallow water repeater first produced this limitation but it is frequently important in other applications that the amount of cable in the machine shall be kept to a minimum.)

(*iii*) A machine capable of easy and rapid maintenance and cleaning on site. Again, this feature was influenced

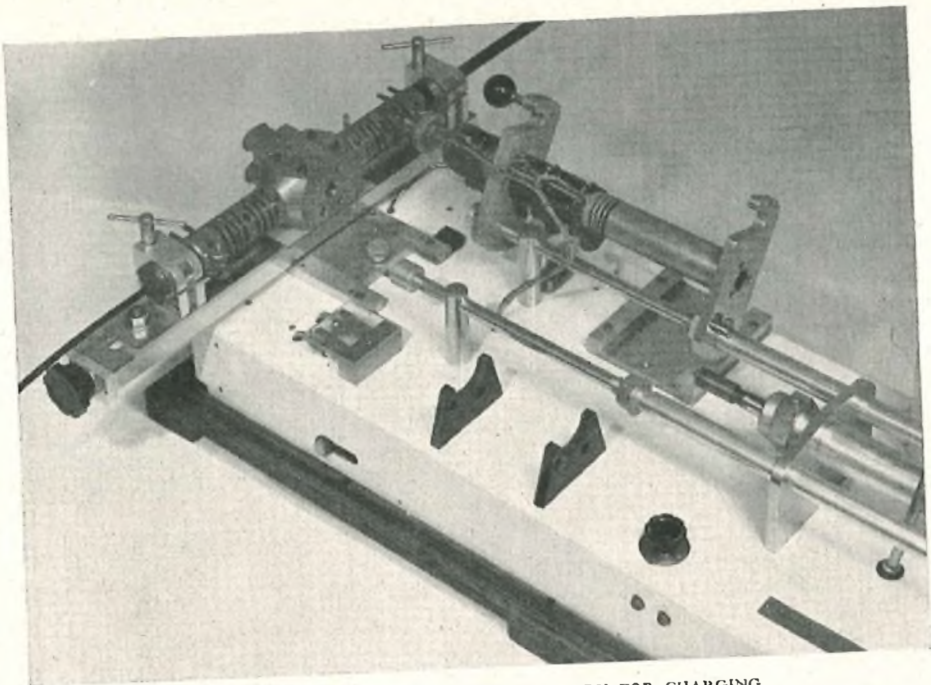


FIG. 2—JOINTING MACHINE. BARREL READY FOR CHARGING

by the knowledge that the machines would be used in very inaccessible parts of the world.

(*iv*) Adequate control and indication of process temperature, injection pressure and conductor tension. This is necessary to cater for the present wide range of cables, and it is to be expected that the range will continue to increase.

The design and construction of a small number of machines to meet the above requirements was undertaken at the Post Office Research Station, the later stages of design being influenced by the decision to use them for the jointing work on the Newfoundland land section of the transatlantic telephone (T.A.T.) cable scheme. This particularly influenced the portability and the provision of adequate filtering in the water-circulating unit to permit operation from any water supply.

DESCRIPTION OF THE MAIN MACHINE UNIT

The main unit of the machine comprises an aluminium chassis mounted on a wooden base and fitted with the polythene heating cylinder with its associated breaker plate and nozzle, the hydraulic ram, the mould assembly and the conductor clamping and tensioning equipment. A wooden cover fits over the whole chassis for use during transit and may be used as a work table to set the machine at a convenient height for general jointing work. Spare parts are carried in a compartment inside the cover.

The polythene - heating cylinder (generally referred to as the barrel) is used to heat cylindrical charges of polythene, usually $\frac{13}{16}$ in. diameter and 4 in. long, and is carried on a cross-head, which in its working position is constrained by tension members secured to the hydraulic ram unit. To charge the cylinder, this assembly is rotated on one of the tension members (Fig. 2).

The barrel is heated by two band heaters clamped round it near the delivery end. Heating of the other end is reduced by the provision of deep grooves (visible in Fig. 3) which serve to reduce the thermal conductivity from the heaters towards the open end of the barrel.

As a result of its low thermal conductivity, polythene is extremely difficult to heat uniformly in mass and the material heated in the barrel tends to be unevenly heated. It is therefore arranged to pass the partially

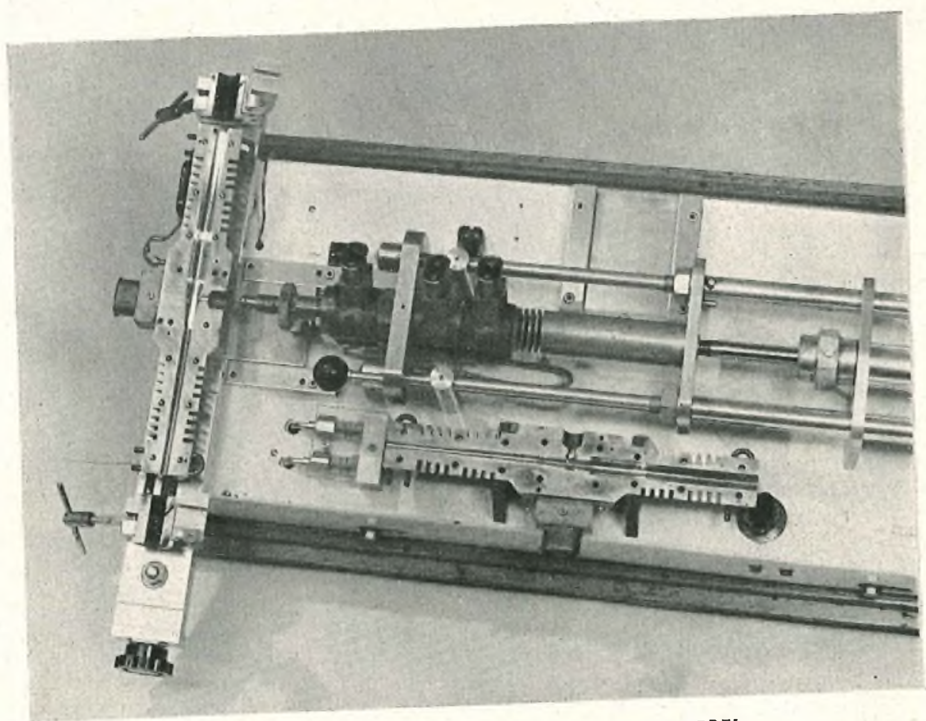


FIG. 3—JOINTING MACHINE SHOWING CLOSE-UP OF BARREL

heated polythene through a heated breaker-plate system. In this the polythene is broken up into three ribbon-like streams, each about ½ in. wide and $\frac{1}{16}$ in. thick, which are subjected to additional heating to working temperature by a third band heater clamped around the breaker plate.

These three streams are reunited in the conical aperture leading into the injection nozzle. The form of the breaker-plate aperture and nozzle are all inter-related and considerable effort was involved to ensure that uniform heating and complete recombination of the polythene takes place. The conventional form of breaker plate is a heated plate with axial holes through which the plastic material is forced. These plates are very difficult to keep clean and the present design used in this machine has proved to be a considerable improvement, both in respect of the cleaning and in operation. As may be seen in Fig. 4 the centre is removable for cleaning purposes.

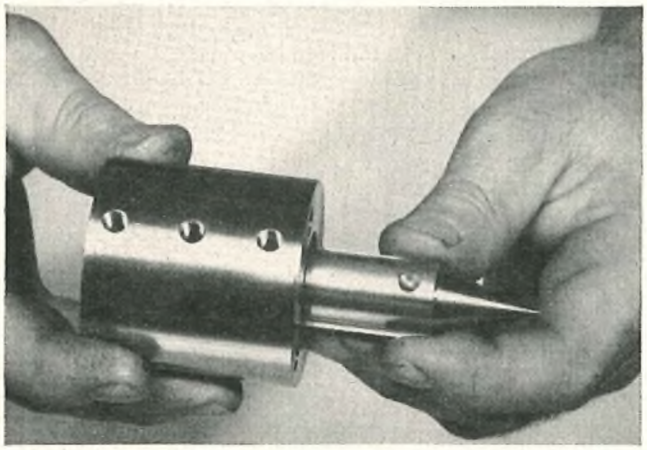


FIG. 4—BREAKER PLATE

The nozzle is fitted into the mould by a cone and socket joint, retained by a sleeve nut. This nut has a nylon skirt to provide thermal insulation to permit preliminary tightening with the fingers. The screwed connexion between the nozzle and the mould ensures that the force resulting from the injection pressure on the molten polythene is carried in the nozzle and not in the chassis. The design of the mould is dealt with in a separate section.

The Hydraulic Unit

The thrust required for injection purposes is developed by a hydraulic ram operated by a small hand pump housed within the chassis. The ram is of the double-acting type and a change-over valve is provided so that the ram may be retracted from the barrel for charging purposes.

Hydraulic pressures up to 1,000 lb/in^2 may be obtained, and the pressure on the polythene in the barrel is 2·86 times the hydraulic pressure, which is indicated on the gauge fitted on the chassis. Considerable difficulty was experienced with the proprietary type of change-over valve originally used, and so the present type was designed and manufactured specially for this purpose. By avoiding the use of coupled needle valves a considerable increase in simplicity and reliability has been obtained. In the valve used the only moving part is a piston which carries five synthetic rubber "O" rings and may be set in either of two positions. The necessary hydraulic circuits are obtained by interconnexion of the cylinder ports via grooved sections of the piston.

THE CONTROL UNIT

The control unit is contained in a separate transit case and includes the switches, fuses, energy regulators and indicator lamps for the various heaters; together with the water-pump switch and fuses and also the temperature-indicating meter and its selecting switch.

Power for each heater is controlled by an energy regulator which is a bi-metal-strip switching device, the make/break ratio of which is continuously variable and is controlled by rotating the external knob. The energy regulator dial is graduated in percentage "make" times.

The shunted indicator lamps are in series with each heater unit in order to provide continuous indication of the satisfactory operation of the heaters.

The temperatures at the mould, breaker plate, and barrel-heating zones are measured by thermo-couples, the connexions to which are routed from the machine chassis via a multi-core flexible cable that is terminated on a 6-position switch in the control unit. By this means the temperature of any zone is read directly on the temperature-indicating meter.

THE WATER CIRCULATING UNIT

In order that the equipment may be used away from piped water supplies, a water pump unit is employed to provide cooling water for the mould. This unit consists of a small tubular-steel framework housing a four-gallon tank, a filter unit and an electrically driven centrifugal pump to circulate water through the mould and back to the tank. The pump is mounted underneath the tank so that it is self-priming, and the filter is in the feed line from the tank to the pump.

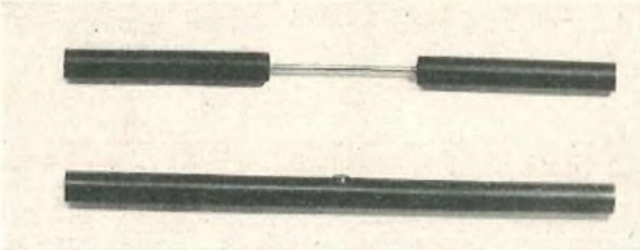
The pump unit is connected by two hoses to the main machine chassis on which is fitted a shut-off valve, flow indicators and push-on connectors for the small-bore tube connexions to the mould. The flow indicators consist of a pair of Perspex tubes, each containing a spindle carrying a brass helix. The spindles are mounted in nylon-bearing blocks having axial holes through which the water flows thus causing the helixes to rotate as a visual indication that sufficient water is flowing to the mould.

THE MOULDS

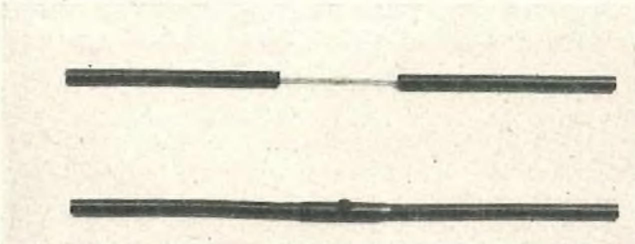
The moulds used on these machines have been standardized in respect of external fixing dimensions and cooling arrangements.

In order to obtain complete bonding of injected polythene and the cable ends, it is necessary to pre-heat the central portion of the mould to ensure that the polythene on the cable ends is at approximately the same temperature as the injected material. It is further necessary that the cable core at the ends of the mould shall not be heated and water cooling is used at these points. This is achieved by circulating water through water-ways drilled in the ends of the mould.

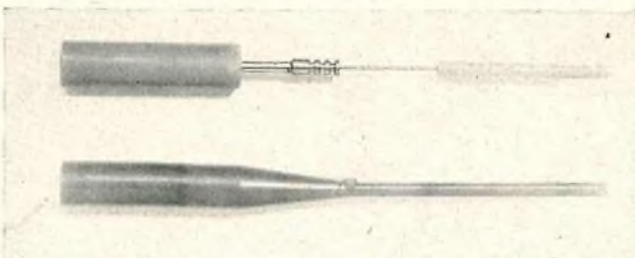
This arrangement also satisfies the essential requirement that the mould shall cool from the ends towards the centre, so that the injection point is always the hottest point. A further requirement is that the temperature gradient between the central, heated part of the mould



(*a*) 0·620 in. to 0·620 in. diameter joint



(*b*) 0·310 in. to 0·310 in. diameter joint



(*c*) 0·935 in. to 0·310 in. diameter taper joint using ferrule

FIG. 5—THREE JOINT PROFILES

and the cooled ends shall be as uniform as possible. This is achieved by a series of grooves of graded sizes machined into the mould itself. In this way the thermal resistance between the heated and cooled zones is increased and a certain amount of air cooling is also obtained through the fins formed on the mould.

The details of the bore and central region are varied for each type of joint. To illustrate some of these considerations, three typical joint profiles are shown in Fig. 5, and Fig. 6 shows the lower half of a mould for 0·620 in. to 0·310 in. diameter joints.

Fig. 5(*a*) shows a 0·620 in. to 0·620 in. diameter joint profile (as used in the T.A.T. cable). Here the conductor is butt brazed with no increase in diameter, and hence the moulding can be kept to the diameter of the core whilst preserving the same radial thickness of insulant. The distance between the shoulders of the joint prior to moulding is 4 in. and vent valves are placed at the shoulder points to facilitate expulsion of air necessarily contained in the mould prior to injection.

Fig. 5(*b*) shows a 0·310 in. to 0·310 in. diameter joint profile. Here the stranded conductor is butt brazed but the solidification of the strands produces a slight increase in diameter. To compensate for this and the difficulty of obtaining complete concentricity, the central region of the mould is increased in diameter, in this case by 0·065 in. Again the vent valves are located at the shoulders, which are $2\frac{1}{4}$ in. apart.

Fig. 5(*c*) shows the profile of a 0·935 in. to 0·310 in. diameter taper joint. The large diameter ratio of the two cables calls for careful positioning of the injection point, which in this case is at the 0·310 in. end of the taper. Experiment has shown that in this particular case, if the injection point is at the centre of the taper, voids form in the 0·310 in. core, due to the failure of the "make-up" polythene to compensate for contraction in the 0·310 in. region during the cooling of the injected material.

In all cases it is important that the injection port should blend smoothly with the mould profile in order to prevent undue residual stresses in the moulding. To achieve this, the radiused profile where the port enters the bore is carefully scraped by hand and polished.

The required mould for any particular joint is fitted to the tensioning beam. This in turn is carried on a slide which engages with corresponding slide members on the machine chassis. By this means the mould can be brought into engagement with the nozzle on the end of the barrel when required.

The mould is heated by cartridge heaters, usually four in number, fitted in reamed holes centrally disposed around the injection port. The heaters are usually rated at 200 watts per cartridge, and are adequate to raise the temperature of the mould to 220°C with the ends continually cooled.

A thermo-couple is fitted to the lower part of the mould so that the temperature of the central zone may be measured. This thermo-couple is connected via a plug and socket on the machine chassis and a multi-core flexible cable to the control unit.

At the ends of the mould, the top and bottom waterways are joined together by a short length of flexible tubing and the flow and return connexions are made to the respective connectors, located on the end of the machine chassis, via two flexible tubes. The flow of water through each end of the mould is shown by the indicators previously mentioned.

As a means of locating the core during moulding operations two clamps are mounted at the ends of the tensioning beam. One clamp is fitted directly to the beam, and the other is fitted to a slide so that the tension can be applied to the core by means of a screw and spring mechanism. A graduated scale (reading up to 100 lb) is provided to indicate the resultant tension applied.

A general view of the assembled equipment is shown in Fig. 7.

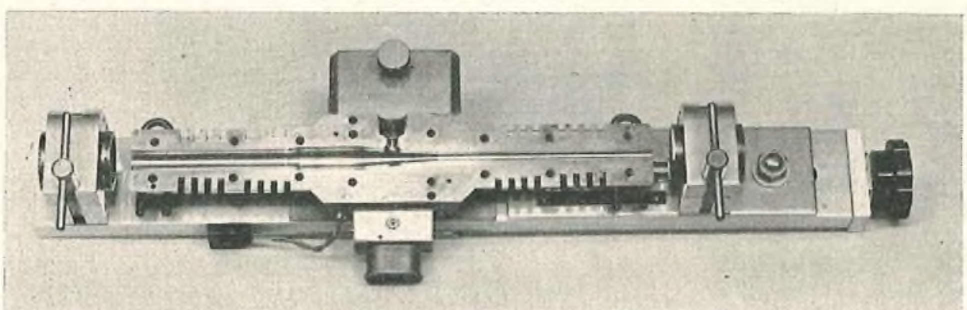


FIG. 6—MOULD FOR 0·620 IN. TO 0·310 IN. DIAMETER JOINTS

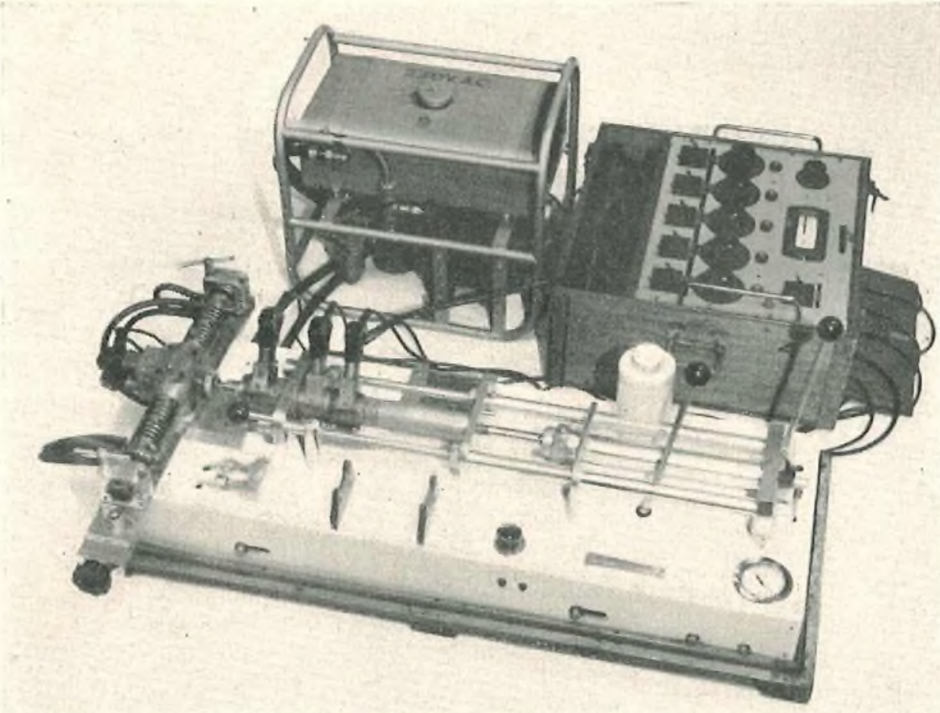


FIG. 7—GENERAL VIEW OF ASSEMBLED MOULDING EQUIPMENT

MOULDING PROCEDURE

Having described the individual parts of the moulding machine, their use is best illustrated by describing the process of making a moulding on a typical cable. It is assumed that the conductor joint has been made and examined and details of trimming the cable ends back have been carried out.

Joints of the highest quality can only be assured if the machine and auxiliaries are kept in a scrupulously clean condition. It is essential that the barrel, breaker plate and nozzle system shall contain only uncontaminated polythene and a cleaning procedure exists to achieve this. The internal surfaces of the mould are cleaned and polished prior to each moulding operation and are treated with a minute quantity of silicone grease to facilitate the removal of the finished moulding from the mould. During this cleaning operation, any polythene "sprues" left in the vent valves from previous mouldings are removed.

The polythene charges are kept in their sealed wrappers until actually introduced into the barrel of the machine, and the prepared cable is kept covered until fitted into the mould.

To ensure a smooth sequence of work, it is usual to start the heating of the fully charged injection barrel before making the conductor joint. This ensures that the correct working temperatures have been reached when required.

The cable is fitted in the cable clamps and the conductor joint adjusted to its correct position in the lower part of the mould (the upper part is not refitted after cleaning). The cable is tensioned and after a final inspection the upper half of the mould is fitted and securely clamped to the lower half.

The electrical-heating and water-cooling connexions are made to the mould and the vent valves are opened. The mould at this stage is still dissociated from the nozzle of the injection barrel. The circulation of cooling water is commenced and the mould heaters are energized.

The mould is allowed to reach the prescribed temperature, and is maintained at this temperature for sufficient time to ensure that the whole of the polythene in the cable ends is correctly pre-heated. This "soaking" time is usually of the order of three minutes, and during this period it is convenient to eject a small amount of polythene from the nozzle. This ensures that the polythene entering the mould is at the breaker-plate temperature.

The mould is then connected to the nozzle and the sleeve nut tightened to ensure a pressure-tight connexion. Injection of the polythene is then started, the indicated pressure being kept as low as possible until the mould is full. This is indicated by polythene filament being ejected from the vent valves. These are closed after about three inches of filament has been ejected and the hydraulic line pressure is then raised to the prescribed figure (generally 400 lb/in^2 giving an injection pressure of the order of $\frac{1}{2}$ ton/in^2).

The mould-heating current is then switched off, but the injection pressure, heating of the polythene and circulation of the cooling water are maintained until the mould temperature has fallen to 30°C. When this temperature has been reached the pressure is released and the mould is disconnected from the nozzle. The cooling water is then shut off and the mould opened. The cable tension is removed and, after opening the cable clamps, the moulded joint is lifted out of the lower half of the mould. The injection and vent-valve sprues and slight flash are then carefully trimmed off.

Examination and Testing

The scope of the examination is governed by the specification for the particular cable scheme and may require the use of one or more of the following testing techniques:

(*a*) Visual examination for surface defects, e.g. any signs of imperfect fusion of the injected and original polythene and also the presence of "hard bake." Hard bake is charred polythene produced by the repeated heating of residual polythene which may adhere to the inside of the barrel and which if left to accumulate is liable to flake off and be injected into the moulding. Hard bake, being similar in chemical structure to polythene, cannot be detected by X-ray examination. When necessary, hard bake can be detected by the use of a light box.

Provided that the proper cleaning routine is carried out, the presence of hard bake inclusions is avoided.

(*b*) X-ray examination for internal voids, inclusions, conductor concentricity and incomplete fusion.

It is usual to make three exposures at 120° around the cable to ensure that all the insulant is examined. The section of cable examined covers the injected portion and the adjacent parts of the original core.

(*c*) High voltage and insulation resistance tests are carried out by fitting a water bath around the moulded joint and using this water as the high-potential electrode whilst the centre conductor of the core is earthed.

TYPICAL PERFORMANCE OF JOINTS

In the British section of the T.A.T. cable system, in which this equipment was employed, it was found that the following limits of performance of joints could readily be met and they are quoted as typical:

0·620 in. to 0·620 in. Core Joint Specification Requirements

Conductor Joint. The increase in diameter is not to be more than 0·005 in. The tension at the breaking point of the centre wire (less tapes) is not to be less than 425 lb. The elongation of the conductor at breaking point is not to be less than 15 per cent in a 2 in. length.

Brazed joints should withstand 20 turns round a ¼ in. diameter mandrel.

Typical results on 10 consecutive joints were:—

Joint No.	Tension at break	Percentage elongation
1	502	27
2	501	27
3	500	25
4	500	27
5	503	27
6	500	25
7	503	24
8	498	29
9	502	24
10	504	21

All joints fractured in the annealed portion adjacent to the braze. The unbrazed conductor fractured at 502 lb.

Mouldings. Mouldings are to be completely free from voids or any indication of incomplete fusion. The X-ray examination is sufficiently sensitive to detect a void of minimum diameter of 0·008 in. It is inherent in the manufacture of the cable that there is a possibility of dust-like inclusions which are opaque to X-rays. In an effort to ensure that the quality of the joint shall be no worse than the core, a specification was formulated as a result of X-ray examination of sections of production core. As an example of the application of this limitation, one single inclusion of 0·016 in. diameter would result in the joint being rejected and having to be remade.

Concentricity of Joint. The minimum radial thickness of polythene is to be not less than 0·177 in., compared with the ideal of 0·231 in.

External Diameter. To be within the limits 0·605–0·640 in.

Insulation Resistance. To be greater than 20×10^6 megohms.

High Voltage Test. For field testing it was considered that the highest practicable voltage for testing joints was 40 kV d.c., and this was applied for one minute to all joints without any breakdown occurring. In the development of this jointing system, a batch of 10 consecutive joints was tested at higher voltages and each joint withstood 200 kV for two minutes. Subsequently eight joints were broken down in the region of 500–520 kV and two joints in the region of 350–400 kV.

Polythene Charges

The polythene charges for this equipment were moulded from the same material as was used in the manufacture of the cable and were all subjected to X-ray examination to ensure that the inclusion content was no worse than that allowed for the finished joint.

CONCLUSION

The satisfactory nature of the equipment and method that have been described may be judged from the performance obtained in the jointing work on which they were employed in the British section of the T.A.T. cable scheme.

For the T.A.T. cable a total of 220 joints of three types were made under arduous field and marine conditions with a rejection rate of approximately 10 per cent, which were entirely due to inclusions. Many of these rejections were border line cases in a very stringent specification and the joints concerned would undoubtedly have been perfectly satisfactory under any service conditions.

ACKNOWLEDGEMENTS

The authors wish to thank their many colleagues for their valuable assistance in the design and production of this equipment.

Book Review

"The Theory of Networks in Electrical Communication"

—*continued from p. 21.*

almost exclusively with those topics which one finds in corresponding books written 25 to 30 years ago and, moreover, in the style and outlook of that period. For example, duality, which is now well appreciated as a very useful concept, is certainly mentioned, but only just, and its consequences are not driven home when the opportunities present themselves. Again, the analysis of circuits in terms of mesh currents is described but the more valuable nodal analysis is not. Foster's Reactance Theorem, the very foundation stone of network synthesis, is dismissed in one page in a 46-page chapter devoted to two-terminal networks! Everywhere the treatment is in terms of the real variable ω; the beautiful unification of otherwise loosely connected ideas which comes about by the introduction of the complex frequency variable is not described at all.

The book has plenty of worked examples taken from London University examinations, and as an aid to students whose sole purpose is to pass similar examinations it may serve its purpose. It is certainly quite clearly written, easy to read and understand, and will make no great demands on the imagination of the intended reader—which is a pity.

An attempt to inject an air of real-life into the pages has been made by including the measured results of various laboratory experiments as illustrations of the theory. One of these is an oscillogram showing the step response of an alleged critically damped tuned circuit; the waveform has about 5 per cent overshoot. There are also pictures of lengths of cable and of the outsides of various commercial measuring equipments.

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A Compandor for a 12-Circuit Carrier Telephone System for Use on Unloaded Audio Cables

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A compandor is described which has been designed as part of the 12-circuit carrier telephone system for use on unloaded audio cables that was described in recent articles in the Journal.[1,2] The compandor has a compression ratio of two and gives a subjective improvement of signal/noise ratio of about 25 db without producing material distortion in the transmission of v.f. signals or facsimile telegraphy.

INTRODUCTION

THE 12-circuit carrier telephone system designed by the Post Office Research Station provides additional circuits over distances of 25 to 100 miles on existing audio cables. Far-end crosstalk at carrier frequencies is a major problem when using a cable that was primarily designed for audio working, and the use of a compandor represents an elegant solution which produces a specific advantage of about 25 db independently of cable rearrangements made to improve crosstalk. A detailed description of the system, and an account of its field trial on an audio cable between Elstow and Hendon repeater stations, has appeared in previous articles.[1,2]

The decision to incorporate compandors in the channel equipment of a carrier system imposes restrictions on their physical size and complexity. Reduction of size increases the difficulty of heat dissipation, and in order to restrict the temperature rise a low-power-consumption valve, type CV850, has been chosen. The total heat generated in the compressor is equivalent to 4·6 watts, and in the expander 2·1 watts, most of which is produced by the valves and so is well removed from the more temperature-sensitive elements of the circuits.

THE COMPANDOR

The compandor consists of two separate units; a volume-range compressor at the transmit terminal and an expander at the receive terminal. Thus, one compressor and one expander are required for each channel panel of the carrier system.

Since the gain of both units is a function of signal level, it is necessary to specify the level at which the channel should be lined up. This level may conveniently be the normal channel-test level (the level at a specified point when a 1 mW signal is applied to the origin of the circuit). For all other levels within the range of compandor action, for either the compressor or the expander, a change of input level from the test level has a fixed ratio to the resulting change of output level when both are expressed in logarithmic units. This ratio is known as the compression ratio, and its reciprocal as the expansion ratio. It follows that the condition for the compandor to have a constant overall gain is that the expansion and compression ratios shall be the same.

In this compandor a ratio of two has been chosen as one that is easily realized in practice, gives a substantial subjective improvement in signal/noise ratio, and is not high enough to impose an unduly severe limitation on the degree of line stability required. With this ratio the expander will double any changes of gain which occur within the system between the compressor output and the expander input; thus the pilot-operated level control is required to reduce line changes to $\pm 0{\cdot}5$ db so as to achieve an overall gain stability of $\pm 1{\cdot}0$ db. This doubling action also influences the permissible attenuation/frequency "roll" within the pass-band of the channel filters and the location of the line-up frequency upon the roll.

With the ordinary distribution of speech volumes on trunk telephone circuits, little is gained by maintaining the compandor characteristic over a range (before compression) greater than about 60 db; this figure has been taken as the requirement for the present design. As the signal level is reduced there is a transition in the region of the nominal lower limit of the compression range from the compression–expansion condition to a condition of constant gain in both compressor and expander.

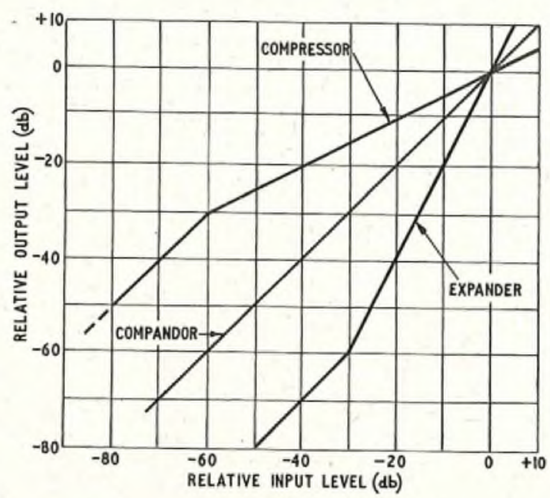

FIG. 1—IDEAL STEADY-STATE CHARACTERISTIC OF COMPANDOR

The ideal steady-state characteristic of the compandor is illustrated in Fig. 1. The departure from the ideal of the actual output level of the compressor is $\pm 0{\cdot}5$ db over the range of compression, and 0 db to $-2{\cdot}0$ db at levels below this; the corresponding figures for the expander are $\pm 1{\cdot}0$ db and 0 db to -3 db. The compressor and expander are separately adjusted to be within these limits by the selection of one resistor in each, so that any compressor may work to any expander. The overall error of a compressor and expander in tandem is rather less than is implied by these limits because the nature of the error characteristics is such that a positive error in the compressor law is largely cancelled by a negative error in the expander law.

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[1] REYNOLDS, J., JEYNES, E., TURNER, D., THOMPSON, C. D., and CROSSLEY, J. The Design and Field Trial of a 12-Circuit Carrier Telephone System for Use on Unloaded Audio Cables. *P.O.E.E.J.*, Vol. 50, pp. 173 and 252, Oct. 1957 and Jan. 1958.

[2] CHILVER, L. W. J. and WATKINS, A. H. New Line Transmission Equipment. *P.O.E.E.J.*, Vol. 49, p. 12, Apr. 1956.

NOISE REDUCTION

The compandor will improve the subjective signal/noise ratio of a circuit only when the interfering signal is injected between the compressor output and the expander

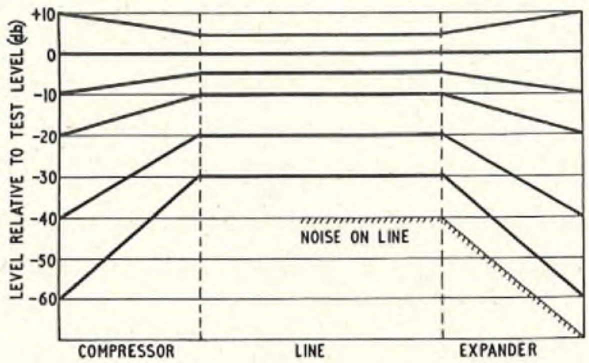

FIG. 2—LEVEL DIAGRAM FOR A CARRIER SYSTEM CONTAINING A COMPANDOR

input. This is the condition when the compandor is situated in the terminal equipment of a carrier system and the interfering signals are line noise and crosstalk.[3]

The gain of both the compressor and the expander is controlled by the rectified envelope of speech signals on the line, a reduction of gain in the compressor being accompanied by an equal increase in the gain of the expander. Fig. 2 is a simplified level diagram for a carrier system containing a compandor. With no signal input, the compressor introduces 30 db gain and the expander 30 db loss relative to the condition at test level. Thus, any line noise receives 30 db attenuation within the expander, provided that the level of the noise is 30 db or more below test level, as is normally the case. With an input signal to the compressor of, say, −30 db relative to test level and a noise level of −40 db relative to test level on the line, the compressor introduces 15 db gain and thus improves the signal/noise ratio on the line from 10 db to 25 db. The expander, which is controlled by the higher level signal, has a loss of 15 db, so that the noise now receives only 15 db attenuation within the expander; but when the signal ceases, the loss to the noise rapidly increases to 30 db so that the noise at the output of the expander falls to −70 db relative to test level, and would be inaudible.

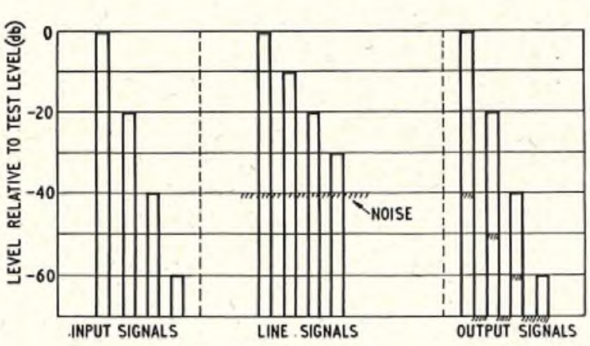

FIG. 3—COMPANDOR RESPONSE TO DISCRETE SIGNALS

Compandor action may be illustrated as shown in Fig. 3, where the input signal (*a*) represents discrete sounds of various levels separated by silent intervals, e.g. separate words or syllables. The signals after compression are shown at (*b*), where the first aspect of compandor advantage may be seen in the improvement of signal/noise ratio on the line for all signals below test level. The effect of the expander is seen at (*c*), where the original signal level has been restored and the received noise is dependent on the signal level. The noise is greatest when the signal is loudest, and least during the interval between words. It is this effect of a silent background which greatly contributes to the subjective improvement produced by the compandor; this is particularly so if the interfering signal is intelligible crosstalk.

In practice the compandor is not instantaneous in action, as suggested by Fig. 3, but both compressor and expander have time constants which are chosen from consideration of the characteristics of telephone speech.

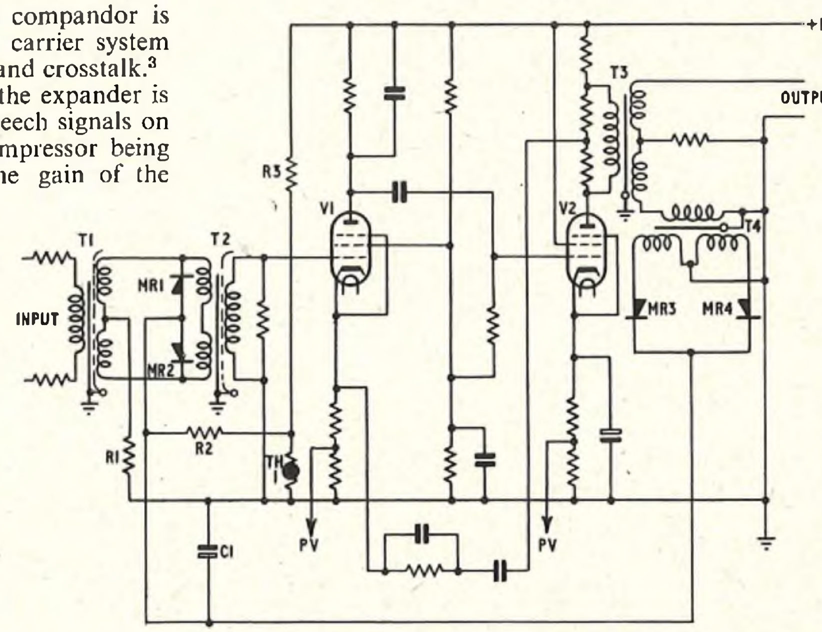

FIG. 4—CIRCUIT OF THE COMPRESSOR

THE COMPRESSOR

The circuit of the compressor is shown in Fig. 4 and a view of a model is shown in Fig. 5. The voltage ratio of the variable-loss network T1, MR1, MR2 and T2 is controlled by a unidirectional biasing current. The output of this network is amplified by a 2-valve amplifier with overall a.c. negative feedback, and local d.c. negative feedback applied to valve V2 so as to stabilize its operating point against valve changes. The output transformer T3 is connected as an asymmetrical hybrid coil which provides two independent outputs and divides the power in the ratio 3:1 between the control path and the signal path. Two advantages are obtained by the use of this circuit:

(*a*) The harmonic currents in the control path, which are produced by the full-wave rectifier, are isolated from the signal output by the loss presented by the hybrid coil.

[3] LAWTON, J. The Reduction of Crosstalk on Trunk Circuits by the use of the Volume Range Compressor and Expander. *P.O.E.E.J.*, Vol. 32, p. 32, Apr. 1939.

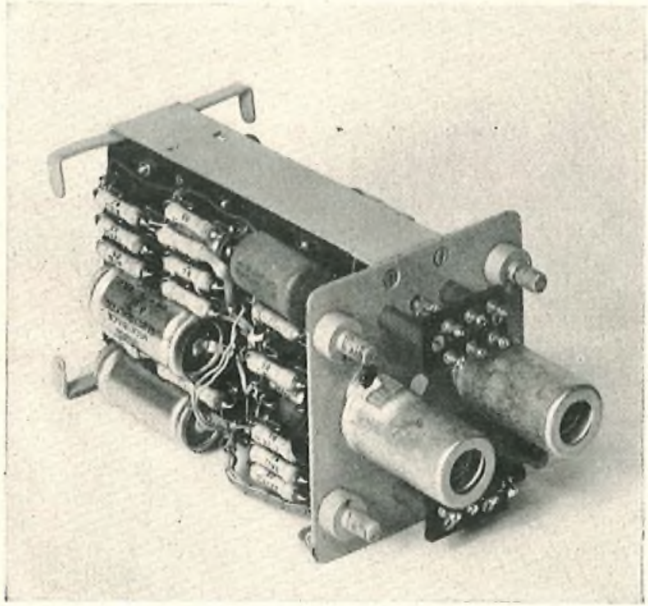

FIG. 5—COMPRESSOR

As a result no buffer stage is required.

(*b*) The control current is not affected by signals that may be injected at the output of the compressor, such as signalling tones.

The control circuit, consisting of T4, MR3, MR4, C1 and R1, produces a unidirectional current which is directly proportional to the peak voltage at the compressor output for sinusoidal signals, and will follow the envelope of the waveform for speech signals. The time taken for this current to reach 80 per cent of its final value after a sudden increase in signal level is made sufficiently short to avoid distortion on the build-up of a speech-waveform envelope. The time constant for decreasing signal levels is made short enough to prevent noticeable bursts of line noise at the end of speech sounds. Suitable values are found to be 5 ms for build-up and 20 ms for signal decay.

The transition from a 2:1 law to a 1:1 law at the lower extreme of the compression range is determined by the magnitude of the steady bias current supplied by R3 and R2 to the variable-loss network. This current supplements the control current, and in the absence of a signal the gain of the variable-loss network, which is at its maximum value, is determined by R2. This resistor is selected on test to set the nominal lower limit of the compression range at 60 db below test level at the input of the compressor. Some measure of temperature compensation is obtained by controlling the current in R2 with a thermistor, TH1, which is bolted to the framework of the compressor.

THE EXPANDER

The circuit of the expander is shown in Fig. 6, and a view of a model is shown in Fig. 7. The power required to control the gain of the variable-loss network is obtained by full-wave rectification of the incoming speech signals by the bridge circuit MR1, MR2, MR5 and MR6. The harmonic currents flowing in this circuit are isolated from the signal path by the hybrid-connected transformer T1. The input power is divided between the signal and control paths in the ratio 1:4.

The 2:1 law of the expander is more difficult to obtain than that of the compressor for the following reasons:

(*a*) The control current is slightly lower, being limited by the available input power.

(*b*) The presence of the generator and load resistances in the variable-loss network cause a reduction of gain relative to the desired 2:1 law for inputs approaching test level.

(*c*) The maximum value of a.c. resistance of "loss" rectifiers MR3 and MR4 at low current causes an increasing excess gain relative to the desired 2:1 law as the signal level falls. The effect of this is reduced by the control current falling more rapidly than the input signal, due to the increase in effective generator impedance of the rectifier bridge at low current values.

The error is further reduced by causing the steady bias current, which determines the transition point from a 2:1 to a 1:1 law, to be related to the incoming signal level. This bias is obtained from a low-impedance source and its magnitude is controlled by the d.c. resistances of the loss and drive rectifiers, these being related to the incoming signal level.

The time constants of the expander are identical to those of the compressor so as to ensure that the compandor has a constant gain at all times.

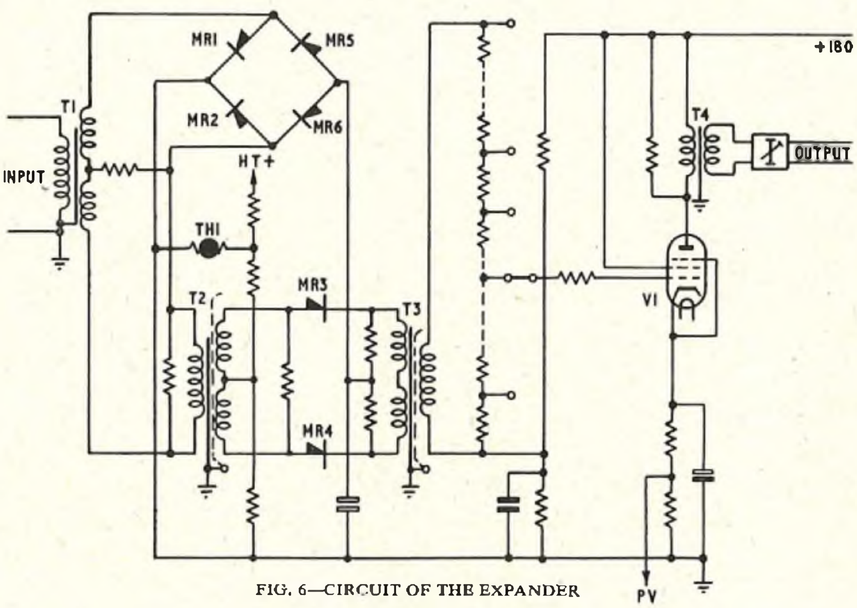

FIG. 6—CIRCUIT OF THE EXPANDER

The expander includes a single-valve amplifier, V1, with local d.c. negative feedback in the cathode circuit, and a grid potentiometer to adjust the gain in ten steps of 0·5 db. This is a panel control and would normally be used for routine adjustment of gain, in the same manner as the panel gain control of the channel amplifier in a carrier system without compandors. Soldered-in pads of 2, 3 and 4 db are provided in the output circuit for use in the initial alignment of the channel.

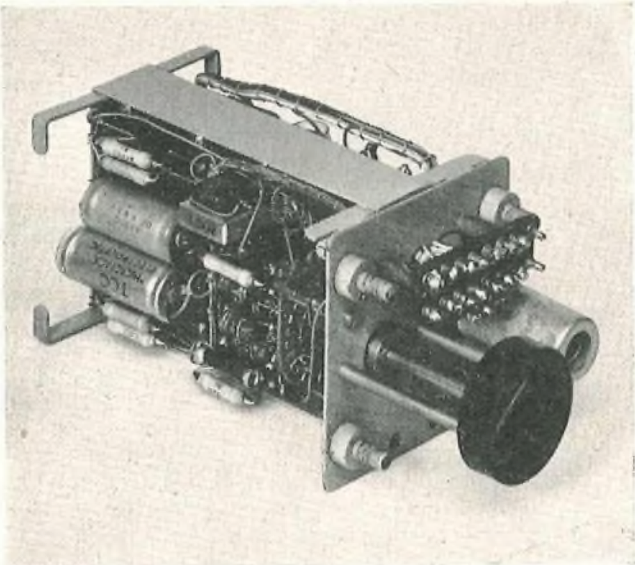

FIG. 7—EXPANDER

EFFECT ON SPECIAL TYPES OF SIGNAL

V.F. Telegraphy

The intermodulation distortion which results when two frequencies are applied simultaneously to a typical compandor increases significantly as the frequency difference falls below 200 c/s. Thus with the 120 c/s channel spacing of multi-channel v.f. telegraph systems it is possible, under adverse circuit conditions, for the crosstalk between adjacent channels to approach 25 db. For circuits permanently set up for v.f. telegraphy it would be a simple matter to lock the gain of both compressor and expander by means of a steady biasing current, should this level of crosstalk prove unacceptable.

Facsimile Telegraphy

The presence of noise and crosstalk on a circuit carrying amplitude-modulated facsimile-telegraphy signals produces a coarse grain structure and a reduction of detail in the dark areas of the received picture. These defects may be considerably reduced by the inclusion of a compandor in the circuit, and even on a noise-free line the presence of the compandor can hardly be detected by an examination of the reproduced picture.

V.F. Signalling

Tests were conducted by the Circuit Laboratory of the Telephone Development and Maintenance Branch to determine the effect on v.f. signals of a compandor connected in the transmission path. Signalling receivers tested included types TL1750, TL2750, AT4931 and NS5696. In general the difference in pulse distortion with and without the compandor did not exceed ± 1 ms, and the levels at which complete failure to pulse occurred did not differ by more than 1 db between the two conditions. The advantage, if any, was in favour of the compandor.

CONCLUSION

A compressor and expander have been designed as part of the channel equipment of a carrier telephone system to produce a subjective improvement of the signal/noise ratio of the order of 25 db. Tests have shown that the compandor produces no material distortion in the transmission of v.f. signals or facsimile telegraphy. In the latter case a considerable improvement in picture quality results from compandor action when noise is present on the line.

Book Review

"Electricity and Magnetism." J. Newton. (Intermediate Science Series.) Sir Isaac Pitman & Sons. 613 pp. 365 ill. 25s.

After some years of close association with applied electricity, an engineer's attitude towards the fundamentals of elementary electrical physics as taught in schools undergoes a substantial change. Electrostatics seems curiously unrealistic; the tangent galvanometer is rather a useless device; and a metre-resistance wire potentiometer is far removed from the equipment used in a testing laboratory! These are examples of the classical approach to the teaching of electricity in physics classes, where the aim is to inculcate basic scientific principles into the mind of the young student. This is the emphasis of such teaching. Applications to applied science such as electrical engineering can follow later; and an average student well grounded in physics should make rapid progress in later years when he reads for an engineering degree or, at a lower level, follows a course for the Higher National Certificate. Mr. Newton's book is planned to give such a grounding to students taking Advanced Level Physics, the General Certificate of Education or the National Certificate in Applied Physics.

Discussion of fundamental, abstract, concepts is a welcome feature of this book, because, as the author says, a firm grasp of fundamentals is essential to any real understanding of the subject. This is a refreshing outlook for the writer of a school textbook, and one which deserves commendation. The book is planned on somewhat unconventional lines in other ways also. For example, practical aspects which can be readily verified by laboratory experiment come in the first part of the book. More abstract work, such as electrostatic theory and an excellent chapter on units, are left to the end, where they really belong as far as the average student is concerned. A small amount of a.c. circuit theory is included to help link the book to a more advanced syllabus such as would be followed later by a student of electrical engineering.

The book is clearly written by an experienced teacher of physics who has taken some pains to discover the best way to present the subject to students. The explanations are clear and full, without being verbose. Diagrams are freely used. Elementary calculus is essential, of course, in a book of this type, as a student must also be studying mathematics to be accepted on a physics course for advanced level of the General Certificate of Education. Worked examples are given in many places, and questions are set at the end of each chapter. It is pleasing to see that the book is based on the C.G.S. system of units—which some teachers of electrical engineering now find is, after all, the best for students of applied physics—but comparison is made with the M.K.S. system at the end of the book so that the reader can become accustomed to both systems.

This is one of the best of the modern textbooks in elementary electrical physics. It is published in the Intermediate Science Series and it should prove valuable to all teaching establishments aiming at a high standard in applied physics.

C. F. F.

Plastics in Cables

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Since the 1939–45 war plastics have replaced traditional materials as insulants and protective coverings for many types of cable. This article reviews the present stage of the use of plastics in cables, with particular reference to Post Office practice; it discusses briefly the various plastics that are suitable for use in cables and then describes the application of these plastics in cables used in telephone exchanges and in underground and aerial telephone cables. The use of plastic coverings for the protection of telephone wires and cables against the effects of contact with power lines and for the protection of cables against corrosion are also briefly discussed, and the article concludes with a discussion of the application of plastics to power cables.

INTRODUCTION

ANY account of the utilization of plastics in the manufacture of cables should not fail to impress the reader with the revolution that has taken place in the make-up of cables during the last decade. This article deals with the supplanting of materials that have been traditional to the industry almost since cables were first made, not only in the main field of insulation, but also for sheathing and protection. It is impossible, therefore, to avoid reference to the use of other materials if the advantages which have been gained by the use of plastics are to be fully appreciated.

Generally speaking, the plastics referred to in the article dealing with plastics in telephone exchange equipment, in a previous issue of the Journal,[1] are not the materials used in cables. In telephone exchange equipment the majority of the plastics are thermosetting, in cables they are thermoplastic. Thermosetting compounds undergo chemical change when subjected to heat and pressure. They are thus converted to an insoluble, infusible state which cannot be further reformed even by the application of more intense heat and pressure. Thermoplastic compounds, on the other hand, can be softened and resoftened indefinitely by the application of heat, provided that the heat applied is insufficient to cause chemical decomposition. For cable applications, readily extrudible materials to give smooth coverings of uniform thickness over long lengths are required. It is also important that pigmentation of the material be readily effected for identification purposes and that the material be satisfactory both mechanically and electrically.

There are two main materials in current use, polythene and polyvinyl-chloride (p.v.c.), to place them in their relative order of insulating properties. Others are polytetrafluorethylene, nylon and polyethylene terephthalate. The story of the development and production of these materials, together with complete data of the physical and electrical properties of the various grades of each, would furnish sufficient material for another article and only the barest details can, therefore, be given here. Rubber, which for many years has been applied by the extrusion technique that is normally used for applying thermoplastics in cables, is mentioned only as one of the superseded materials. It is not a plastic as normally conceded by the term, but an elastomer*, a title shared with the similar materials para-gutta, gutta-percha, K-gutta and the synthetic rubbers.

PLASTICS USED IN CABLES

Polythene

Polythene was first prepared in March 1933 but it was not until December 1935 that the first successful "quantity production" experiment was concluded, yielding 8 grams of polythene.[2] Comparing this with the planned production of 760,000 tons in 1960 indicates the phenomenal growth in the production of polythene. It is expected that 10 per cent of this amount will be used in the cable industry. It can truly be said that the course of the 1939–45 war was materially affected, maybe its outcome decided, by this country's knowledge and development of polythene. Without it the radar systems which were so effective against enemy attack whether on or below water, or in the air, would have been impossible.

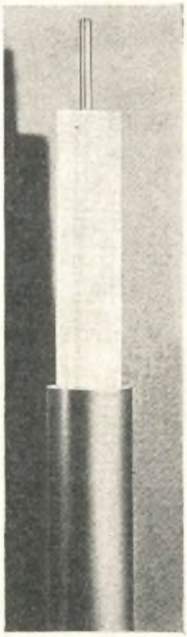

FIG. 1—TYPICAL SOLID-POLYTHENE-INSULATED LEAD-SHEATHED RADIO-FREQUENCY CABLE. APPROXIMATE OVERALL DIAMETER 1 IN. ATTENUATION 0·9 DB/100 FT AT 100 MC/S

Polythene, with its high dielectric strength, low loss-factor even at centimetre wavelengths and its remarkable physical properties has, in fact, revolutionized telecommunications engineering. Nothing illustrates this as dramatically perhaps as the successful completion of the transatlantic telephone cable.[3]

Polythene is susceptible to attack by ultra-violet light, immunity being given, however, by the inclusion of a minimum of 2 per cent of evenly-dispersed carbon black. It is because of this that all polythene-sheathed cables intended for external use are sheathed with black compound. Even though the cables are to be placed underground, it is considered advisable to give them the carbon black protection in case they are left exposed to sunlight while on the drum and awaiting installation.

Government Departmental Electrical Specification (G.D.E.S.) No. 27, issued in 1950, is the only current official document covering polythene as used in cables. Harder grades than those included in that specification are now in current use and Government Departments have found it necessary to issue their own documents. The British Standards Institution is likely to issue a specification in the fairly near future, a draft having already been prepared by a Ministry of Defence Committee.

High-Density Polythene

Until recent years the production of polythene has depended on polymerization‡ at high pressures. Now,

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*An elastomer is a material that can be stretched repeatedly to at least twice its initial length and thereafter will return rapidly and with force to its original length. Application of heat to the gutta compounds is necessary before they will meet this definition.

‡Polymerization is the building-up of long-chain molecules from relatively simple molecular structures. In the case of thermosetting compounds cross-linking of the molecules occurs.

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high-density materials (the term is relative only as normal and high-density materials have densities of 0·92–0·94 and 0·94–0·96, respectively) are being produced by low-pressure and modified high-pressure polymerization. The resultant materials are tougher and have a higher melting point and lower water-vapour permeability. They may, therefore, prove superior to conventional polythene for a number of applications.

Irradiated Polythene

Bombardment of polythene in an electron stream causes a change in the molecular structure which varies with the amount of radiation. Early experiments had to be conducted in atomic piles and the products were naturally comparatively expensive. The development of electron accelerators has now provided a cheaper source of irradiation so that it is a relatively simple matter to irradiate long lengths of insulated conductor.

It is rather early to say what applications this material will have in the cable industry. Resistance to deformation and displacement of the conductor when a cable is subjected to overload may be important in radio-frequency cables. Irradiated polythene has already enabled soldered joints to be made on heavy copper conductors without deformation of the insulation.

Cellular, or Expanded, Polythene

The inclusion in polythene of organic compounds which decompose and liberate nitrogen during extrusion results in an expanded plastic containing fine, uniformly distributed, non-intercommunicating cells. The final density of material marketed at present is approximately 0·4, with corresponding lower permittivities. The material is particularly suited to low-loss high-frequency cables and has already been used by the Post Office for low-capacitance cables for h.f. transmission.

Polyvinyl-chloride

Vinyl-chloride was first obtained by Regnault in 1838 and was polymerized in 1912 by Ostromislensky. Not unnaturally, little effort was devoted to exploitation of the discovery in view of the more than adequate supplies of natural rubber and plant for processing it. It was not until the rubber supplies were cut off during the 1939–45 war that attention was seriously given to the use of p.v.c.

Early opportunity of trying out the new material was taken by the Post Office, a specification for Wire, Flameproof, P.V.C.-Insulated being issued in 1941. Production at that time was, however, somewhat disappointing. Due to the employment of unsuitable plasticizers wires became sticky in service and there were low-insulation troubles. Colours were found to fade and there were complaints regarding the unpleasant smell in apparatus rooms in which the wire was used. There is no doubt that p.v.c. was, due to pressure of wartime requirements, used far too extensively before being adequately developed. As a result it acquired a bad reputation and the immediate post-war reaction was a return to the conventional pre-war coverings.

The first move to establish standards for p.v.c. used in the manufacture of cables was the issue of G.D.E.S. No. 18 in 1942. This specification, and particularly its subsequent issues, went a long way towards establishing confidence in p.v.c., but the Post Office felt that there was a need for a superior grade for insulating purposes. In 1952 a specification, CW 129, for "P.V.C., Post Office Grade, for Wires and Cables" was issued. This p.v.c. became commonly known as "Hard Grade." Improved physical and electrical properties, not previously regularly achieved, were called for. Considerable singleness of purpose on the part of the Post Office representatives at discussions with manufacturers of polymer and makers of cable was needed over a long period before CW 129 was established.

In 1953 G.D.E.S. 18 became Defence Specification No. 9 in the Ministry of Defence series, and was eventually incorporated in British Standard 2746 in 1956. To the Post Office's credit, the hard-grade insulating compound was adopted in this last standard and has become generally accepted as the most suitable for many applications.

The world production of p.v.c. at the present time is estimated at 600,000 tons per annum, of which some 15–20 per cent is used in cables.

Polytetrafluorethylene

Although it was produced initially in 1941, polytetrafluorethylene (p.t.f.e.) has only recently been used in cables. It is somewhat difficult to process as it has no true melting point, the nearest approach to plasticity being at 327°C, when it takes on a rubbery, jelly-like state. In appearance p.t.f.e. is similar to polythene, having a hard waxy finish. Further, it possesses similar high-quality electrical characteristics. Most important of all it is suitable for operation at higher temperatures than other plastics. The construction of fighter aircraft has had to be switched from aluminium to steel because of the frictional heat generated by the air at supersonic speeds. Cables which can work in contact with these hot surfaces and actually in the heat of the jet engines are essential. P.T.F.E. has met this need, being used extensively in such applications. It is also of great importance in the wiring of guided missiles, but so far no Post Office cable requirement for p.t.f.e. has arisen.

Nylon

The extensive use of nylon in the clothing industry is well known but its applications in cables may very well go unnoticed. Dielectrically, nylon is a poor material, but its extraordinary toughness and resistance to abrasion make it suitable as a protective covering over other materials. Thousands of miles of p.v.c.-insulated wire sheathed with extruded nylon have been made in the last few years for paying out from low-flying aircraft or moving military vehicles to facilitate the rapid provision of field communications. Unfortunately, the susceptibility of nylon to deterioration by ultra-violet light (e.g. it fails in about six months under Indian summer conditions) renders it unsuitable for external use except for temporary installations.

Nylon is also produced as a monofilament and can therefore be used as a braided covering. As such it is being used on switchboard and telephone instrument cords.

Polyethylene Terephthalate

Polyethylene terephthalate is another material first used in the clothing industry and now finding an application in cables. It is commonly known as Terylene, the form used in cables being called Melinex. Melinex is a tape, similar in appearance to Cellophane, and obtainable in thicknesses of 0·5, 1·0 and 1·5 mils and in varying width to suit particular applications. It is used as an inter-layer tape or outer binding tape on multi-core cables. Dielectrically, it is a good cable material and its very high tensile strength enables it to be used in the thin tapes mentioned to tighten up the stranded layers of conductors into a compact cable.

MANUFACTURING PROCESSES

The introduction of plastics has revolutionized cable manufacturing processes by making the extruder the most common item of plant in a cable factory. Apart from the manufacture of power cables, the lapping head, which is used for applying paper tapes as the insulation of paper-core telephone cables, the silk and cotton coverings of equipment wires and the hessian tapes used for external protection of underground cables, is becoming increasingly redundant. The same applies to the textile braider, used mainly for the application of outer protective coverings. The approximate operating rates of some commonly-used cable machinery, relative to a conductor 0·020 in. diameter, in terms of minutes of manufacturing time per mile per head or plant unit, are

Enamelling	25 min	Lacquering	30 min
Textile lapping	300 min	Extrusion	7 min
Braiding	1,500 min	Striping for colour	
Paper insulating	45 min	identification	120 min

On the face of it the extrusion technique, even with striping, gains considerably over any combination of the other processes, such as enamel plus textile plus lacquer, or enamel plus textile braid plus lacquer. Also, taking a telephone switchboard cable as an example, all the conductors need to be lapped with textile whereas only about 33 per cent of the p.v.c.-insulated conductors have to be striped with colour. It should be remembered, however, that extruders usually require the full attention of one operator, while enamelling, textile lapping and braiding units are often run in banks of ten. Furthermore, the floor space taken up by an extruder with cooling troughs will be greater than that taken up by some of the other units. The overall costs of applying plastics are, however, slightly less than the costs of applying the older coverings.

Some indication of the reductions in price of Post Office items which have been achieved by the use of plastics is demonstrated by the cost comparisons given in Table 1, showing the percentage reductions in price for a number of items compared with those applicable some ten years ago on superseded designs. Allowance has not been made in the calculation of these percentages for variations in copper prices. The costs used for current items were, however, those ruling before the recent fall in the price of this commodity. When it is remembered that the general rise in price levels would have resulted in increases had the specifications remained unchanged, the saving is all the more remarkable.

TELEPHONE CABLES

Uses of Polythene

Polythene was first used by the Post Office on submarine cables made at the end of 1943 and the beginning of 1944. In all, 350 miles of 0·062 in. coaxial cable were manufactured in preparation for continental communications after the allied armies' landings in France in 1944. Since that time many other polythene-insulated submarine cables have been provided leading up to the transatlantic telephone cable laid in 1955–56.

Another early use of polythene was in land coaxial cables, a marked improvement in the performance of the 0·375 in. coaxial pairs being achieved in 1947 when the ebonite spacers were replaced by polythene spacers.

The introduction of polythene into multi-core telephone cables was delayed until 1950, the main reason being the difficulty of extruding thin radial thicknesses of fault-free material on the relatively small conductors of such cables. A specification was, however, prepared in that year for cables up to 30 pairs, having 20 mils of polythene insulation on conductors of 6½, 10 and 20 lb/mile, a polythene sheath being provided overall. This type of cable is being used in increasing quantities, the extrusion technique having been improved to such an extent that the conductors are now insulated with 12 mil radial thicknesses as standard provision. The fact that polythene-sheathed cables are sufficiently robust to be buried direct in the ground without other protective covering has enabled them to be used extensively in areas of post-war building development.[4] Recent economic studies show that polythene distribution cables up to 50 pairs in size may be laid in duct without adding to the cost of providing circuits. As an indication of the extent to which polythene cables are at present used, some 9 per cent of the loop mileage provided in exchange networks during 1956–57 was in polythene cables, amounting to 86,000 out of 883,000 loop miles. Production on an experimental basis using 8-mil radial thicknesses of insulation is already in hand, and it is confidently expected that before long unit-type

TABLE 1

Cost Comparison between Plastic Cables used by the Post Office Engineering Department and the Relative Superseded Items

Superseded Item		Current Item		% Saving in Cost	Approximate annual consumption miles
Cable PCTD	15 Pair 6½	Cable Polythene Twin	15 Pair 6½	8·8	1,000 plus
Cable E and CC	1 Pair 10	Cable PVC No. 1	2 Wire 9¼	80	1,600
Cable E and CC	10 Pair 10	Cable PVC No. 1	21 Wire 9¼	53	176
Cable IRV CB	1 Pair 12½	Cable PVC No. 2	2 Wire 9¼	27·2	2,000
Wire Switchboard and Switchplate	1 Wire 6½–9¼	Wire PVC No. 3A	1 Wire 6½	10–75*	3,600
Wire Flameproof	1 Pair 12½	Wire PVC No. 1	1 Pair 12½	30·3	5,600
Cable Switchboard	100 Wire 9¼	Cable PVC No. 3	100 Wire 6½	29·2	365
Cable Switchboard	150 Wire 9¼	Cable PVC No. 3	150 Wire 6½	39·2	65
Cable Switchboard	Lead Covered 200 Wire 9¼	Cable PVC No. 3	200 Wire 6½	32	12
Cable ES and WQ	202 Pair 10	Cable PVC Terminating	200 Pair 10	40	16
Cable IRVCT	1 Pair 12½ Flat	Cable Leading-In	1 Pair 12½ Flat	76	5,300
Cable IRV B and C		Cable Drop-Wiring		32	6,500

* According to Type.

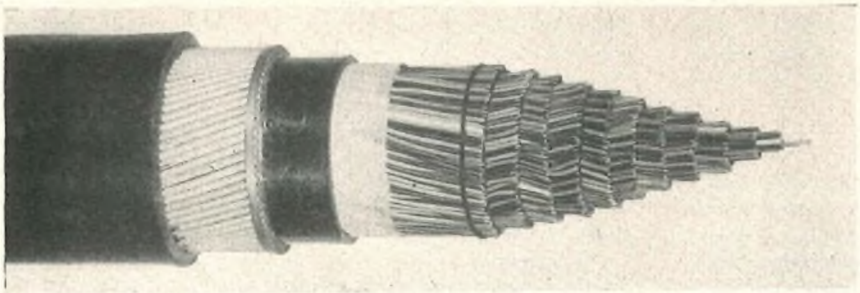

FIG. 2—A 403-PAIR, 10LB POLYTHENE-INSULATED-AND-SHEATHED SINGLE-WIRE-ARMOURED AND POLYTHENE-OVERSHEATHED CABLE

cables will also be produced in polythene-insulated polythene-sheathed versions. It is possible, therefore, that the end of the lead-sheathed paper-core cable is in sight, a development which cannot fail to reduce very considerably the maintenance costs of underground plant.

Uses of P.V.C.

It was apparent that the major use of p.v.c. would be in internal wiring and the most profitable item for early experiments was the flameproof wire familiarly known as "jumper wire." The superseded item had been in use for at least 30 years and consisted of a tinned conductor lapped with rubber, followed by wool lappings and with wool braiding overall. It was necessary to impregnate the finished wire in a bath of size to reduce inflammability. Furthermore, before the textiles were applied they had to be specially treated against moths. The first new version of "jumper wire" that was tried had only p.v.c. insulation. While this was satisfactory at the smaller exchanges (up to 1,000 lines) it was found to be damaged by frictional heat during the drawing-in or withdrawal of jumpers on the more congested frames. To overcome this a cotton braid protected with a flame-retarding lacquer finish was tried and found suitable. This is now the standard item.

Textile-insulated wires and cables have also been successfully replaced. The first move was the supersession of enamelled wires since these were the most expensive. Stripping the conductors with specially designed tools proved easier than removal of textile and enamel, and the handling of p.v.c. was much preferred to handling the wax finishes of many of the earlier items. The sheathing of switchboard cables with p.v.c. was also a very great improvement. Anyone who has handled the old paint-impregnated textile-braided sheaths will know how easily a powdery dust, inimical to automatic equipment, is produced when running cable. The rough surface of the braided sheath all too readily holds dirt and is impossible to keep clean. Both these disadvantages have been eliminated with p.v.c.

A constant source of difficulty with the textile-covered switchboard wires was the identification of colours. Not only were there disputes as to actual colours—slate versus white or blue, orange versus brown and red, etc.—there was also the hazard of dipping the cable ends in the bath of beeswax. All too often the wax was allowed to blacken due to prolonged over-heating. Then, despite the care with which the colours of the textiles had been selected and applied, the identification was obliterated.

The present method of providing identification colours on p.v.c.-insulated wires was not adopted solely because it reproduced the spiral markings of the textile. Any method of identification by means of colours (e.g. by intermittent dots of a second or third colour, by transverse bands or even a multiple extrusion of colours) would have been acceptable, provided that all colours were visible at a glance. The spiral colour marking using p.v.c. inks applied over a pigmented p.v.c. base by means of a rotating head has proved to be the most economical method, and has produced well-defined bright colours.

The first exchange to be fully wired and cabled with p.v.c. cable was Wotton-under-Edge, a U.A.X. No. 14. Manufacture took place during 1947, and installation was completed about January 1949. The next installation was a 1,400-line extension to Grangewood Exchange in the London Telecommunications Region, which was completed during 1951. An overall textile lap and lacquer was used on these early installations, but it was later decided that for exchange wiring the general standard would be plain p.v.c.

Rubber is still being used to a small extent in some power wiring but to an ever-diminishing degree. As explained earlier, cotton braiding is used on jumper wire. One manufacturer is using an open cotton braid over the stranded cores of switchboard cable before application of the p.v.c. sheath, as it is claimed that this makes for a generally tighter and more satisfactory cable. Apart from these exceptions all exchange wiring now being provided employs plain p.v.c. for insulation and sheath.

Wiring of Subscribers' Premises. As in exchanges, p.v.c. is now replacing the earlier cables and wires in subscribers' premises. Cable, E. & C.C. (enamelled and cotton-covered conductors, lead-sheathed wax-filled cable), has not been purchased for some years. Its replacement is similar to the exchange-type p.v.c. cables in all respects except the colour scheme and number of conductors in the various sizes. Cotton braiding has been retained on some of the smaller cables despite the change from rubber to p.v.c. insulation of the conductors, it being considered that a cotton-braided finish is more suitable in domestic premises. With the successive reductions of overall diameter that have been achieved on these cables by the use of smaller conductors and lower radial thicknesses of insulation, they are becoming much less conspicuous. In many situations twisted p.v.c.-insulated pairs or triples could no doubt be run without overall protection; in any case it would be a logical step to replace the braid by a p.v.c. extrusion.

Leading-in to Subscribers' Premises. It is not many years since pole leads and cabling on walls were run in single-pair, rubber-insulated, lead-sheathed cables. Fractures of the lead sheath and low-insulation faults were not infrequent, which, while tolerable on older exchange systems, always gave rise to a large amount of work at times of exchange conversions to automatic working. The current construction consists of two p.v.c.-insulated conductors laid side-by-side and sheathed overall with p.v.c. Field-trial lengths of a double-D cable have been

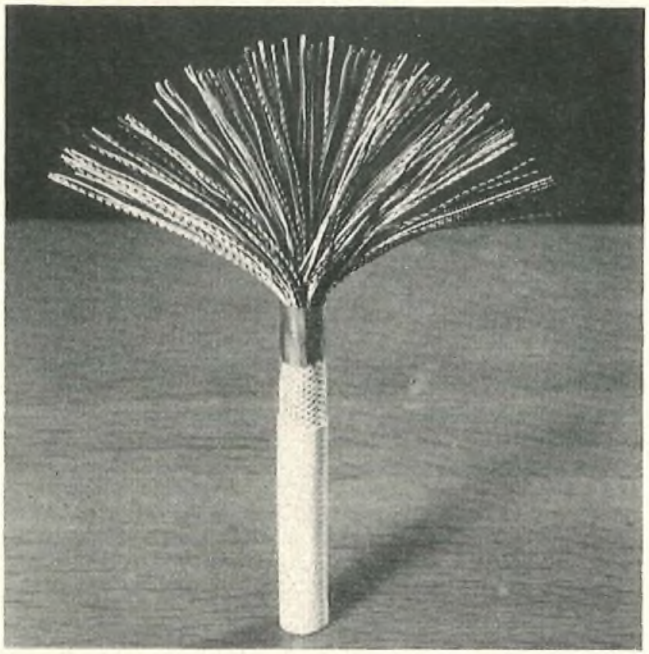

FIG. 3—A 200-WIRE 6½ LB P.V.C.-INSULATED, P.V.C.-SHEATHED SWITCHBOARD CABLE PROVIDED WITH OPEN COTTON BRAID TO COMPACT THE CORES BEFORE SHEATHING

obtained. This consists of two conductors laid side-by-side and covered overall by a single extrusion of p.v.c. Conductor identification is obtained by providing a longitudinal fin on one side of the flat cable. As a result of the trials it is intended to change over to this type of cable.

Another item likely to be completely superseded by p.v.c. cable in the near future is the "drop wire," i.e. the overhead twin lead run from a distribution pole to a subscriber's premises. The conventional item is of flat twin construction with tough-rubber-insulated cadmium-copper conductors covered overall with a cotton braid impregnated with a bitumastic compound. The replacing item is similar in construction to the double-D leading-in cable previously mentioned except that identification of the conductors is obtained by tinning one of the pair of cadmium-copper conductors.

AERIAL CABLES

Paper-insulated alloy-B lead-sheathed cable is still the standard type for use as an aerial cable, but a number of alternatives have been tried, and there are three main types of plastic aerial cable currently under consideration, all of the self-supporting type; these are,

(*a*) A cadmium-copper-conductor, polythene-insulated, p.v.c. or polythene-sheathed cable.

(*b*) A combined type, in which the polythene-insulated copper conductors and steel suspension strand are enclosed in a single p.v.c. sheath, the cross-section being of figure-eight shape.

(*c*) A cable consisting of polythene-insulated conductors, each individually sheathed with p.v.c., stranded round a polythene-insulated steel suspension strand. This cable does not have an external protective sheath.

In addition to the above specially manufactured items, polythene insulated and sheathed underground-type cable is being lashed to its suspension strand by lashing machines in the field or produced as a pre-lashed cable in the factory. The economics and relative engineering advantages of the various types are being considered with a view to standardizing practice, and the trials of these cables will be discussed in greater detail in a future article.

PROTECTION OF AERIAL LINES

Around 1942–43 the Ministry of Supply introduced a p.v.c.-insulated line wire for army use in wooded areas. It was commonly known as "tree wire" and consisted of a 70 lb/mile cadmium-copper conductor insulated with a 30 mil thick covering of p.v.c. A similar item has now been adopted as a replacement for the J wire, a line wire covered with impregnated paper and impregnated braid that was formerly used for routes passing through trees.

Not only physical protection has been afforded to overhead routes. The introduction of plastics has had a profound effect on Post Office policy at crossings of overhead telephone plant and power lines, particularly for power lines of 11 kV and 33 kV. Among the methods of guarding specified prior to 1953 it was required that either the power line or the Post Office circuits were to be placed underground; a cradle guard be erected; or, for low-voltage power systems, P.B.J.-covered power or telephone wire be used. Placing a line underground and the provision of cradle guards were both expensive operations and the protection given by P.B.J., when weathered, left something to be desired.

With the above points in mind it was decided in 1953 to experiment with p.v.c.-insulated wires and polythene-sheathed aerial cable at power crossings. From field tests[5] it was found that a pair of 70 lb/mile cadmium-copper telephone wires each sheathed with 60 mils of p.v.c. could safely withstand without electrical or mechanical failure the stresses imposed by a live 33 kV power conductor falling directly across them. From these same trials it was found that a polythene-sheathed aerial telephone cable lashed to a bare steel suspension strand would safely withstand similar stresses imposed by a falling 11 kV power conductor. These trials led to further investigations which showed that overhead power lines of up to 11 kV if sheathed with 60 mils of p.v.c. could be run quite safely above open-wire telephone routes or metallic-sheathed aerial cables. These findings have resulted in the extensive use of p.v.c.-covered wire and plastic-sheathed cables at power crossings, with a considerable reduction in the cost of guarding.

The successful introduction of p.v.c.-covered wires and polythene-sheathed aerial cables at power crossings has resulted in the joint use of Post Office and Electricity Board poles. It has been the practice since 1951 to adopt this joint-construction, as it is termed, with the Electricity Boards' low-voltage service (415/240 volts). This has lead to consideration of an extension of the practice to 11 kV lines. Experience on a number of such routes has so far been satisfactory. On these the Post Office circuits have been run in p.v.c.-covered wire and polythene-sheathed aerial cable; the power conductors being left bare.

PROTECTION OF UNDERGROUND CABLES

In 1950 polythene protection of lead-covered cables was first tried. It was hoped that by using polythene instead of the standard hessian and graphite finish, sheaths of main cables could be insulated from earth, thus giving a means for immediate detection of faults due to mechanical damage. Difficulties were experienced, however, in maintaining the insulation resistance at jointing points, and in view of the higher cost of this type of protection its use has been restricted.

The reader may question why polythene instead of p.v.c. has been used for both the sheath of plastic cables and as an overall protection of lead. Cost has had little bearing on the matter as the generally lower prices per pound for p.v.c. have been offset by its higher density. Admittedly, p.v.c. is somewhat tougher and more resistant to abrasion, but for duct work polythene has advantages, being lighter and having a lower co-efficient of friction. The high insulation resistance to earth, previously mentioned, was also needed. It is not certain, however, that polythene as a protecting material will maintain its position. The Electricity Boards are using p.v.c. extensively as a protection for armour, and the Post Office has not dismissed the potentialities of p.v.c. As long ago as 1951 an 8-pair 40 lb/mile cable was laid between Beal and Holy Island[6] on the N.E. Coast. This cable, $1\frac{1}{4}$ miles long, is paper-insulated, lead-sheathed and p.v.c.-protected. It is covered by each tide, and to date has been free from faults. P.V.C. was chosen for this work because of its toughness, which would resist the penetration of any sharp stones.

During 1954 a paper-core cable sheathed with polythene was laid between Dover and Deal.[7] It was thought that, without the barrier provided by a metallic sheath, permeation by water vapour would by now have lowered the insulation resistance of the cable, and provision was made for drying it out by gassing. No deterioration has, however, been observed and further experimental lengths have been or are being provided. Even if polythene by itself is successful, the metal sheath will not be entirely excluded from new works as railway electrification will demand a high degree of screening on a number of routes. Aluminium is the most suitable metal although it has a high susceptibility to corrosion. Bitumen-impregnated hessian tapes are inadequate protection for aluminium and a number of lengths of aluminium-sheathed cable having polythene or p.v.c. protection are being purchased.

FIG. 4—AN 11 KV, 3-CORE SUBMARINE POWER CABLE, 0·07 IN² CONDUCTORS, POLYTHENE INSULATION WITH SEMI-CONDUCTING SCREENS, INTERSTITIAL WIRES TO PROVIDE EARTH RETURN PATH, P.V.C. FILLING AND BELT AND P.V.C.-COVERED ARMOUR WIRES

POWER SUPPLY CABLES

Polythene-Insulated Supply Cables

Paper is still the most widely used material for electricity supply cables; it is applied in successive lappings of 4 or 5 mils thickness up to a total of one inch for the 132 kV to 200 kV cables. To eliminate voids in which ionization, or gaseous discharge as it is sometimes termed, may occur, the insulating papers on high-voltage cables are impregnated with oil. Ionization, when it does occur, results in local attack of the insulation, and leads to breakdown. For cables intended to work at voltages in excess of 11 kV, pressurization with nitrogen up to 250 lb/in^2 is resorted to. Such cables must of necessity be provided with a lead or aluminium sheath and substantial armouring as protection against mechanical damage and loss of pressure.

If the paper insulation could be replaced by polythene or p.v.c., the gas-tight sheath would not be needed and, with the greater robustness of the plastic-insulated cable, a reduction in the weight of the armour would be permissible. Thus, despite the fact that plastics cost about twice as much as oil-impregnated paper an overall saving would result. Unfortunately, both polythene and p.v.c. have their drawbacks as insulation in high-tension cables.

Polythene is somewhat sensitive to ionization. The voids in which it occurs can arise from the high co-efficient of expansion of polythene. During extrusion, the polythene first to come in contact with the conductor can become chilled and solidified; so also can the outer skin of the extrusion in contact with the water in the cooling trough. The subsequent contraction of the polythene within these annuli lifts the inner layer off the conductor. Pre-heating of the conductor and application of a vacuum behind the extruder, i.e. where the conductor passes through the point of the extruder die, have considerably improved the performance of plastic-insulated power cables. They are, however, still in an early stage of development and probably not much in excess of 25 miles of polythene 11 kV a.c. mains cable is in use in this country at the present time. It is worth noting that one British company has supplied 11 kV polythene-insulated power cable for use overseas. About 150 miles of 3-core, 0·075 in^2 cable has now been shipped for submarine installation in Lake Maracaibo, an inland stretch of water opening on to the Caribbean Sea, to power the oil-well pumping stations and drills used for exploiting the vast oil deposits lying beneath the lake bed. Due mainly to the fact that the next higher supply voltage in the United Kingdom is 33 kV, it has been left to other countries to experiment with higher voltages. About 150 miles of cable working at 15 kV and 20 kV a.c. have been installed in America and in Europe.

Ionization and breakdown are the adjuncts of a.c. working. A cable may be operated with d.c. at up to five times the a.c. voltage permissible for a given construction and, most important of all, the dielectric losses are eliminated with d.c. working. For paper-insulated cables pressurization is unlikely to be required unless the operating stresses are particularly high, say, on a 200 kV cable. National grid systems operate on high-voltage a.c. overhead lines, and it was not possible to take advantage of the economics of d.c. cable links prior to the development of rectifiers of the mercury-arc series-connexion type. The first high-voltage d.c. cable to be installed was in Sweden, 90 km long between Gotland and the mainland. This was, however, of traditional construction. Two projected cross-Channel cables to link the British and French power grids are to be designed to work at 200 kV d.c. with a power-carrying capacity of 150,000 kW each. Were these cables to be insulated with polythene a new field of application for this valuable plastic could be inaugurated. Possibly the scheme is of too great consequence for such an innovation. Nevertheless, it is considered that polythene-insulated power cables for high-voltage d.c. operation are a certainty in the future.

P.V.C.-insulated Supply Cables

The dielectric loss of p.v.c. is high and p.v.c.-insulated power cables have generally been considered uneconomic when compared with paper-insulated cables. Nevertheless, 11 kV a.c. cables have, or are now, being installed in this country and the Americans are using 15 kV cables. The Germans claim that 32 kV is practicable. These results have been achieved by high-purity p.v.c. and the screening of cable cores.

Power Cables used on Consumers' Premises

The power cables so far mentioned are those concerned with electricity supply, i.e. those linking generating station to consumer. There is another large range of rubber-insulated and rubber-sheathed cables specified in British Standard (B.S.) 7, which caters for the voltages from 250 volts to 11 kV that are normally used on consumers' premises. Only in the 250-volt range has the alternative use of plastics been officially acknowledged by the issue of British Standards.

B.S. 2004 covers p.v.c.-insulated cables and flexible connexions. The circuit capacity of a given size of conduit is governed by the I.E.E. Regulations for the Electrical Equipment of Buildings and although the use of p.v.c. results in smaller insulated cores it does not therefore permit of a larger maximum number being installed in a conduit. The lower frictional resistance of p.v.c. compared with that of the rubber-insulated impregnated-cotton-braid type to B.S. 7, together with the smaller diameter, does, however, simplify installation.

P.V.C.-insulated cables having the dimensions quoted for rubber in B.S. 7 are already being marketed for operation at voltages up to 3·3 kV. This is an extravagant use of material in view of the superior mechanical properties of p.v.c., and it is hoped that a British Standard for such cables will be issued, recognizing this.

Another British Standard, B.S. 1557, has been published covering the construction of polythene-insulated p.v.c.-sheathed cables in the 250-volt range. The use of polythene permits a lower radial thickness of insulation, but in the case of single cores a larger overall diameter on finished cable than is called for in B.S. 2004 results, because it is considered desirable to provide an outer covering of p.v.c. to reduce the fire risk inherent with polythene. The reduction achieved in the overall dimensions of the twin and triple cables, which are always sheathed, is rarely of any account as these cables are usually run on the surface. It is therefore questionable whether the B.S. 1557 make-up has much future.

CONCLUSION

It will be appreciated that this article is little more than a general survey of the advances made by plastics into the cable manufacturing field. An incomplete survey perhaps, as no details have been given of the combinations of traditional and new cable sheathings tried in the U.S.A. and Germany. Nor has mention been made of the many instances where plastics are beginning to encroach upon the use of rubber in telephone instrument and switchboard cords. Sufficient evidence has been presented, however, to show the radical changes that have taken place in the construction of cables. So rapid has been the development and so many advances of research into polymerization remain to be explored that no attempt will be made to forecast what the future holds for the cable designer and manufacturer, except to say that wire coverings are likely to become so good from the insulating point of view that when used in multi-core cables, more than the minimum thickness required for insulation will be needed to safeguard the transmission characteristics.

ACKNOWLEDGEMENTS

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Radio Interference

Part 3—Suppression

R. A. DILWORTH, A.M.I.E.E.†

U.D.C. 621.396.828:621.397.828

Parts 1 and 2 of this article introduced the subject of radio interference and described the Post Office radio interference service. Part 3 considers how the interference is generated and propagated and describes methods of suppression. Details are included of a number of radio-interference suppressors at present in use. Further articles will deal with the measurement of radio interference, incidental radiation devices and the control of radio interference.

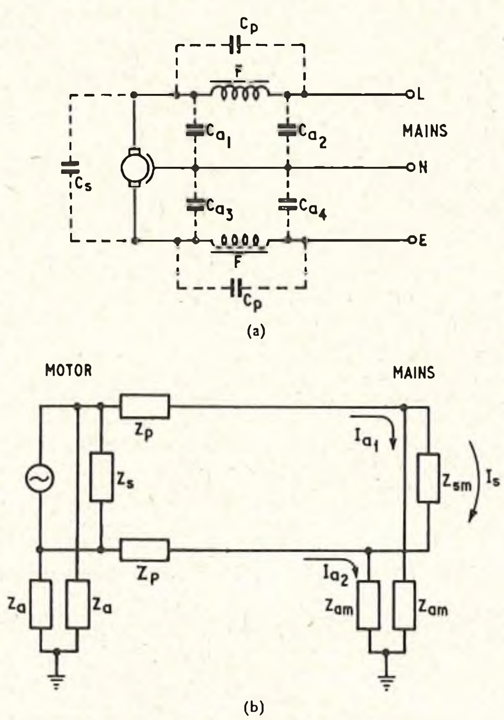
GENERATION OF INTERFERENCE

By far the greatest number of complaints of interference are made about equipment in which the generation of radio-frequency energy is incidental to the operation of the device, e.g. electric motors and thermostats.

Impulsive Interference

Any sudden change of current that takes place in an electrical circuit can by Fourier analysis be shown to have components extending throughout the entire radio-frequency range. Radio-frequency currents flowing in an electrical circuit can set up similar currents in other circuits electrically coupled, but not necessarily physically connected, to the first circuit, the secondary current depending on the electrical nature of the secondary circuit, the coupling factor and the magnitude of the primary current.

Taking a common source of interference (the commutator motor) as an example. Fig. 5(*a*) shows the basic motor circuit with a simplified representation of the distributed capacitance. Fig. 5(*b*) is an equivalent diagram of the same machine when joined to the electric power mains, in which Z_{sm} represents their symmetrical impedance and Z_{am} their asymmetrical impedance. The currents flowing in the external connexions to the machine, I_s, I_{a1} and I_{a2}, are those mainly responsible for interference with broadcast and television reception. Radiation from the machine itself only becomes a significant factor at very high frequencies.



(*a*) Schematic diagram showing distributed capacitance
(*b*) Equivalent diagram of motor connected to mains

FIG. 5—COMMUTATOR MOTOR

Since the mains wiring is not symmetrical to radio-frequency currents the symmetrical component, I_s, very soon develops an asymmetrical component, which flows between mains wiring and earth in a loop of relatively large size and good radiating properties.

Continuous-Wave Interference

Radio-frequency energy is necessary for the operation of certain types of equipment, e.g. plastic welders, radio transmitters and receiver oscillators, which produce continuous-wave interference; these will be dealt with in a later article in this series.

PROPAGATION OF INTERFERENCE

The radio-frequency energy generated as outlined above is propagated in one or a combination of the following ways:

(*a*) By radiation from the interference source and any wiring immediately associated with it.

(*b*) By conduction along the electricity supply cables from which the equipment draws its power.

(*c*) By conduction along wires or other conductors not directly connected to the source or its power supply but closely coupled thereto.

Direct Radiation

The term "direct radiation" is used to describe the process whereby electromagnetic energy generated by an interfering device is transferred to free space and from there to the receiving aerial. Radiation can occur partly from the equipment itself and partly from its flexible cable, if any, or from the first few feet of the mains-supply cable. The coupling between the equipment or its mains lead and free space becomes more effective at higher frequencies. In small motor-driven domestic appliances, which are almost invariably of a portable nature, the conditions for radiation at television frequencies are particularly favourable.

Propagation along Power-Supply Cables

Any interference source connected to the power mains will inject radio-frequency noise currents into the mains. At the lower broadcast frequencies such currents can travel considerable distances along street cables and flow into house wiring connected to the cable. These currents set up radio-frequency noise fields in houses and, although such fields are very weak and do not extend very far from the mains cables, the aerial or

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part of it may well be coupled to the wiring. At television frequencies the attenuation of the mains cable is quite considerable and, generally speaking, little difficulty is experienced from mains-borne interference.

Propagation along Conductors Not Connected to the Interference Source

Noise currents may be induced in conductors passing through a strong radio-frequency field, be conveyed for considerable distances along the conductors and subsequently picked up by a receiving aerial placed near to them. Attenuation of these currents is greater at the higher frequencies, and at television frequencies this mode of propagation is not responsible for many complaints.

REDUCTION OF INTERFERENCE BY MEASURES TAKEN AT THE RECEIVING INSTALLATION

Before considering what can be done to suppress interference at the source, the points that should first be given attention at the receiving installation will be considered. These are:

(*a*) Develop the best possible signal/interference ratio at the radio receiver input by using a good aerial installation.

(*b*) In the case of television and v.h.f. receivers use limiters to reduce the effects of impulsive interference.

(*c*) Provide adequate protection against spurious responses, i.e. response to interference signals not in the band of frequencies transmitted.

(*d*) Provide adequate protection against interfering voltages present on the mains leads and, in the case of v.h.f. and television receivers, the aerial feeder also.

Aerial Installations. Whatever the mode of propagation of interference from source to receiver input, the better the receiving aerial installation the less chance there is of interference being received, unless there are exceptional circumstances to be considered. It cannot be too strongly emphasized that a good aerial installation is the first step to interference-free reception. Many of the cases investigated show that interference could very often be eliminated by a better aerial. Even in areas of high field strength, machines fitted with standard suppressors may still be the cause of complaint when inefficient aerials are used. This point is of considerable importance since it is unreasonable to insist on the suppression of an interfering machine unless the complainant has a satisfactory receiving installation. Unfortunately, tenancy restrictions sometimes make it impossible to use an efficient aerial but greater interest is now being shown in communal aerial systems, particularly for television reception in Local Authority flats. Although statistics for 1956–57 showed that some 9 per cent of the total complaints could have been obviated by an improved aerial and/or attention to the receiver, there is little doubt that many more installations are unsatisfactory.

Limiters. Modern television receivers are equipped with limiters on both sound and vision channels. The sound limiter is generally not adjustable, whereas the vision limiter may be either self-biasing or preset to limit the increase in brightness to that of peak-white. A few models use a "black spotter" device in which signal voltages exceeding a certain limit are amplified, inverted and superposed on the output signal to produce grey or black spots in place of white ones. Some system of limiting is essential in equipment for receiving the frequency-modulation broadcast service if the full benefits of its relative freedom from interference are to be enjoyed.

Spurious Responses. Nearly all modern receivers use the superheterodyne principle and are subject to the peculiarities of this type of circuit. The main difficulties that arise are due to the spurious responses at the intermediate and image frequencies, although cases do occur where the spurious response involves multiples of the oscillator frequency. Any interfering signals that may be present at these frequencies appear in the intermediate-frequency amplifier without being greatly attenuated. These difficulties occur principally with television receivers.

Mains Leads and Aerial Feeders. Interference conveyed via the mains into low-frequency and medium-frequency radio receivers can be reduced by suitable filters in the mains-supply lead. Interference voltages picked up by the aerial feeder of v.h.f. and television receivers can be injected into the input circuit, and a low-impedance connexion from the coaxial sheath to earth or to chassis is necessary on an unbalanced feeder, or a high degree of balance at the terminals of a balanced feeder system. Since adequate balance is difficult to obtain in commercial production it is usually preferable to use coaxial cable.

Manufacturers take such steps as they consider to be necessary and commercially practicable to reduce the susceptibility of their products to radio interference. British Standard Specification No. 905–1940, "Anti-interference Characteristics and Performance of Radio Receiving Equipment," is now being revised, and the revised specification will include methods of test and requirements relating to the susceptibility of receivers to radiated and mains-borne interference. It is hoped that when the revised specification is published manufacturers will take steps to ensure that at least their better quality receivers conform to it. It has not yet been possible to incorporate in B.S. 905 requirements relating to image response and intermediate frequency rejection.

SUPPRESSION AT SOURCE

Table 6 shows an analysis of the complaints listed in more detail in Table 4* (Items 1–19). Dealing with items No. 5 and 7 of the table requires techniques not discussed in this article, which is concerned with sources in which the interference is principally mains-borne, e.g. items 1, 2, 3 and to some extent item 6. As a matter of interest, interference with television reception is caused by filament lamps (item 4) oscillating at a frequency

TABLE 6

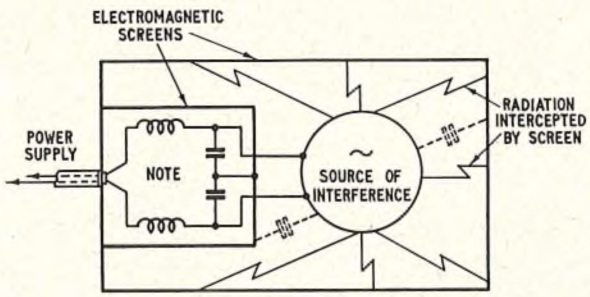
Complaints Attributed to Specific Sources 1956–7

Source	L.W. & M.W. Sound	Television and V.H.F. Sound
1. Motor-driven machines	8,252 (41½%)	33,610 (60%)
2. "Contact" devices	2,902 (15%)	6,385 (12%)
3. Discharge lamps (all types)	2,468 (12%)	2,355 (4%)
4. Filament lamps	90 (½%)	2,353 (4%)
5. Power lines	484 (2½%)	4,348 (8%)
6. Radiation from receivers (oscillators, time-base circuits)	5,553 (28%)	4,917 (9%)
7. Industrial and medical equipment	88 (½%)	1,691 (3%)

*Part 2.—Vol. 50, p. 229, Jan. 1958.

in the television band. Since this phenomenon is confined to vacuum lamps it is more economical to fit a gas-filled lamp than to attempt suppression of the interfering item. Motor vehicle ignition does not feature as a separate item in this table because very few complaints are made to the Post Office although it is known that many viewers do in fact suffer interference from this cause.

The basic principles of suppression are shown diagrammatically in Fig. 6. In the case of most inter-



Note.—Filter to prevent the propagation of noise currents along power lines

FIG. 6—PRINCIPLE OF SUPPRESSION AT SOURCE

fering devices it is not necessary to provide an electromagnetic screen since the metal framework of the machine generally forms an adequate if incomplete shield; additional screening is essential only when a considerable reduction in interference is required. Where, however, leads pass through the screen, e.g. to supply power to the machine, the radio-frequency energy would be conveyed out of the enclosure if filters were not fitted at or near this point.

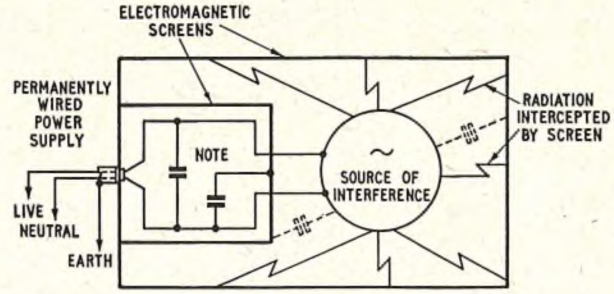
SAFETY PRECAUTIONS

In practice the metal parts of a machine to which suppressor capacitors may be connected are frequently accessible to the user. If the machine is portable there is a serious risk of the earth connexion becoming disconnected without the user's knowledge; indeed many machines are used without any earth connexion at all. There are two ways in which risk of shock can arise to a user who is connected to earth.

(*a*) Danger of fatal shock if the capacitor between live conductor and frame becomes short-circuited. This is guarded against by using adequately sealed capacitors with a d.c. test voltage of nine times the working r.m.s. voltage and an average d.c. breakdown voltage (when tested to destruction) of twice that value.

(*b*) Danger of serious shock and possible secondary accidents, due to current flowing from the 50 c/s mains via the capacitor and body to earth. This risk is avoided by limiting the capacitor size to 0·005μF, hence limiting the current flowing to approximately 0·4 mA when the mains supply is 250 volts, 50 c/s. This current is imperceptible to the average person.

Permanently connected equipment or mains wiring where the danger of wiring disconnexions is negligible may be fitted with large-value capacitors (up to 2μF) but even here the



Note.—Filter to prevent the propagation of noise currents along power lines

FIG. 7—SUPPRESSION-CAPACITOR ARRANGEMENT FOR PERMANENTLY EARTHED EQUIPMENT

capacitors are connected between live and neutral conductors and neutral conductor and earth, as shown in Fig. 7. Since only the neutral conductor is connected to frame via the capacitor there is no danger of shock if the earth becomes disconnected. An earth connexion via a flexible cable is not considered to be a permanent connexion. Machines are now available of an all-insulated or double-insulated construction in which the metal parts of the motor framework are not accessible and need not therefore be earthed. The suppression problem is eased since there is no earth connexion to increase the asymmetric current and larger values of suppression capacitor may be used without danger of shock.

PRACTICAL SUPPRESSION ARRANGEMENTS

The suppression of interference caused by mains-powered machines usually resolves itself into designing separate suppressor circuits for the sound broadcast bands (medium and low frequency) and the television bands, since the components required for these two bands differ very considerably in their characteristics. At high frequencies capacitors appear electrically as series tuned circuits, the inductance being that of the foil windings and connecting leads. Capacitors must therefore

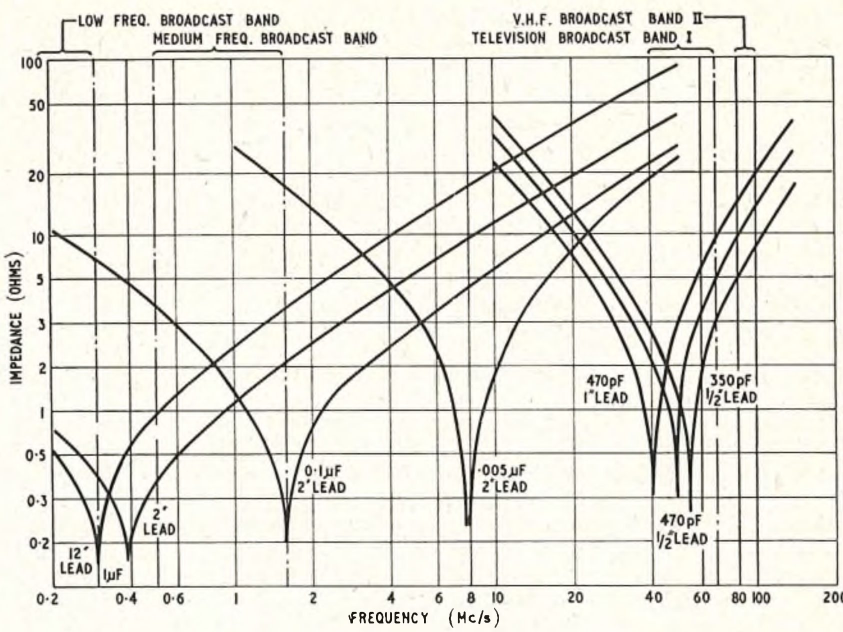


FIG. 8—IMPEDANCE/FREQUENCY CHARACTERISTICS OF TYPICAL CAPACITORS

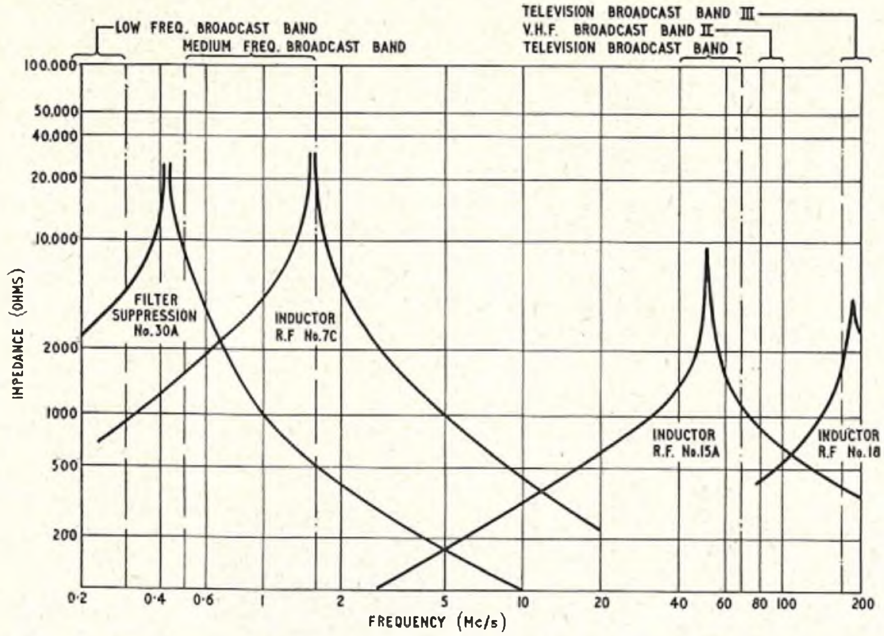


FIG. 9—IMPEDANCE/FREQUENCY CHARACTERISTICS OF TYPICAL RADIO-FREQUENCY INDUCTORS

be chosen that have a low impedance throughout the frequency range to be suppressed. Inductors, on the other hand, appear electrically as parallel tuned circuits, the capacitance being that of the inductor windings. Inductors must be chosen, therefore, that have a large impedance throughout the frequency range to be suppressed. This is illustrated in Fig. 8 and 9.

Television - band components must be mounted either inside or very close to the machine to minimize radiation from the leads connecting the suppressor. Broadcast-band intereference being principally mains-borne, the suppressors may be mounted several feet away without their performance being appreciably affected.

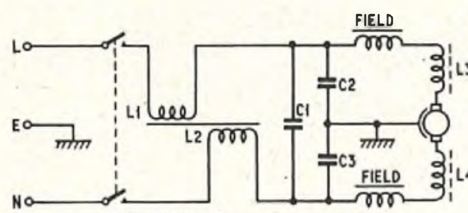
Typical arrangements for the suppressors for several different devices are illustrated in Fig. 10, 11 and 12.

The suppression of interference from motor-vehicle ignition presents a somewhat easier problem than those outlined above, and suppression adequate to protect television broadcast reception can be obtained by fitting resistors of between 5,000 and 15,000 ohms near the spark gaps, i.e. in the h.t. lead near the distributor, and sometimes in addition at the sparking-plug terminals.

The position chosen for the components used and their suppression characteristics are governed partly by the physical construction of the machine and partly by its electrical characteristics in the radio-frequency spectrum involved. It is rarely possible to assess the optimum suppressor arrangement by inspection of the machine. This leads to a trial-and-error method of assessing the most suitable arrangement of components and their physical location in the machine. The methods of measurement will be dealt with in a later article in this series. For practical purposes, where small mains-operated equipment is concerned, measurement of the interference voltage appearing at the machine terminals gives a satisfactory indication of its interfering properties and makes trial-and-error methods of assessing suppressor performance a practical process.

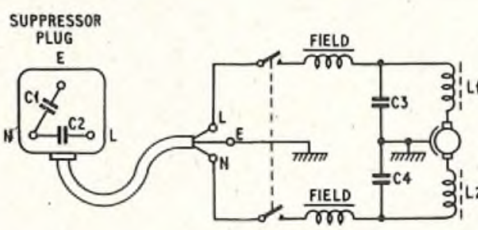
SUPPRESSOR COMPONENTS

The Post Office has maintained stocks of radio-interference-suppression components since the early 'thirties. In pre-war days interest was focused on suppressing interference to medium-frequency and low-frequency reception and relatively bulky components were used. Since the



C1 = 0·1 μF } For medium-wave and
C2 = C3 = 0·005 μF } long-wave suppression
L1 = L2 = 2 mH
L3 = L4 = 5 μH for television suppression

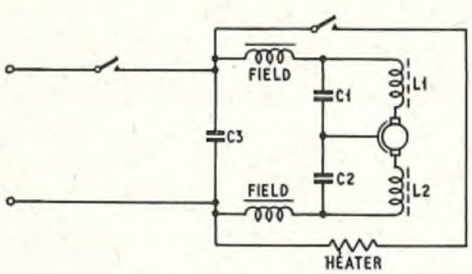
(a) Manufacturers' arrangement where casing can be modified to enclose suppressors.



C1 = 0·05 μF } For medium-wave and
C2 = 0·1 μF } long-wave suppression
C3 = C4 = 470pF } For television suppression
L1 = L2 = 5 μH }

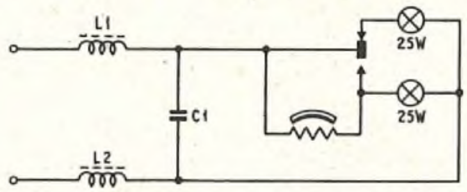
(b) "Field" suppressor where all components cannot be fitted inside case

FIG. 10—EARTHED PORTABLE MACHINE (ELECTRIC DRILL)



C1 = C2 = 0·005 μF } For medium-wave and
C3 = 0·1 μF } long-wave suppression
L1 = L2 = 5 μH for television suppression

FIG. 11—UNEARTHED PORTABLE MACHINE (HAIRDRYER)



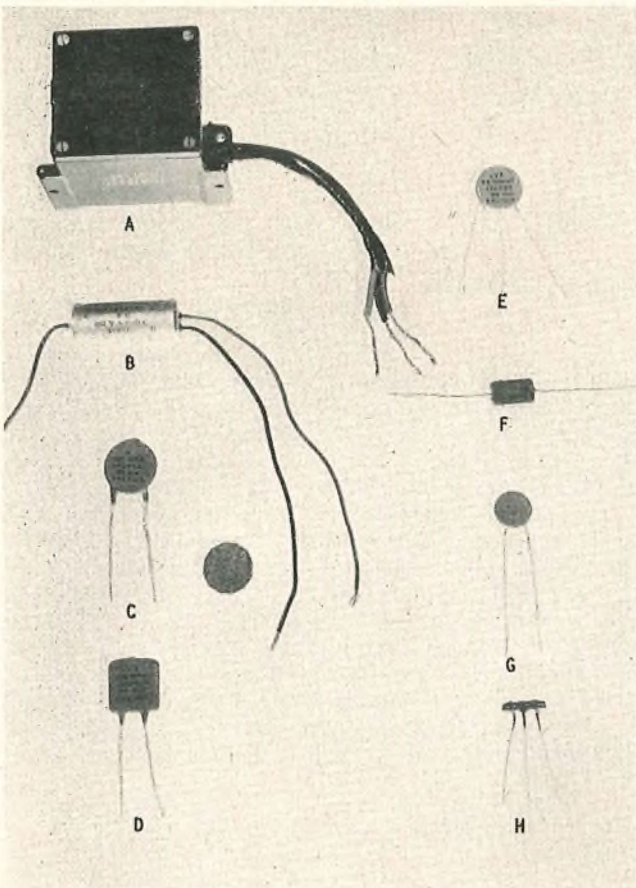
C1 = 0·5 μF for medium-wave and long-wave suppression
L1 = L2 = 5 μH for television suppression

FIG. 12—UNEARTHED PORTABLE MACHINE (FLASHING SIGN)

general trend is towards smaller electrical equipment the difficulty of finding space for suppressors becomes more serious as time goes on and the quest is always for smaller components.

Capacitors

Relatively large capacitors (of the order of 1 μF) can only be fitted to permanently earthed machines or electric wiring where their physical size is not important. An example shown in Fig. 13 consists of two 1 μF capacitors in a moulded case provided with 12 in. of 3-core cable for connexions. Capacitors of this size are very effective suppressors at broadcast frequencies; it



A. Filter, Suppression, No. 23C, 1 μF + 1 μF
B. Unit, Capacitor, No. 8C, 0·1 μF + 0·005 μF + 0·005 μF
C. Capacitor, Ceramic, No. 1305, 0·035 μF
D. Capacitor, Ceramic, No. 1303, 0·02 μF
E. Capacitor, Ceramic, No. 1304, 0·005 μF + 0·005 μF
F. Capacitor, Mica, No. 5212, 500 pF
G. Capacitor, Ceramic, No. 1302, 470 pF
H. Capacitor, Ceramic, No. 1306, 470 pF + 470 pF + 470 pF

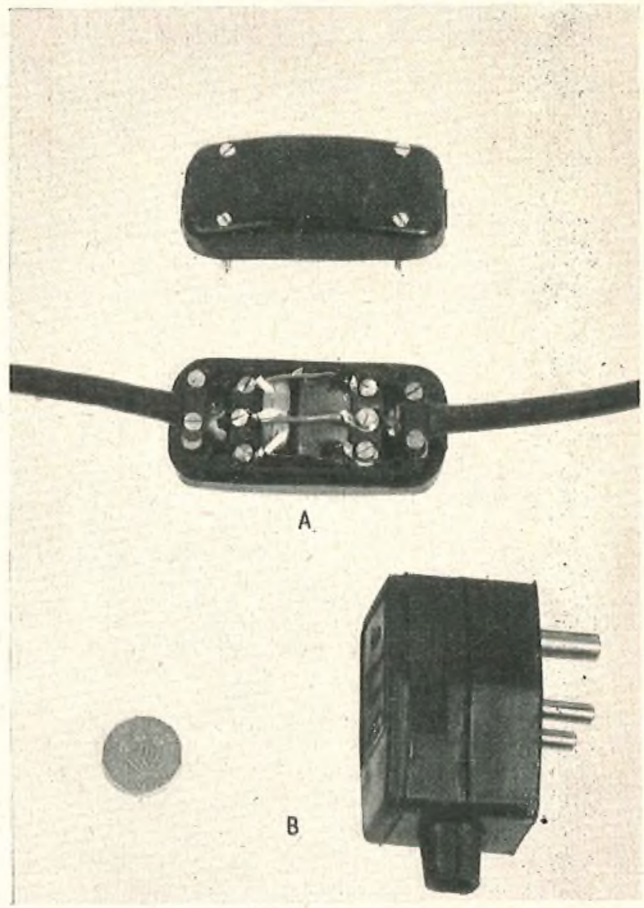
The size of the components can be judged by comparison with the threepenny piece near C

FIG. 13—CAPACITORS

will be seen from Fig. 8 that the impedance of such capacitors can be less than 2 ohms over the frequency range 0·2–1·5 Mc/s. The most useful sizes in the current range of capacitors of small value (0·1 μF or less) are illustrated in the same figure. They can very often be fitted inside the interfering machine either as a composite unit, or, if space is limited, as separate components. These small values effectively suppress the medium frequencies but are not very satisfactory at low frequencies due to their relatively high impedance at 200 kc/s. This point is clearly illustrated in Fig. 8.

For the smallest machines it is necessary to use external suppressors and a housing designed to fit in the flexible power cable can be used. An alternative arrangement houses capacitors in the power plug. Both the plug and flex-lead case illustrated in Fig. 14 are moulded in black rubber to avoid breakage.

The use of capacitors in television suppressors is limited because machines generally have a low impedance at the frequencies concerned. The optimum value for Band I television work is between 300 and 500 pF and Fig. 13 shows three stock items (F, G and H) now available; typical impedance/frequency characterics appear in Fig. 8.



A. Case, Filter-Suppression, No. 29B, containing 0·005 μF + 0·005 μF + 0·1 μF capacitors
B. Plug, Suppression, No. 1, containing 0·05μF + 0·1 μF capacitors

The size of these components can be judged by comparison with the threepenny piece near B

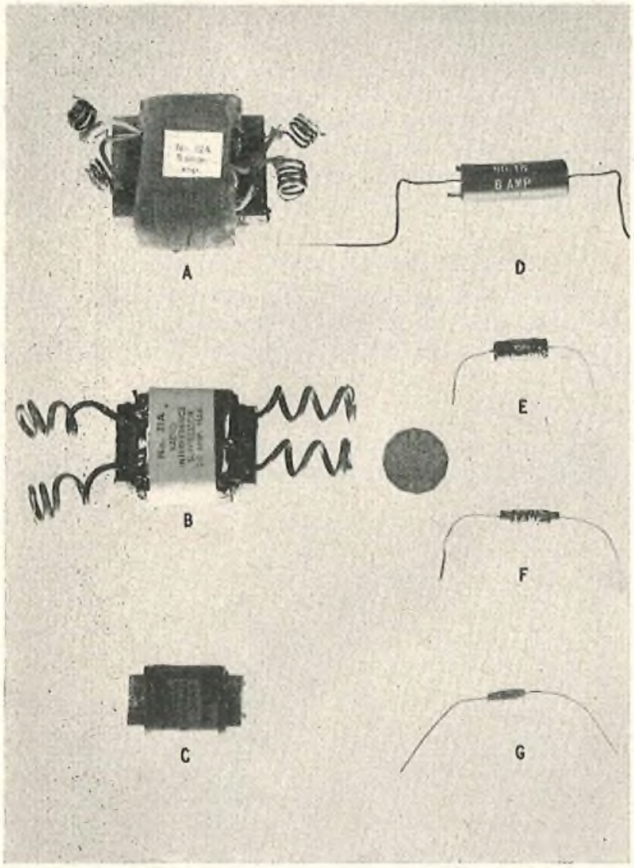
FIG. 14—EXTERNAL SUPPRESSORS

In addition to these items there are a range of metal-cased tubular capacitors similar to item B of Fig. 13, of values between 0·005 μF and 0·25 μF, and a range of mica capacitors similar to item F of values between 50 pF and 0·01 μF. All are designed for use at 250 volts a.c.

Inductors

Post-war development of magnetic materials has enabled satisfactory inductors to be wound that are substantially smaller than their pre-war equivalents. These are illustrated in Fig. 15 (Items A to C). They are wound in pairs on a common core so that the supply current drawn by the suppressed machine produces zero magnetization of the core and thus minimizes saturation effects. This method of winding materially improves the rejection of the asymmetrical interference component, which is the more difficult to suppress, at the expense of the symmetrical component, which can readily be suppressed by means of a capacitor connected between line and neutral wires. Inductors capable of carrying heavier currents can be designed but demands for these are very limited and maintaining a stock of the items is not justified.

Early types of inductors for the television band were air-cored and if made large enough to be efficient could not be fitted inside small machines. Inductors now



A. Filter, Suppression, No. 32A, 2 mH+2 mH, 3 amp
B. Filter, Suppression, No. 31A, 2 mH+2 mH, 2 amp
C. Filter, Suppression, No. 30A, 2 mH+2 mH, 0·75 amp
D. Inductor, R.F No. 16, 5 μH, 8 amp
E. Inductor, R.F. No. 15A, 5 μH, 3 amp
F. Inductor, R.F. No. 15A, 5 μH, 1 amp
G. Inductor, R.F. No. 18, 1·2 μH, 3 amp

FIG. 15—INDUCTORS

available are wound on miniature dust cores and have a very satisfactory performance in Band I, 41–68 Mc/s, and Band II, 88–95 Mc/s. These components will fit inside the smallest machines now in use. Although these inductors are relatively inefficient at Band III television frequencies they are usually found to provide adequate suppression. An inductor designed for Band III is available, however, and is illustrated with the others in Fig. 15 (Item G). Typical impedance/frequency characteristics appear in Fig. 9.

Complete Filters

In Post Office radio interference suppression work a wide range of sizes and shapes of interfering machines is dealt with and separate components are generally more useful than complete filters, which may fit only a few machines. Where sufficient demand exists, complete filter units have been provided.

The recently developed technique of "potting" components in epoxy resins has enabled comparatively small filter units to be produced at a cost little greater than that of the component parts. One of these filters, Filter, Suppression, No. 1B, contains two television-band inductors, two broadcast-band inductors, two 0·005 μF capacitors and one 0·02 μF capacitor and will carry 0·75 amp. Yet it is small enough to be fitted into a moulded-rubber flex-lead case, for use where space cannot be found inside the machine. Another filter, Filter, Suppression, No. 33A, designed for sewing machines, contains a 0·025 μF capacitor and two television inductors.

FUTURE DEVELOPMENT

There seems to be little scope now for any further reductions in the size of components for suppression at television frequencies. Fairly robust terminals are required to withstand the arduous conditions imposed on them in a portable machine and they already approach the size of the active element of the component. Moreover a substantial insulation coating is required to meet the voltage-breakdown requirements and mechanical stresses.

It is possible that new developments in ceramic and film dielectrics will permit some reduction in the size of capacitors in the range 0·01 μF to 0·1 μF but substantial changes are unlikely. The cost of developing such capacitors suitable for continuous working at 250 volts a.c. would be considerable unless associated with other development work, bearing in mind that the cost of the final product must be competitive with existing components. For these reasons it is generally necessary to await developments in other fields before applying new techniques to interference-suppression components.

The same argument applies to the development of new core materials for inductors, where as far as possible advantage is taken of development work done for other purposes. There seems little hope at present, however, of any major reduction in volume of general-purpose inductors.

The trend in commercial suppressor design is towards complete filters, particularly where a substantial quantity of identical items is required. By sealing-in or "potting" methods some economies can be achieved in components, since individual sealing is unnecessary.

With the increasing use of higher frequencies for broadcast services, interference from mains-powered machines will cause fewer complaints in future. More trouble is likely to be caused, however, by harmonics of radio and television receiver oscillators, industrial and medical radio-frequency equipment. The suppression of interference from these sources involves the manufacturers of the equipment and is not likely to be undertaken generally by the Post Office.

(*To be continued*)

Cyclic-Pulse Switching Systems

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U.D.C. 621.374.3:621.316.5

Electronic computers and telephone systems have much in common, including pulse generators, gates and pulse stores. Cyclic-pulse systems using apparatus of these kinds to perform familiar metering and relay-set operations are described by examples.

EVOLUTION IN SWITCHING

SWITCHING engineers have long been familiar with relays, uniselectors, Strowger and cross-bar and other switches and mechanical counters and the seemingly endless number of ways in which they may be interconnected to perform a great variety of tasks. This situation was reached in the 1930's. Switching engineers might perhaps have been excused for feeling that something like finality had been reached, because they could and did assert with confidence that their art was able to solve any switching and control problem which could be logically posed. They had progressed in about two generations from the concepts of isolated problems each solved round some piece of apparatus to more general treatments of switching systems. Thus, when some new machine was required, they were able to request that only what it should do should be specified, not how it should do it. That there was some way of achieving the desired result was a foregone conclusion so long as mutually contradictory requirements were excluded. True the cost and size might be prohibitive. Also, the reliability of extremely complex machines might be open to doubt but theoretically at least sufficient reliability was always to be had. What was only vaguely appreciated was that ideas which were to make a profound change to switching practice had already begun to take shape. Eccles and Jordan in London University showed as far back as 1921 that pairs of thermionic valves could be made to behave like locking relays. In Cambridge University, C. E. Wynn-Williams produced thyratron counters in 1931, and W. B. Lewis produced vacuum-valve counters shortly afterwards. These developments foreshadowed a change in the components to be used in switching systems—to electronic components. This change has proved to be complementary to an equally powerful force for change which began about 1935—the interest which mathematicians, notably A. M. Turing in Cambridge, began to take in automatic machinery. Mathematicians are not in general much interested in how things work. They are more concerned with the logic of the set of requirements which specifies what is wanted of a machine. In twenty years of partnership the mathematicians and the engineers have completed the revolution which began so long ago. The mathematicians' main objective has been computers to solve mathematical problems. Communications engineers have not been slow to see that their own problems are basically the same and they have profited by and added to the work on computers. Logical switching using cyclic pulses is the subject of this article, and is a part of the new switching knowledge contributed by communications engineers, the name of G. T. Baker[1] being outstanding in this connexion in this country. In retrospect there appears to have been a process of evolution rather than revolution, as will perhaps be apparent later on in this article.

Vast efforts are being made to translate the new switching knowledge into practice. It is proving to be a comparatively slow process because new tools have to be developed for the purpose and this is always time-consuming. Ultimate success is not in doubt. In this Journal[2] and elsewhere have appeared articles that have included some of the new ideas and the apparatus needed to exploit them. This article is concerned with the basic ideas of pulse techniques which are being increasingly used in telephone switching. The need for fast-operating devices capable of prodigious numbers of operations without deterioration, and hence the importance of electronics to the future of switching, will be apparent.

PULSE SOURCES, GATES AND STORES

Pulse techniques depend on a small number of basic elements, three of which are described in this section together with some of the practical forms that they may take.

Pulse Sources

Fig. 1(*a*) is a graph of an ideal pulse of current or voltage. The current or voltage is seen to change instantly

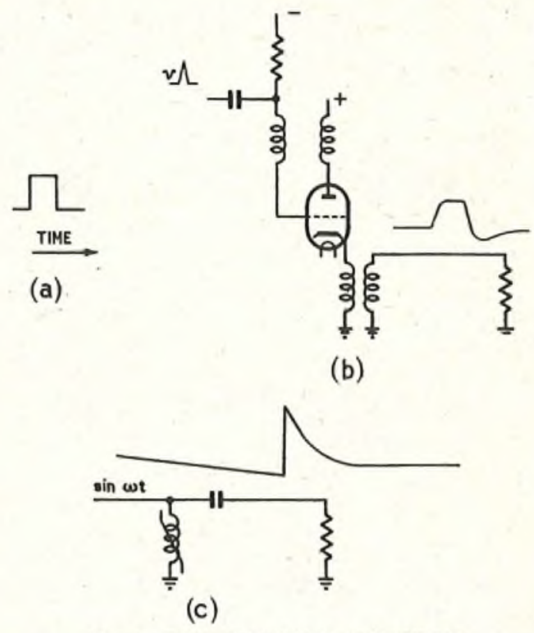

FIG. 1—IDEAL AND GENERATED PULSES

from a normal value to a maximum value, which is maintained for the duration of the pulse, and then return to normal instantaneously. An approximation to this waveform is provided by the blocking oscillator of Fig. 1(*b*) which, when triggered by a very short pulse on the grid, executes one cycle consisting of a short, very nearly rectangular, voltage pulse in one direction followed by a long, but small, pulse in the other direction. An approximation to the ideal waveform is also provided

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by the saturable inductor, Fig. 1(*c*), which, when fed by a sine-wave of current, produces a long small voltage pulse in the unwanted direction and a short large pulse in the required direction. The pulses as generated may be shaped to be more nearly equal to the ideal in a number of ways.

For the switching purposes with which this article is concerned the pulse sources are required to produce pulses at regular intervals, e.g. 1 μs pulses every 100 μs, or 10 μs pulses every 20 ms, or whatever is needed to suit a particular purpose in hand. Regularly occurring pulses from a single source are said to be a pulse train. Fig. 2(*a*)

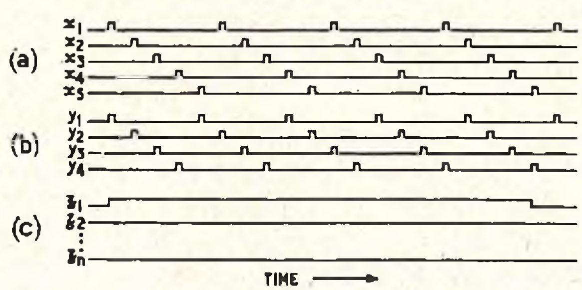

FIG. 2—TYPICAL PULSE TRAINS

and (*b*) show groups of five and four pulse trains, respectively, the pulses within one group being timed so as to occur at equal intervals throughout the cycle time of the pulses. A group of pulse sources of this kind is often called a multiplex pulse source. The pulses of Fig. 2(*c*) also repeat at regular intervals but of too great a period to be accommodated on the figure. The number of pulse trains in a multiplex group is limited by practical considerations, including economics, to between about 10 and 25. However, by suitable combinations of pulses from a number of synchronized multiplex pulse sources, very long cycles containing in effect a very large number of pulses can be produced. Taking the pulse trains of Fig. 2, four cycles of group (*a*) take the same time as five cycles of group (*b*): there are 20 combinations of one pulse train in each of the two groups: a new group of 20 pulse sources can be formed from devices which give an output only on the coincidence of pulses in the two primary groups. Combinations of the three groups of Fig. 2 give still greater numbers of pulses in a still longer cycle. A cycle for an electronic exchange may well require 20,000 pulses, one for each subscriber's line and one for each junction and every other inlet to, and outlet from, the exchange.

The cycles of pulses in the groups as in Fig. 2 are called minor cycles and the pulse trains are identified as x_l, y_m, z_n. The pulses of major and minor cycles are often referred to as "clock" pulses because they keep "time" for a system working to a repetitive cycle of pulse times.

Gates

Fig. 3(*a*) is the general symbol for a device having n input sources and giving an output when r of the sources are supplying inputs. The device is called a gate. If $r=n$, then there is an output only if a_1 and a_2 and so on up to a_n inputs simultaneously have inputs and the gate is called an "and" gate. Similarly if $r=1$ the gate is called an "or" gate. Intermediate arrangements are called r-gates according to the value of r. In general the characteristics, e.g. magnitude and polarity, of the inputs

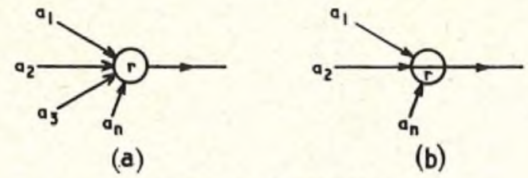

FIG. 3—GATE SYMBOLS

and the output are quite independent of one another. If information contained as a modulation of one of the inputs, e.g. speech, has to be preserved in its passage through the gate, special design is needed and this is indicated by the symbol of Fig. 3(*b*), the modulated input being the one carried through the circle. This article is not concerned with modulated pulses: their existence is mentioned to emphasize a difference which might not otherwise be apparent between them and the type of pulse with which this article is concerned.

Voltage gates usually use rectifiers, as shown in Fig. 4(*a*) and (*b*) for "and" and "or" gates, respectively.

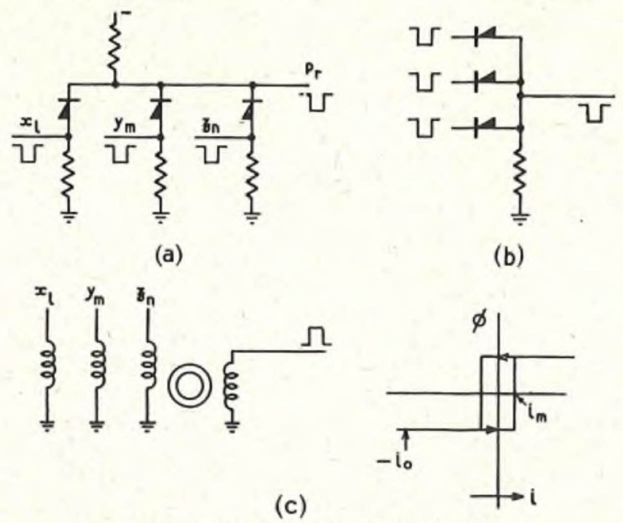

FIG. 4—VOLTAGE AND CURRENT GATES

Transistors are also very useful as gates. Current gates often use rectangular hysteresis loop magnetic cores[8] for which a current i through one of the windings produces flux ϕ as shown in Fig. 4(*c*), the core being biased by a current $-i_0$. The gate gives an output when the sum of the currents in the windings exceeds the value i_m. By suitably arranging the bias and the operating currents the gate will give an output when a given number of inputs is present.

The gate of Fig. 4(*a*) is shown as combining the outputs of three pulse sources to produce a pulse train p_r. This is a regularly recurring clock pulse. In Fig. 5(*a*) a clock pulse p_r individual to an exchange line appears as an input to two "and" gates each having a second input which is not a clock pulse. The second input to one of the gates is a meter pulse from a meter wire M. The meter pulse is the conventional metering arrangement of a pulse transmitted through the exchange switches to operate a meter individual to the line. It differs from the usual arrangement in that the meter wire is normally at earth potential and is taken to -5 volts for the period of the meter pulse. The length of the pulse may be 100 ms or more but need not be an exact

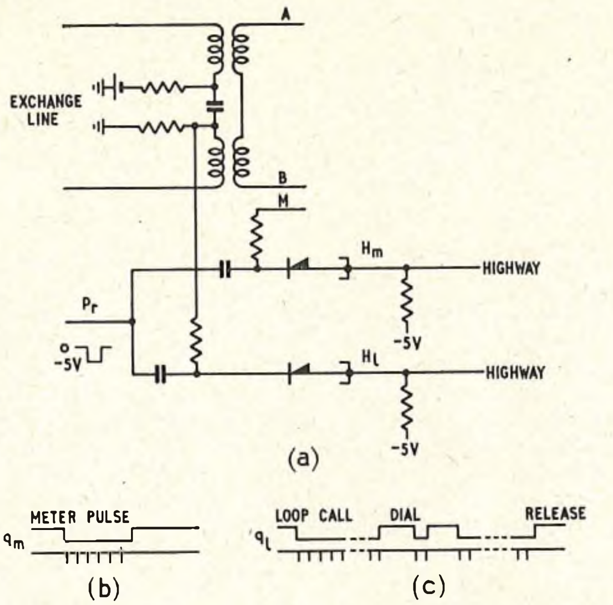

FIG. 5—PART OF EXCHANGE LINE CIRCUIT SHOWING GATES AND HIGHWAYS

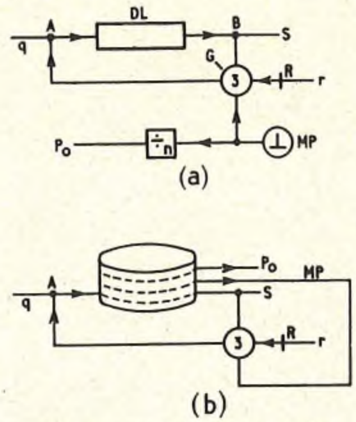

FIG. 6—CYCLIC-ORDER STORES

duration or occur in any particular part of the clock pulse cycle. The second input to the second of the gates is similarly normally earth potential but becomes about −5 volts when the exchange line is looped. The outputs from these gates are pulses occurring at the pulse time p_r but only if a meter pulse occurs, Fig. 5(*b*), or the line is looped, Fig. 5(*c*). Fig. 5(*c*) shows the line looped, one dialled digit and the line cleared. The pulses that emerge from these gates are always at clock time p_r. They will be called q pulses and their presence or absence conveys information concerning some part of the system. The q pulses of other lines on the exchange are combined by "or" gates as in Fig. 5 to single channels known as highways, and examination of these highways enables the state of the lines to be ascertainable in pulse cycles for which 20 ms is a convenient cycle time. The cycles are often called "scans" and the operation of examining lines in sequence is called "scanning".

Stores

Stores are often called memories and this expresses their function, that of keeping a record of the pulses which occur in a system. The several known kinds of store are classified in a number of ways. Here they will be classified according to the way in which the information pulses are recorded and read.

Cyclic-Order Stores. One type of store operates according to a pre-arranged time-cycle governed by a "clock" which divides the cycle up into a number of pulse positions. A cycle may, for example, consist of 100 pulse positions at 10μs intervals giving a cycle time of 1 ms. The pulse positions would in this case be numbered p_0 to p_{99}. Stored pulses will be called s pulses. An s_x pulse stored in a system would be characterized by a pulse being produced every time the *x*th pulse time occurred. Fig. 6(*a*) shows the elements of a system of this type using a delay line, DL, which can take in a pulse at A and reproduce it at B after a delay, in the example under consideration, of 1 ms. A master-pulse generator MP produces a continuous pulse train of 5 μs pulses every 10 μs. A pulse q_x put into the delay line at clock time *x* emerges at B at the same clock time but one cycle later. For a good practical reason the delay is made slightly less than the cycle time and the emerging pulse is lengthened a little so that it overlaps in time one of the master pulses. A 3-gate G has as inputs the pulses emerging from the delay line, the master pulses and the release control R which normally provides an input to operate the gate. Hence a pulse once introduced into the delay line is continuously reproduced, i.e. stored, until removed by an appropriately timed pulse, called an r pulse, which removes the input from the lead R at the pulse time of the pulse to be taken out of the store. The bar across the R lead is the symbol that indicates that the operation is the reverse of normal, i.e. a pulse on R removes the input to the gate. Master pulses are put through a divide-by-*n* device which allows every 100th pulse to emerge at p_0 to mark the beginning of every cycle. A pulse in the delay line can be identified by counting the number of master pulses after the p_0 pulse until the pulse to be identified occurs.

The example just given illustrates the general principle of cyclic-order stores leaving out most of the detail. Cyclic-order stores can be formed out of apparatus other than delay lines, and in fact the chosen example of a delay line store for 100 pulse positions in a cycle of 1 ms would be most unusual in practice. Pulse spacings of 1 μs with 100 to 1,000 pulse positions are more common. The pulse rate and the number of pulses in the cycle are matters of technique and economics. By using numbers of stores in parallel and in series, stores of any size and cycle time can be built up to suit any particular requirement; there are some minimum requirements which have to be satisfied before this is true but these will be described after some other forms of store have been described.

The magnetic drum is an important cyclic-order store. In principle it functions in the same manner as the delay-line store just described. In Fig. 6(*b*) a non-magnetic drum has its peripheral surface coated with a thin layer of magnetizable material on which pulses can be recorded by writing heads and read by reading heads. The problems of recording pulses on a medium of this kind are not relevant to this article. It is sufficient to state that 3,000 or more pulses can be recorded on one peripheral track which passes under one pair of writing and reading heads. It is common for the two heads to be mounted diametrically opposite to one another on the track as shown in the figure. Permanently written on to two other tracks are the p_0 pulse and the master pulses. It is not difficult to see that the track on the drum of

Fig. 6(*b*) behaves in the same way as the delay line of Fig. 6(*a*) with the slight detail difference that every stored pulse is written twice on the drum. This is for practical convenience. There is also the difference that a pulse in a delay line disappears on emergence unless it is re-written into the delay line, but a pulse once written on the drum is permanently recorded and can be read indefinitely without being re-written. This is a valuable feature of the drum not possessed by many forms of storage. However, use is seldom made of this property when the recording has to be changed frequently. In practice, the most convenient way of altering the information on a track is a writing method which is writing all the time, i.e. pulse or no-pulse in every pulse position, and which overwrites anything which is already written on the track. This means that functionally one track on a drum is the same as one delay line when the pattern of stored pulses has to be altered frequently. In fact, all kinds of cyclic-order pulse stores can be represented symbolically (as shown later in Fig. 9 and 10) by a box with inputs for q and r pulses and an output for s pulses.

There is a kind of information which changes only infrequently. The director translations of exchange codes, tariff rates and the classes-of-service of the different lines connected to an exchange comprise most of the information of this type. It can be written as pulses on the tracks of a magnetic drum, or by jumper wires on a tag field or in a variety of other ways. Magnetic-drum tracks storing this so-called permanent information usually have a writing head used infrequently to change the record and a reading head operating all the time. The wire-on-tag store has a set of tags connected to sources of p pulses and sets of tags each joined through an "or" gate to a highway. Jumpers between the two sets of tags build up on the highway patterns of pulses which can be used in the same way as tracks of permanent information on a magnetic drum.

It is not difficult to see that the temporary storage of one pulse by a delay line or a magnetic drum is equivalent to the relay circuit of Fig. 7(*a*) in which the relay X is

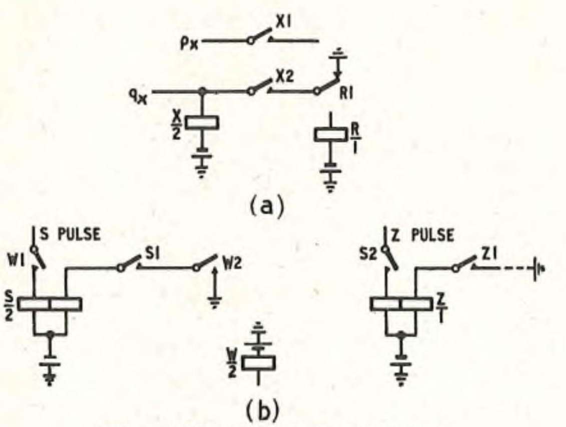

FIG. 7—EQUIVALENT RELAY CIRCUITS

operated by a pulse q_x, locks and thereafter emits the pulse train p_x until released by the operation of relay R. One delay line or drum apparatus costs much more than one or two relays, but the delay line can store the order of 10^3 pulses and the drum the order of 10^6 pulses at little greater cost than either can store one pulse, and they are then equivalent to the same number of relays as pulses stored. The economical use of the new techniques is much bound up with having large units of apparatus so that it is not surprising that common control apparatus like directors has seen the first applications. Also, although locking relays are common in electro-mechanical switching systems, to build circuits in which the main component was the locking relay operated by timed pulses would seem very strange and puzzling at first sight. It has been part of the evolution of circuit design to accomplish just this and it is one of the purposes of this article to explain what the new circuitry has to do. At this stage in the description it may be recalled that the pulse-operated locking relay is known in existing circuits by the S and Z timing scheme shown in Fig. 7(*b*), and that it can be used in the new circuits.

Random-Order Stores. Consider a rectangular array of magnetic cores as in Fig. 8, the cores having the magnetic characteristics previously described and shown in Fig. 4(*c*). Any core can be set into one or other of two magnetic states by $\frac{1}{2}i_m$ currents in each of the two wires threading it, one in the horizontal and one in the vertical direction. Similarly the magnetic state of any core can be ascertained by pulsing it with current at least equal to i_m, say $+i_m$. Then if it is already in the $+i_m$ condition it will produce no output on a wire threading the core, but if in the $-i_m$ condition it will change to the $+i_m$ state and produce an output on a third wire threading the core. In these ways pulses on either the vertical or the horizontal wires may be written into the store and read out at any time and in any order, which features have caused this type of store to be called "random-order". The record is destroyed on reading, so that to preserve it, it must be re-written each time it is read.

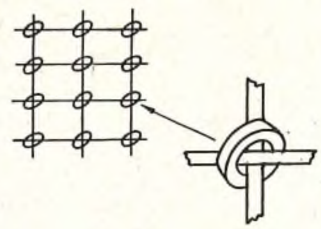

FIG. 8—RECTANGULAR ARRAY OF MAGNETIC CORES

Cathode ray tubes in which the beam writes on and reads off the screen are also known to be used as random-order stores.

Because information which is held in a random-order store is immediately available, whereas in a cyclic-order store it is available only at particular times in a cycle, under conditions which are otherwise similar, equipment having random-order stores can always work faster than equipment having cyclic-pulse stores. If speed is not the decisive factor, the choice between random-order and cyclic-order stores in any particular case is one of economics or practical convenience and not some fundamental operation of the system under contemplation. In fact it often turns out that a mixture of cyclic and random order is employed. To economize in auxiliary apparatus, some part of the operation of random-order stores is often made cyclic; on the other hand it is usual to have to employ numbers of delay lines or magnetic-drum tracks which, although they individually work cyclically, can be selected in random order for the recording or reproducing of pulses. There is therefore less difference between the two methods than might be supposed at first glance. The remainder of this article is concerned with cyclic-order stores but it must be understood that with somewhat different techniques the same results can also be produced with random-order stores.

RELATIONS BETWEEN PULSE SOURCES AND PULSE STORES

Pulse stores have the capacity to store a given number of pulses in a cycle controlled by a clock. q pulses also occur in cycles of given numbers of pulse positions controlled by a clock. The first requirement for q pulses to be stored in a pulse store is synchronism between the q and s pulse systems. This means simply the same clock to control both. Synchronism does not necessarily mean, however, that the cycle times and numbers of pulse positions in the two systems must be identical, although simple relationships between them are essential as will now be established.

q and s Pulses of Equal Pulse Rate and Cycle Time

Fig. 9(*a*) is the symbolic form of a pulse store for q and s pulse systems of equal pulse rate and equal numbers

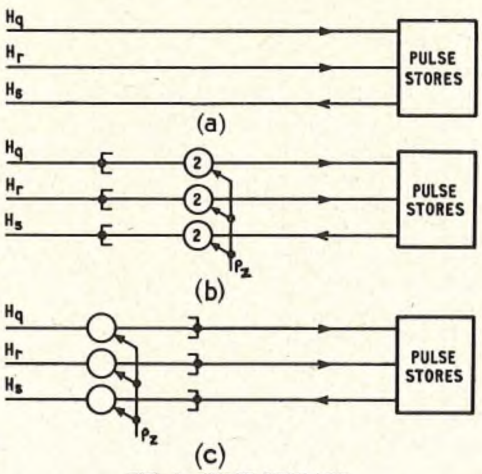

FIG. 9—PULSE STORAGE

of pulse positions. A q pulse on the H_q highway produces a corresponding s pulse on the H_s highway until an appropriately timed r pulse occurs on the H_r highway.

q and s Pulses of Equal Pulse Rate and Unequal Cycle Time

Correct storage can also be effected if instead of the cycle times of the q and s pulses being equal, one is an exact multiple of the other. 2-gates are needed in the highways as shown in Fig. 9(*b*) and (*c*), the gates being fed with p_z pulses of cycle time equal to the longer of the two cycles and pulse duration equal to the cycle time of the shorter of the two cycles. If the q pulses have the longer cycle, then the storage will be operative on only a portion of the q pulse cycle. For example, the q pulses may represent the state of the loops of all the 10,000 lines in an exchange, and the storage system be able to store only 100 pulses. In this case, however, 100 of the storage systems each with its 2-gates commoned to the highways as shown by the commons in Fig. 9(*b*) can between them store all the 10,000 pulses, provided that the p_z pulses fed to the gates are time-spaced so that each coincides with a different group of 100 q pulses. If the storage system has the longer cycle, then the q pulses will fill only a portion of it: a number of q pulse sources each with its 2-gates can be commoned to the one storage system as shown in Fig. 9(*c*), and fill up the storage space.

q and s Pulse Positions Not Equal in Number

The two previous cases of equal pulse rates for the q and s pulses have been directed toward showing that the number of pulses in the q and s pulse cycles can be equated under a variety of conditions. Although this is a basic requirement of the kind of pulse system under consideration, it has no practical use by itself. The use and value of the pulses is in the logical operations which can be performed as a result of their existence. The basic requirement is that each q pulse shall have a group of s pulses individual to it; one of these s pulses, called s_1, retains a record for just one cycle of the existence of each q pulse as it occurs, and the other s pulses are available for purposes still to be described. As each q pulse position occurs in the cycle the presence or absence of a q pulse is written into the s_1 store while being compared with what was written into the s_1 store on the previous cycle.

The s pulses of a group associated with one q pulse may follow one another in time, the q pulse coinciding with the first, which is s_1. For example, the 3,000 pulse positions round a track of a magnetic drum may be divided into 100 groups of 30 pulses, each group serving one exchange line. Fig. 10(*a*) shows this general case.

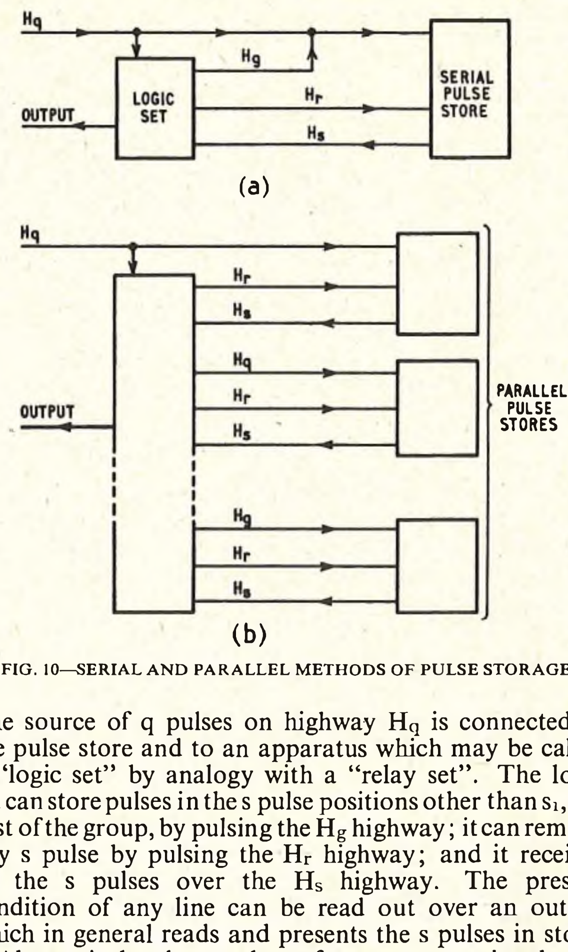

FIG. 10—SERIAL AND PARALLEL METHODS OF PULSE STORAGE

The source of q pulses on highway H_q is connected to the pulse store and to an apparatus which may be called a "logic set" by analogy with a "relay set". The logic set can store pulses in the s pulse positions other than s_1, the first of the group, by pulsing the H_g highway; it can remove any s pulse by pulsing the H_r highway; and it receives all the s pulses over the H_s highway. The present condition of any line can be read out over an output which in general reads and presents the s pulses in store.

Alternatively, the s pulses of a group associated with one q pulse may all be coincident in time with the q pulse and be stored in different pulse stores as shown in Fig. 10(*b*). Whether this parallel arrangement is used or the series method of Fig. 10(*a*) is a matter of convenience according to the type of store employed. The logical operations will vary in detail according to the method used but the basic logic is identical. The notation used to explain the operation of such systems tends to vary according to the practical form of the apparatus. In this article no attempt can be made to show how logic sets work and the notation which is used merely states in tabular form the result which has to be achieved.

LOGICAL PULSE OPERATION

A number of practical examples of logical pulse operations will be described, from which it is believed the underlying principles will become clear.

Metering

Consider the sequence of q pulses represented in Fig. 5(*b*), i.e. a meter pulse. The q column of Fig. 11(*a*) shows the initial absence of q pulses corresponding to the one line under consideration. This condition is indicated by a zero followed by a vertical line of dots to indicate a great many pulse cycles without a q pulse. This is the normal condition. When a meter pulse occurs, there will be a succession of q pulses, indicated by 1's, and then zeros again when the meter pulse ceases.

s_1	q	s_9	s_8	s_7	s_6	s_5	s_4	s_3	s_2
0	0	0	0	0	0	0	0	0	0
	:	0	0	0	0	0	0	0	1
	:	0	0	0	0	0	0	1	0
0	1	0	0	0	0	0	0	1	1
1	1	0	0	0	0	0	1	0	0
1	1	0	0	0	0	0	1	0	1
1	1	0	0	0	0	0	1	1	0
1	1	0	0	0	0	0	1	1	1
1	0	0	0	0	0	1	0	0	0
0	0	0	0	0	0	1	0	0	1
	:	0	0	0	1	0	0	0	0

(*a*) (*b*)

FIG. 11

The q pulse is written into the s_1 store and therefore becomes available one cycle later when it can be compared by the logic set with the next q pulse. It will be noticed that there are two unique combinations of s_1 and q pulses, namely 01 and 10, the first at the beginning and the second at the end of the meter pulse. Fig. 11(*b*) shows the binary-code combinations of pulses used to record the meter reading which occupies the remaining s pulse positions associated with the q pulse. Pulse positions s_2 to s_5 refer to the units digit of the meter reading and store the digit in binary-coded decimal form. This means that the four digit places can each have the value 0 or 1, giving 16 combinations of which only 10 are used, one for each decimal digit. Fig. 11(*b*) shows the binary combinations 0000 to 1001 as representing the decimal digits 0 to 9. The logic set, when it detects the s_1 q combination 01, reads the pulses in the s_2 to s_5 pulse positions and adds one to the reading. When this addition results in the units digits changing from 1001 to 0000, one is added to the tens reading in pulse positions s_6 to s_9, and so on for the hundreds and thousands digits. Fig. 11(*b*) shows the columns s_2, s_3 . . . . ., reading from right to left to conform with the usual arithmetical notation of the least significant digits to the right, and each meter reading exists for a great many cycles of the pulse store before being changed to the next digit.

The logic set which performs all the operations detailed may be very complicated and expensive but as only one is required to operate on the q and s pulses for many lines in an exchange, the cost per line can be small.

The description given establishes the principle of counting on a cyclic store. In practice, metering arrangements would be somewhat different because of the need to safeguard against faults which might destroy the records inadvertently, but the principle is not thereby altered.

s_{11}	s_{10}	s_9	s_8	s_7	s_6	s_5	s_4	s_3	s_2	s_1	q	line condition
0	0	0	0	0	0	0	0	1	0	0	0	open
0	0	0	0	0	0	0	0	1	1	0	0	
					:					:		
0	0	0	0	0	0	0	1	0	1	0	1	looped
0	0	0	0	0	0	0	0	0	0	1	1	
0	0	0	0	0	0	0	0	0	1	1	1	
0	0	0	0	0	0	0	0	1	0	1	1	
					:					:		
0	0	0	0	0	0	0	1	1	1	1	1	
					:					:		
0	0	0	0	0	0	0	0	1	1	1	0	dial break
0	0	0	0	1	0	0	0	0	0	0	0	
0	0	0	0	1	0	0	0	0	1	0	0	
0	0	0	0	1	0	0	0	1	0	0	0	
0	0	0	0	1	0	0	0	1	1	0	1	dial make
0.	0	0	0	1	0	0	0	0	0	1	1	
0	0	0	0	1	0	0	0	0	1	1	0	dial break
0	0	0	1	0	0	0	0	0	0	0	0	
0	0	0	1	0	0	0	0	0	1	0	0	
0	0	0	1	0	0	0	0	1	0	0	1	dial make
0	0	0	1	0	0	0	0	0	0	1	1	
0	0	0	1	0	0	0	0	0	1	1	1	
0	0	0	1	0	0	0	0	1	0	1	1	
0	0	0	1	0	0	0	0	1	1	1	1	
0	0	0	1	0	0	0	1	0	0	1	1	
0	0	0	1	0	0	0	1	0	1	1	1	
0	0	0	1	0	0	0	1	1	0	1	1	
0	0	0	1	0	0	0	1	0	1	1	1	
0	0	0	1	0	0	0	1	1	1	1	1	end of
0	0	0	1	0	0	1	0	0	0	1	1	dial train
					:					:		
0	0	0	1	0	0	1	1	0	1	1	0	open
					:					:		
0	0	0	1	0	0	1	1	1	1	0	0	release
0	0	0	0	0	0	0	0	0	0	0	0	

FIG. 12

B and C Relay Functions

Fig. 5(*c*) shows the existence of q pulses when an exchange line is looped. In present conventional circuits the B relay detects that the loop has been broken for a minimum time and the C relay detects the end of a train of dial pulses. The q pulses for each of the lines in conjunction with a group of s pulse stores and a logic set common to all the lines can perform the same functions.

Referring to Fig. 12, each row represents the condition q of the loop of an exchange line, of a store s_1 recording the value of q on the previous scan, and the condition of a number of other pulse stores s_2 to s_{11}, there being other pulse stores not shown in the figure. The time between successive scans is assumed to be about 20 ms. Pulses are indicated by 1's, and absence of pulses by zeros, as before. The number of lines included in one scan is limited to the number which can be accommodated within the 20 ms cycle time. The pulse stores are operated by a logic set common to all the lines with their stores. The number of scans during the time involved in this example is much too large to be accommodated in the figure, nor is it necessary to do so because only those scans in the neighbourhood of changes in condition of the line loop are significant. These are the ones shown in the figure, the existence of blocks of identical scans being indicated by dots in vertical line. The combination $q=1$, $s_1=0$ indicates that the line has been looped since the previous scan, and $q=0$, $s_1=1$ that it has been opened since the previous scan. The occurrence of either of these combinations causes the logic set to return the 3-digit binary pulse store s_4 to s_2 to zero, i.e. to 000. On every scan the logic set operates on this store to add one to its count. The count progresses through the eight combinations of 000 to 111, then back to 000 and so on, being interrupted only as stated by being returned to 000 when the loop condition changes between scans. As the count is proceeding during idle periods, the first row of Fig. 12 shows it arbitrarily as 010, and as 101 in the third row when the line is looped. On that scan the count is returned to 000 but it is not until one scan later that this value is indicated by the stores s_4 to s_2. There may be many cycles of eight scans before the loop is opened again, but this is of no consequence. During a train of dial pulses, since eight scans take longer than the duration of a make or a break of the dial, the count will not again reach the value seven (111 in stores s_4 to s_2) until after the last break. Hence the combination $q=s_1=s_2=s_3=s_4=1$ indicates the end of the dial train and is equivalent to the release of the C relay in relay circuitry. This combination will generally occur many times before, between, and after dialling but the logic set can recognize the significant occurrences, as will be explained later. Similarly the combination $s_1=q=0$, $s_2=s_3=s_4=1$ indicates the elapse of eight scans since the line was opened and hence is equivalent to the release of a B relay. The logic set then releases any apparatus associated with the particular line concerned. The combination stated will occur every eight scans thereafter and the logic set will for uniformity of operation take the same action, but only the first release has any significance.

Digit Counting and Storing Functions

Many exchange systems use registers, e.g. directors in Strowger areas, in which the pulses of digits dialled are counted and the counts stored for future use. These functions can be performed by pulse logic and stores. Four pulse positions per decimal digit are commonly used in conjunction with two others which function as digit distributors for incoming digits and as digit switches for sending out digits. In Fig. 12, stores s_5 to s_{10} handle the first dialled digit, stores s_{11} to s_{16} would accommodate the second digit, and further groups of six pulse stores up to the number required to store all the digits would be provided in a practical case. The normal condition of all the digit stores is absence of pulses, i.e. zeros. Considering the first digit group, stores s_7 to s_{10} are used to count in binary code using the combinations described for Fig. 11(*b*). The combination $s_1=1$, $q=0$ defines a dial break and the first time it occurs after the line is looped, the logic set writes a 1 in store s_7, the second time a zero in s_7 and 1 in s_8 and so on until the end of the dial train, which is detected as previously described. A 1 is then written into store s_6 to close the first digit against further addition of dial pulses. The second dial train will be received into the second digit group, which is closed by a pulse in s_{11}, and so on. To carry out these operations the logic set detects the combination of store pulses and q pulse which defines the end of a digit, then examines the numbers stored in the digit groups and writes a pulse in the first store, e.g., s_5, s_{11} . . . , of the last digit group to contain a count which is not 0000. It is not difficult to see that this action results in the required action of closing a digit which has just been completed and in no action at other times that the stated conditions occur before, between and after dialled digits. The second pulse store, e.g., s_6 s_{12} . . , in each group is used later to indicate that the digit has been pulsed out.

A total of 64 binary pulse positions can receive and store a 10-digit number such as might be required for a national number in a nation-wide dialling system, and with three more groups, making 82 digits in all, the necessary translations could also be accommodated. On a magnetic drum this would mean using an area some 0·82 in. long and 0·05 in. wide: a drum able to store 820,000 binary digits could provide an individual register for each 10,000 exchange lines, and this is in fact proposed for some electronic systems. Dial tone is not then required.

Other Functions

Many other functions familiar to telephone switching engineers can be provided by pulse stores in conjunction with a logic set. Translation is one of these: one way in which translation is effected includes having the translations written into a permanent store in some order determined by the exchange codes which they represent. The logic set examines each of the digit groups as they are scanned and when enough digits have been received for translation to take place, the logic set reads the appropriate translation. The magnetic-drum directors at Lee Green operate in this manner and will be described in a future article in the Journal.

Conclusion

This article cannot attempt to explain how a logic set is constructed to perform the operations required of it. It is thought that the principles of pulse logic will be apparent and that this will make subsequent and more detailed articles readily understandable. It should be possible to imagine the power and scope of the techniques available: that vast numbers of relays and other electro-mechanical switches spread over many individual pieces of equipment can be condensed into pulse stores needing only a fraction of the space and cost. It should be apparent that the number of switching operations performed by pulse equipment may be thousands of times greater than that of equivalent electro-mechanical apparatus and it will not then be difficult to understand why the new pulse techniques did not evolve until electronic switching devices had become well established.

One of the major problems to be solved is a method equivalent to present circuit diagrams of expressing the operations involved. This article has used tables in Fig. 11 and 12 because it is believed that for simple operations these are the easiest to understand. However, tables become too lengthy for anything but simple operations. After some familiarity with the principles of pulse logic, more concise methods of expression[4] become readily understood.

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Chain Conveyors in Postal Engineering

W. J. SMITH, A.M.I.E.E., and J. D. ROGERS, GRADUATE I.E.E.†

U.D.C. 621.867.3:656.85

Three chain-conveyor systems have been brought into use in sorting offices at Leamington Spa, Southampton and Luton. These installations, which were preceded by a small experimental conveyor erected in the Power Branch postal engineering laboratory at Mount Pleasant, London, are the forerunners of more than twenty projects now in various stages of planning.

INTRODUCTION

INDUSTRY to-day uses many different types of conveyors for a variety of purposes. Commonly, the need is to deal with a series of individual items possessing some degree of uniformity, such as components on a production line, or the conveyance of raw materials in bulk, where special safeguards against spilling or breaking the material being carried are rarely necessary. By contrast, mechanical aids used in the postal service are required to handle items of varied shape, size and weight and it is vital that none of the items shall be lost, damaged or delayed in transit.

Trucks are still the most widely used method of moving mails and offer the advantage that the mails can usually be taken directly to the point required, e.g. where the sorting office is adjacent to the railway station, trucks or barrows may be wheeled directly to and from the train doors. Whether trucks are manhandled or power driven they are, however, open to the objection that their use requires considerable manpower and effort is wasted in returning empty trucks to loading points; furthermore, they cause congestion on stations and in sorting-office gangways and demand space for parking when not in use.

By reason of the number of different classes of mail handled, traffic movements within a sorting office are complex. The consequent multiplicity of routes and processes makes it difficult to achieve complete mechanization, particularly where the structure of an existing building is being adapted.

Flat-belt conveyors with side plates are used when large numbers of bags are to be carried or where loose mail is to be handled. They are quiet in operation and can run at high speeds, but their routing is inflexible and this sometimes makes planning difficult. The use of troughed belts (without side plates) entails too great a risk of spilling for mail-handling, and slat conveyors and studded belts are liable to cause serious damage to material in transit if a blockage occurs.

The need for a radical change in the established British Post Office techniques, based on belt conveyors supplemented by lifts and a few other vertical-hoisting devices, became particularly apparent when the Engineering Department started to prepare preliminary plans for the mechanization of an extension of the Crewe sorting office in the autumn of 1953. Crewe railway station serves as a junction for several important railway lines and its sorting office, on a site adjoining the station, is in consequence the most convenient centre to receive, sort and forward mail for several counties in the midlands, north and west of the United Kingdom. In some cases little more than an hour is available for a batch of mail to be taken from a train into the office, there to be sorted so that relevant items can catch the next connexion. The merits of a conveyor system which could move bags both ways between three main groups of railway platforms and any of the several processing points in the sorting office, affording preselection of the discharge points at each end, were obvious enough to justify the cost and trouble of the development entailed. A number of manufacturers' standard chain-conveyor systems were suited to the task but there appeared to be no established convenient method of attaching individual mail bags to a chain. The Post Office pattern of self-gripping bag carrier, described in a later paragraph, met this need. For a number of reasons, the analysis of which would be outside the scope of this article, it was not found economic to plan the Crewe mechanization wholly on the use of chain conveyors, but the system has nevertheless found application in many other offices.

Elementary considerations demand that the first cost and running expenses of the equipment should be favourably related to manpower and other savings. In that fact lies one of the principal virtues of the chain conveyor; it is cheaper than an equivalent belt system and has a higher recovery value, and often, in marginal cases, the use of a chain permits a scheme to be developed for a building which could not otherwise be mechanized because of the costly building work entailed. The flexibility of the chain conveyor also makes it possible to serve points in a sorting office which could not, in the present state of knowledge, be linked by other mechanical means. It can be routed at any angle from horizontal to vertical, it can dip or bend to avoid obstructions, and its return side can be readily utilized to provide conveyance in both directions. If the chain can be erected at a height of 13 ft above the floor the bags hang vertically, clear of the guards, without impediment to staff working on the floor beneath. Where headroom of 11 ft is available a clearance of 7 ft can still be provided by trailing bags on a slide plate beneath the chain.

DESCRIPTION OF CHAIN CONVEYOR

Proprietary chain conveyors, the component parts of which are usually prefabricated in standard sections, include five major elements: track, roller chain, drive units, tensioning devices and load carriers.

Track

A typical section of track is illustrated in Fig. 1, from which it can be seen to comprise a pair of hat-section members (flanged channels) having horizontal and vertical running surfaces which, respectively, support the load-carrying rollers and locate the side guide-rollers. There is also an upper horizontal surface which, when the chain is directed through an upward curve, constrains it to the correct radius. The two channels are held in position by stamped metal webs to which they are welded. Straight and curved track sections are available in a variety of sizes, the dimensions of which vary slightly in the several manufacturers' preferred systems, and the complete circuit is assembled by bolting together a

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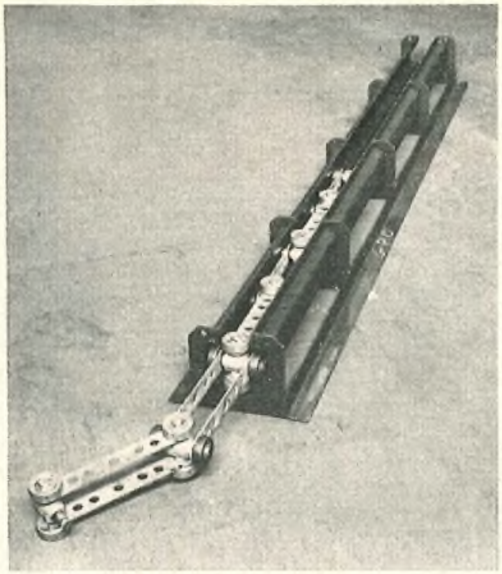

FIG. 1—SECTION OF CHAIN CONVEYOR SHOWING FLANGED STEEL CHANNELS, LOCATING WEBS AND UNIVERSAL CHAIN

number of sections. It is essential for smooth and quiet operation that all joints should be accurately aligned.

The minimum radius for track curves in the horizontal or vertical planes is of the order of 3 ft. When a sharper turn is called for, the chain may be led round an idler sprocket interposed in the track run; by this means, turns of less than 1 ft radius can be negotiated.

Roller Chain

Typical proprietary types of chain are assembled in the form of groups of four rollers mounted on spiders linked by pairs of side-plates placed alternately in the horizontal and vertical planes; the vertical side-plates commonly provide attachment for the load carriers. Some systems employ twin tracks and twin chains arranged one above the other. Only one chain, usually the upper, is engaged by the driving unit and this is provided with projecting "dogs" which transmit the drive to detents mounted on the lower, load-carrying, chain.

Drive Unit

Drive is imparted to the chain by means of a toothed sprocket, the profile of which is such that the horizontal chain-rollers fit into curved recesses on its periphery. The driving sprocket is powered by an electric motor via speed-reducing gear. In some cases variable-ratio reduction gears are specified, and usually a fluid or powder coupling is incorporated to give smooth starting. A mechanical fuse, in the form of a shear pin, may be interposed in the drive so that a serious overload or jam on the conveyor will break this pin before the rest of the mechanism suffers damage.

Tensioning Device

Since the length of a chain must be an exact multiple of the length of an individual link, it is essential that means be provided for fine adjustment of the track length to suit the chain length. The compensating device, usually termed a tension unit, takes the form of a semi-circular curved section of track which can be moved on slides under the control of a screw. It is often convenient to mount the driving gear, with its speed-reducing mechanism and sprocket, on the sliding member, the semi-circular

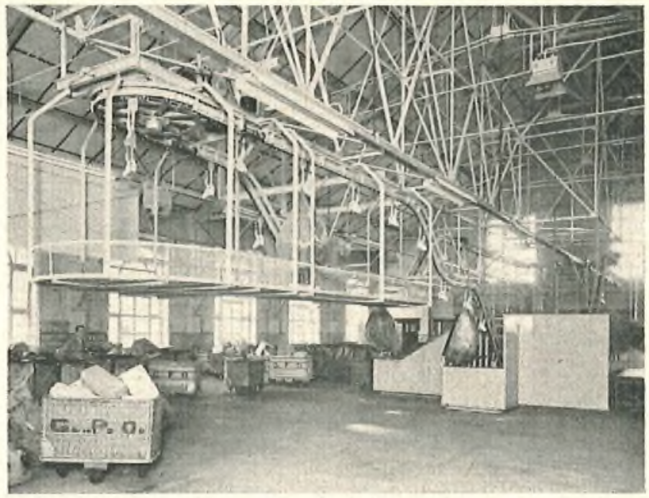

FIG. 2—DRIVE AND TENSION UNIT

piece of track then being replaced by the driving sprocket around which the chain turns through 180°. Such a unit is used at Southampton and is illustrated in Fig. 2.

Load Carriers

For Post Office purposes the bag carrier and commercially-available fixed or tilting trays are the load carriers that are most often used. The bag carrier, which is a wedge-action self-gripping device, was developed in the Power Branch laboratory to meet the requirements that it should:

(*a*) Hold a full parcel-bag without the aid of springs, hooks, etc.

(*b*) Require no knob, lever or other mechanism to be adjusted when loading, the loader's hands being entirely free to manipulate the bag.

(*c*) Accept the bag readily, with wide jaws and an easy lead in.

(*d*) Grip the bag irrespective of the thickness of fabric.

(*e*) Hang vertically on rising or falling sections of the conveyor.

(*f*) Release full or empty bags without fail at desired positions.

(*g*) Lend itself to the use of selective releasing mechanism giving alternative discharge positions.

(*h*) Be robust and cheap to manufacture and maintain.

A number of alternatives were tried before a satisfactory carrier evolved; several are shown in Fig. 3. One of these early designs comprised a wheel having teeth over part of its periphery and arranged to roll on a sloping rack, the inclination of which was adjustable. The

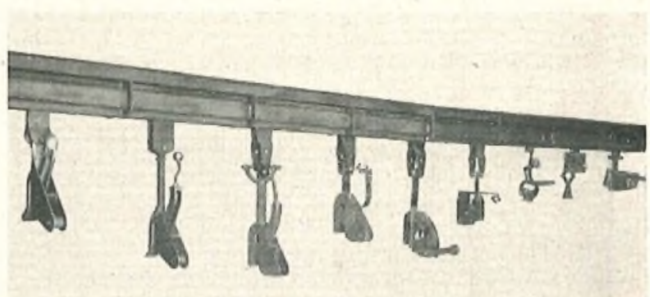

FIG. 3—EVOLUTION OF BAG CARRIER

bag was gripped between a knurled face on another part of the periphery of the roller and a static vertical surface. Increasing the angle of the rack improved the grip on the bag but this was accompanied by an increase in the force required to be exerted on the release lever to drop the bag. Over a limited range of angles there was, however, a satisfactory compromise between these two conflicting factors.

The next step was to simplify the construction of this carrier, the roller and ramp being replaced by a curved surface on a pivoted lever. The release force was applied to an extension of that lever at a mechanical advantage of about 2 : 1. A bracket, bolted rigidly to the vertical side-plates of the chain, provided a pivot upon which the carrier could swing in the vertical plane of the track, so permitting bags to hang vertically whilst the conveyor was rising or falling.

FIG. 4—MALLEABLE CAST-IRON BAG-CARRIER

The most recent design of the carrier is shown in Fig. 4; it is a malleable iron casting, the design of which has been simplified, so far as is consistent with its performance requirements, to facilitate manufacture in bulk.

HANDLING OF BAGS

Loading

The operation of loading a chain conveyor is more difficult than the loading of an ordinary belt but most users acquire the technique after a few minutes' practice. It is done whilst the chain is in motion, by grasping a portion of the loose fabric of the bag with both hands and inserting it between the fixed and movable jaws of a passing carrier. The loader's hold on the bag is then released and as the carrier continues to move with the chain its self-gripping action comes into play and the bag is held firmly. Bags are often loaded upside down to facilitate opening.

At loading points, several of which may be provided on a single conveyor, the chain runs horizontally at a height of 4 ft above the floor, so that the carriers are at a convenient level. The bag has only to be partially lifted; most of its weight remains on the floor. Wear and tear on the bags is minimized by providing a sliding surface of steel plate, hardwood or tiles on the floor beneath the chain at the loading points.

The carriers are spaced from 2 ft 6 in. to 6 ft apart, the distance being chosen to suit the pitch of the links in the chain. As only one bag can be attached to each carrier, it is unlikely that operators will overload the conveyor.

Discharge

Carrier-tripping ramps are provided at all points at which the conveyor is required to discharge bags. The ramp is located in a position to exert the necessary sideways pressure to open the moving arm of the bag carrier. Ramps may be permanently fixed in the "discharge" position, or, alternatively, may be retractable from a "discharge" to a "non-discharge" setting under electro-

FIG. 5—RETRACTABLE DISCHARGE RAMP

magnetic or pneumatic control (see Fig. 5). Both fixed and retractable ramps may also be selective in the sense that they may actuate some or all of the carriers or trays attached to the conveyor.

Non-selective Discharge is employed in small installations where only one delivery point is needed. In a more complex system a non-selective ramp would be used when all carriers are to be emptied, e.g. the last discharge point in each direction before the chain begins its return journey.

Selective Discharge may be effected in several ways, typical of which are:

(*a*) Batch Selection. A retractable ramp is pre-set to its discharge position by means of a press-button, and remains in that position to discharge a batch of traffic. Interlocks may be provided to ensure that only one ramp is operated at any one time. This system has the disadvantage that only one batch at a time can be carried on the conveyor.

(*b*) Pre-coded Individual Selection. The carriers are predestined to particular discharge points and are visually marked, by lettering, numbering or colouring, to indicate the discharge point. Whilst traffic can be sent simultaneously to several destinations, the number of carriers serving each is limited, though this can be offset by spacing the carriers more closely on the conveyor.

(*c*) Operator Selection. The loader is required to set an adjustable pointer on the carrier or depress the appropriate one of a number of trip levers. This method slows down loading and is unlikely to be suited to Post Office needs.

Ticking-in

The checking of bags on arrival at a sorting office, an operation known as "ticking-in," may be performed while the bags are on the conveyor, a section of which is, for this purpose, positioned at such a height that the bag labels can be easily examined. Provision can be made for stopping the conveyor if the tick-in point becomes overloaded or for dropping any "difficult" bag which may be encountered. With certain types of conveyor it is practicable for bags and carriers to be brought to rest at the tick-in position, while they are still supported on the moving chain, so that they queue to await checking.

Bag Opening

Conventional methods of emptying bags for sorting entail considerable physical effort. The work can be made easier by routing the chain conveyor over skips or other suitable receptacles at the bag-opening point. The chain track is erected at a height of 9 ft above floor level and each bag is carried upside down so that its sealed neck is at a convenient height for the bag opener to cut the string and allow the contents to fall out. The empty bag remains on the chain and can be released elsewhere for turning, cleaning or stacking.

Storage and Transfer

Storage facilities are commonly provided at a discharge position by placing beneath the chain a wooden or metal surface, inclined at about 30° to the horizontal plane, and usually known as a glacis. The purpose of the glacis is to eliminate long vertical drops and to permit bags to slide away from the conveyor, so allowing others to drop clear of the chain or to be carried past, unimpeded by the pile of discharged bags. A mechanical or photo-electric guard can be provided at any unattended discharge station to give warning or shut down the conveyor as soon as a pile of bags builds up to danger level.

An alternative (but more expensive) method of storing is by means of a subsidiary loop of chain linked to the main circuit by a transfer unit. By this means it is possible to divert loaded carriers on to the loop, where they may await attention without holding up other traffic and can be brought forward when required with no additional manhandling.

Conveyor Speed and Traffic-Handling Capacity

The optimum speed from the operational viewpoint is 60 ft/min, although higher speeds are practicable. At low speeds the traffic-handling capacity, i.e. the number of carriers presented to the loaders in unit time, is reduced, and the time of transit is longer. Loading becomes difficult when the speed exceeds about 100 ft/min, and at such speeds the noise is likely to be excessive.

Spacing of bag carriers must be such that each bag will hang clear of the next on the steepest sections of the conveyor. A spacing of 4 ft is often convenient; this gives adequate clearance, on 60° inclines, for the largest bags in use and, for a chain speed of 60 ft/min, permits 900 bags to be dealt with in an hour if every carrier is loaded. When a visual selective system is employed the carriers may be spaced more closely: e.g. red, green, blue, white and yellow carriers might be spaced at 1 ft intervals. Whilst with this arrangement it is not possible to load adjacent carriers, any specified colour will recur every 5 ft.

PLANNING

The present emphasis on mechanization in the postal service makes it important to design on the basis of a small number of widely applicable techniques so as to minimize planning work. With this objective in mind, standard symbols and preferred dimensions have been evolved for the more usual applications of a chain conveyor. By such means it has been possible to reduce the time taken to produce contract drawings.

Prevention of Draughts

Mechanization of postal services usually necessitates openings in the walls of a building but draughts and heat loss are reduced by fitting rubber doors or cabinets with hatches at these openings. Experiments are also being made with an air curtain, which, as the name implies, is a broad jet of air across the conveyor aperture, designed to minimize the ingress of draughts; such curtains are in use, in a few places, at the doors of shops and public buildings.

Guards

The risk of damage to mail or injury to people from a falling bag is obviated by the provision of sheet-metal or wire-mesh guards beneath all high-level sections of the conveyor. Where the chain route is too low to give walking headroom, e.g. at the approaches to loading sections, safety fences are erected on the floor.

Extension or Rearrangement of a Chain Conveyor

So long as components of the same manufacture are available it is a simple matter to re-route or add to a chain-conveyor system, which can thus be altered to conform with a revision of the layout of a sorting office with a minimum of wastage of the existing plant.

EXISTING INSTALLATIONS

Leamington Spa Sorting Office

At Leamington Spa a small conveyor, an 88 ft loop, links a ground-floor loading point (Fig. 6) with a

FIG. 6—CHAIN-CONVEYOR LOADING POINT AT LEAMINGTON SPA SORTING OFFICE

parcel office, also at ground level, and a first-floor letter-sorting office. This was the first operational installation of a chain conveyor in the Post Office and was completed in December 1955.

Visual selection is used, red-painted carriers, for parcel bags, alternating at a spacing of 2 ft 8 in. with green ones, for letters. Carriers of both colours are tripped at the loading platforms: thus all carriers are available for outward use. The discharge ramp can be seen on the right of the photograph (Fig. 6).

Southampton Parcel Office

The chain conveyor installed at Southampton in the summer of 1956 carries incoming bags from the loading platform to one discharge point on the ground floor and two on the first floor, and outgoing bags from the ground floor to a fourth discharge point on the loading platform. There is also a bag-opening section on each floor. The overall length of the system is 257 ft, and the low-level section of the chain at the back of the platform can be loaded at any point along its 30 ft length. Batch selection is controlled by push-buttons at the two loading points. The traffic includes a large proportion of heavy bags from overseas and it is of interest to record that the conveyor disposed of two ships' consignments—more than a thousand bags—in a period of two hours during its first day in use.

The Southampton installation incorporated the first batch of cast-iron carriers; those used in the Mount Pleasant laboratory and at Leamington Spa had been fabricated from sheet steel. The only serious teething trouble met at Southampton was in the discharge of empty bags. These are light in weight and a small proportion failed to leave the carriers at dropping points. Failure to discharge is fortunately only a minor embarrassment—the bag merely recirculates and usually falls clear next time it passes the ramp.

Luton Sorting Office

At Luton the whole chain-conveyor system, about 470 ft long, is on the ground floor; it was completed in November 1957.

Every sixth carrier is painted red and is reserved, in the inward direction, for registered mail; the remainder (grey) are used for parcel traffic. Parcel bags are routed to conical storage concentrators above which they are opened in the manner shown in Fig. 7. Two concentrators have been provided, one for the inward and one for the outward primary sorting positions. After being opened, empty bags remain on the chain for discharge later at a storage point near the outward secondary bag-frames where they are next required for use.

The return side of the chain takes both letter and parcel bags, which can be dumped either on to a storage glacis at the rear of the loading platform or on to the platform itself. There are, in all, three loading sections and six discharge positions; two further alternative discharge positions may be added later.

Four pairs of rubber doors are provided, two each at the points where the chain enters and leaves the sorting office.

Luton is the first example of the use of a concentrator in conjunction with a chain conveyor. This device, as its name implies, has the dual function of storing a large number of loose parcels and of delivering them, approximately in order of arrival, without jamming or damage and without powered assistance, to a point within reach of the sorter's hand. Its basic shape is a segment of a conical frustum and it is inclined downwards, on the line of minimum slope, at an angle of 30°. The concept of this structure is attributed to a colleague of the authors and the idea was developed in the Power Branch laboratory; it is a good illustration of the application of the second part of the maxim that the best form of mechanical aid is none and the next best is gravity. It will be realized that the first part of the maxim is implemented by arranging that successive processes, whether manual or mechanical, are so placed as to eliminate the need for transport between processes.

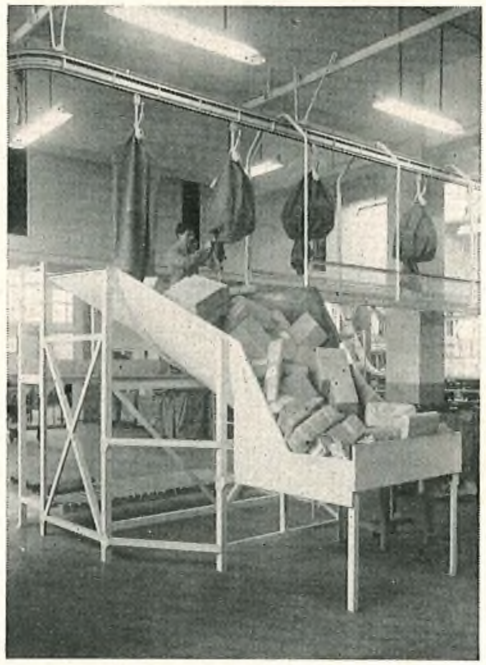

FIG. 7—BAG OPENING ABOVE A STORAGE CONCENTRATOR AT LUTON SORTING OFFICE

FUTURE INSTALLATIONS

The twenty or more chain systems that are now in course of planning include several which will link sorting offices with adjacent railway stations via bridges or tunnels. The characteristics and economics of chain conveyors are particularly suited to this application, where traffic in both directions is essential and where the directional flexibility they afford is of the greatest value in negotiating obstructions presented by intervening buildings or other Authorities' plant. The conveyors are to be erected at a high level in the bridge or tunnel and in most instances a route for trucks will be available beneath the chain, for use if a breakdown occurs.

Research is still in progress and several novel techniques are at present being studied with a view to extending the facilities offered by this system, the scope of which has clearly not yet been fully exploited.

ACKNOWLEDGEMENTS

The authors are indebted to numerous colleagues in the Power Branch of the E.-in-C.'s Office and to engineering power staff in several Regions and Areas who have helped in the development of the plant described; also to many postal experts in the Postal Services Department, the Postal Mechanization Branch of the newly formed Mechanization and Buildings Department, and Regions and Head Post Offices, for encouragement and constructive criticism. The installations mentioned in the article were all manufactured and installed by Teleflex, Ltd., of Chadwell Heath, Essex, whose staff have been most helpful at all times. A special contribution was also made by the Longridge Foundry, Longridge, Preston, Lancs, in connexion with the design of malleable iron castings.

The London Telex Engineering Control

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When the telex service made use of the telephone network, the testing of subscribers' telegraph apparatus and fault clearing were often functions of the visiting telegraph mechanic. With the creation of a separate network of telegraph circuits used exclusively for the telex service it was possible to establish a centralized telex engineering control in London at the Central Telegraph Office. The equipment includes engineering control boards, test desks, telegraph distortion measuring sets and monitoring consoles.

INTRODUCTION

THE number of telex subscribers' lines has increased considerably since the conversion of the telex service from the method that employed 1,500 c/s signals and made use of the normal telephone network to one that makes exclusive use of telegraph circuits provided for the purpose. Table 1 gives figures of the growth in the number of telex lines since the final stage of the conversion, in November 1954, showing those connected to the London telex exchanges and the total for the United Kingdom.

TABLE 1
Growth of Telex Lines

Date	London	United Kingdom
November 1954	1,104	1,556
November 1955	1,477	2,351
November 1956	1,925	3,243
November 1957	2,292	4,081

At the time when the telex service made use of the telephone network, the testing and faulting of subscribers' telegraph apparatus were often functions of the visiting telegraph mechanic, since it was at this point that the change-over from telephone to teleprinter was made. Where there was sufficient justification, a Tester TG 904 was provided at the telephone exchange for testing the lines and telegraph apparatus, but the concentration of telex lines at exchanges was not sufficient to justify widespread use of the tester. The absence of telegraph testing equipment at many exchanges limited the nature of the tests that could be made on lines used for telex purposes and precluded monitoring or subjecting the telegraph machines to marginal tests without sending a mechanic to the subscribers' premises.

With the creation of a separate network of telegraph circuits used exclusively for the telex service,[1] the practicability of establishing a centralized telex engineering control (TLX ENG) in London was realized.

Briefly, the functions of TLX ENG are: the testing of new lines; the acceptance, recording and subsequent location of faults; the distribution of faults to Area telegraph maintenance controls, switchroom maintenance engineers or multi-channel voice-frequency telegraph (m.c.v.f.t.) terminals; co-operation with faultsmen; the recording of faults; and the routine testing of trunk lines.

The London Central Telegraph Office contains three telex exchanges. The London A and London B exchanges cater for inland traffic and the International exchange deals with incoming and outgoing overseas telex traffic for the whole country. From Table 1 it can be seen that over half of all telex subscribers in the United Kingdom are connected to the London exchanges; in addition, almost 900 trunk circuits to provincial and international centres or automatic sub-centres[2] terminate on the switchboards at these exchanges.

Unlike telephone subscribers' lines, which are relatively short and within one Telephone Manager's Area, 40 per cent of telex subscribers' lines radiating from telex switchboards pass through at least one Area boundary and in a few cases into another Region. The extensive use of m.c.v.f.t. channels for telex trunk circuits and long subscribers' lines involves a number of telegraph terminals that are situated some distance from the Central Telegraph Office.

The choice of location of the centralized engineering control was obvious since all telex subscribers' and trunk circuits terminated in London converge on the Central Telegraph Office. It was important, however, that the centralized engineering control became the controlling testing office for all subscribers' lines and trunk circuits terminating in London, including those routed over m.c.v.f.t. channels, and be provided with comprehensive telegraph testing equipment and ready access to all lines under its control.

LAYOUT OF TEST ROOM

Fig. 1 shows the layout of the London TLX ENG test room. The intermediate distribution frame, monitoring console and miscellaneous-equipment racks are in a separate room from that which contains the engineering control board, test-desk suite and regenerative repeaters.[3] The full lines represent existing items and dotted lines the space for additional items to meet future requirements. The auxiliary testers shown in Fig. 1 include a monitor-and-test set and a speaker-and-test set.

The main items of equipment provided include:—

(*a*) Engineering control board.
(*b*) Test desks.
(*c*) Telegraph distortion measuring sets (T.D.M.S.)
(*d*) Monitoring console.

ENGINEERING CONTROL BOARD

Fig. 2 shows the suite of panels comprising the engineering control board, which will provide for the interception of 5,200 circuits before extension becomes necessary. The physical assembly has been arranged to suit local conditions. Nineteen panels are provided, one of these not being equipped with jacks. To facilitate staffing, the first 12 panels have been adapted to form four auxiliary test positions by the provision of writing shelves. The remaining panels are not so equipped, enabling more jacks to be fitted on each panel.

The facilities provided include the following:

(*a*) Test access, on a make-before-break principle, to any subscriber's line or trunk circuit, and testing either to line or exchange. The send and receive lines are wired through separate jacks.

(*b*) Test lines enabling any circuit to be extended to any test-desk position or monitoring set.

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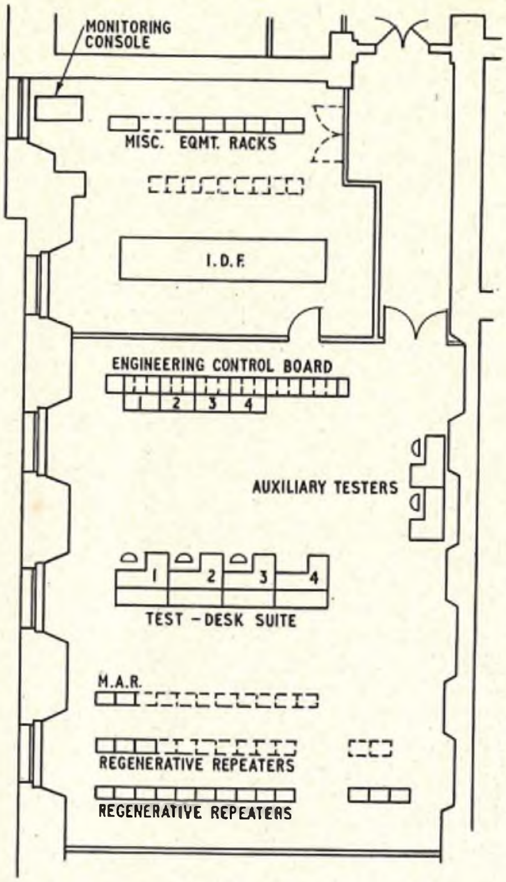

FIG. 1—LAYOUT OF TEST ROOM

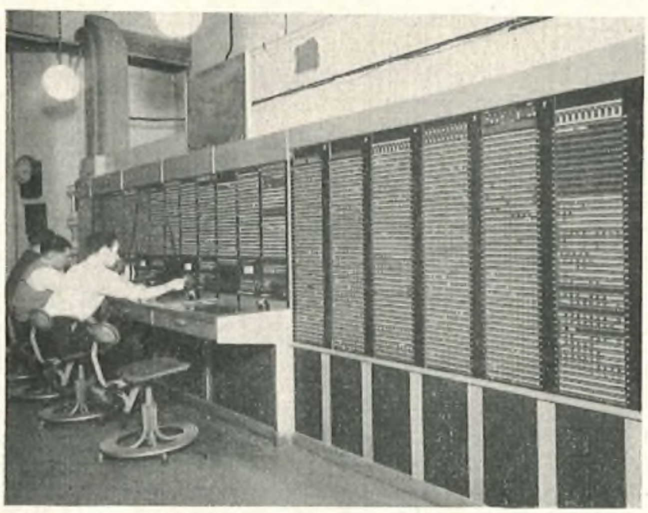

FIG. 2—ENGINEERING CONTROL BOARD

(*c*) The ability to provide line reverse, mark (−80 volts), space (+80 volts), loop or earth conditions.

(*d*) The transmission to line of a switched test message, i.e. one applying various amounts of telegraph distortion in a continuous sequence, to test the receiving margin of telegraph machines.

(*e*) Plugging-up circuits. If the line condition is mark (−80 volts) a 2-position key is operated so that a local alarm is given on change of line voltage to space (+80 volts). The second position of the key similarly caters for the state when the line condition of space (+80 volts) changes to mark (−80 volts).

(*f*) Connexion of up to 20 circuits to inland or international traffic-observation equipment.

(*g*) Loop resistance and insulation resistance measurements.

(*h*) Termination of telephone exchange lines and point-to-point telephone speaker lines.

(*i*) Tie lines to main distribution frame.

(*j*) For circuits on which electronic regenerative repeaters are fitted a group of jacks gives access to both the input and output of each repeater.

(*k*) Access to the teleprinter automatic switching system.

To economize in the provision of certain of the test facilities listed above, not all panels are provided with identical equipment. Inter-panel tie lines are provided enabling test equipment mounted on any one panel to be accessible from another panel.

TEST DESK

The test desk was constructed in the London Telecommunications Region and gives similar facilities to the test desks provided for the public teleprinter automatic

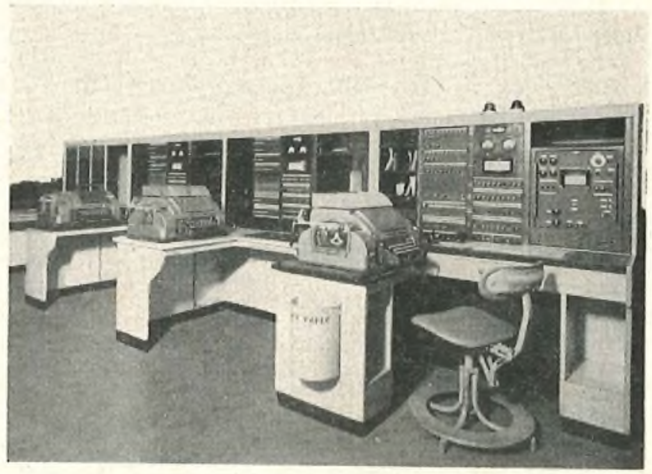

FIG. 3—TEST-DESK POSITIONS

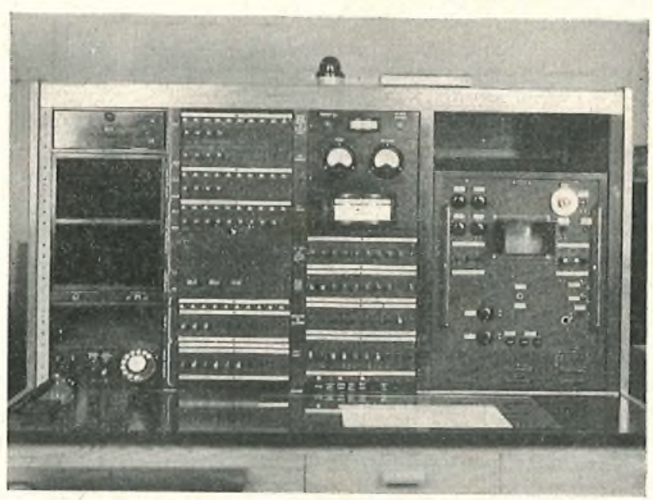

FIG. 4—FACE LAYOUT OF FIRST TEST-DESK POSITION

switching network. A considerable quantity of its equipment is mounted in relay sets on the test-desk-equipment rack (one of the miscellaneous equipment racks shown in Fig. 1). Fig. 3 shows the suite of test-desk positions. The fourth position, although wired, has not been equipped, the intention being to bring it into use when more telex lines are connected to the exchange. Fig. 4 shows the face layout of the first test-desk position, which was provided for a field trial in September 1956. Some physical and circuit alterations have been embodied in the additional positions installed in September 1957 and retrospective changes will be made to the first position. These include a uniform height for the teleprinter and writing shelves, removal of obstructions to the legs when an officer rotates on the chair from the writing shelf to the teleprinter shelf, and moving the dial and telephone handset from the left-hand side of the desk to the right-hand side. To assist telephoning, attempts were made during the field trial to reduce the effect of the noise present in the room, due to telegraph machines and in particular to the teleprinter situated on the test desk itself. A throat microphone was found to cause considerable distortion, and a directional microphone with amplifier although satisfactory was prohibitive in cost. The most efficient protection against noise, commensurate with cost, was obtained by using the standard anti-side-tone circuit for the test-desk telephone, coupled with the use of the recently-introduced sound-reducing Cover No. 10 for the Teleprinter No. 11.

The test desk differs in physical design and other respects from that provided for the teleprinter automatic switching network and includes the following facilities:

(*a*) D.C. testing, including the sending to line of steady $\pm$80 volts potential.

(*b*) Subjecting dials to speed and ratio tests.

(*c*) Transmission of a test message with 0 per cent, 25 per cent and 30 per cent start-stop distortion in cyclic order and an undistorted test message for test purposes.

(*d*) Monitoring of established teleprinter connexions without interference to the circuits.

(*e*) Complete local record of all transmissions from the test desk during testing, including those of the test message when generated.

(*f*) When fitted, the use of the electronic start-stop telegraph distortion measuring set to enable measurements of distortion or speed error to be made on lines either terminated by the set or under "through-switched" conditions.

(*g*) Telephone speaker facilities for speaking over cable pairs either during the installation of a line or during fault finding.

(*h*) Telephone facilities on point-to-point speaker circuits, exchange lines and internal extensions.

(*i*) Association of the test-desk teleprinter with a circuit to either the teleprinter automatic switching network, inland telex or international telex exchanges.

(*j*) Association of the test-desk teleprinter with any circuit via tie lines from the engineering control board.

A compartment for fault cards has been provided in the left-hand side of the desks (Fig. 4) to enable any position to operate as a maintenance-control position. The desks are finished in light oak with green plastic sheeting on the writing shelves.

The test-desk apparatus rack enables a maximum of four test positions to be fitted, additional relay sets being fitted to cater for the increase of circuits.

TELEGRAPH DISTORTION MEASURING SETS

Although the test-desk positions are designed to accommodate the electronic telegraph distortion measuring set (T.D.M.S.), which is known as the Tester TG 1157, there has been some delay in supplying an adequate number of these sets. There are also reasons justifying the provision within the test room of other types of T.D.M.S. First, it is undesirable to appropriate a test-desk position for prolonged use of the T.D.M.S. and deny use of the many other facilities the desk affords. Secondly, it is desirable to augment the facilities of the Tester TG 1157. For these reasons two T.D.M.S. manufactured by the Automatic Telephone & Electric Co., Ltd., and known as their Types 5A and 6A, have been provided, mounted on trolleys.

The T.D.M.S. Type 5A provides the following facilities:

(*a*) Transmission of reversals, steady mark or space or any telegraph character repeated continuously.

(*b*) Transmission of a test message comprising 100 characters, the speed of which may be varied between 20 and 80 bauds.

(*c*) The introduction of up to 50 per cent short or long start-signal distortion into (*b*).

(*d*) Measurement of isochronous distortion of signals received from an external source.

(*e*) Measurement of contact bounce and transit time of telegraph transmitters and relays.

In the main, this T.D.M.S. is used as a generator of telegraph signals, although use is made of the continuously-running circular time-base for reading isochronous distortion.

The T.D.M.S. Type 6A provides the following facilities:

(*i*) Measurement of start-stop or isochronous distortion throughout a range of 20 to 80 bauds, using signals composed of 4 to 14 elements per character, as required.

(*ii*) Inspection of contact bounce and transit time of transmitters and relays.

The Post Office Tester TG 1157 is normally preferred for measuring start-stop distortion since the larger display tube together with the use of a horizontal time-base makes it easier to read distortion accurately than with the spiral time-base of the Type 6A set. In practice the Tester TG 1157 has also been found more accurate for measuring the speed errors of telegraph transmitters.

To further augment the centralized engineering control with distortion-testing facilities to enable it to carry out tests with voice-frequency telegraph terminals in this country and overseas and to cater for measurements at speeds in excess of 80 bauds, the main components comprising the rack-mounted T.D.M.S. and generator made by Standard Telephones & Cables, Ltd., for Type III m.c.v.f.t. equipment have been installed on a rack in the test room.

Summarizing, the various types of sets provided give a comprehensive range of equipment capable of generating or measuring start-stop or isochronous distortion over a wide range of speed or element composition of characters.

"STEPPED" MONITORING CONSOLE

There is a considerable demand for prolonged engineering monitoring of renters' and trunk lines by TLX ENG staff. The teleprinter monitor-and-test set

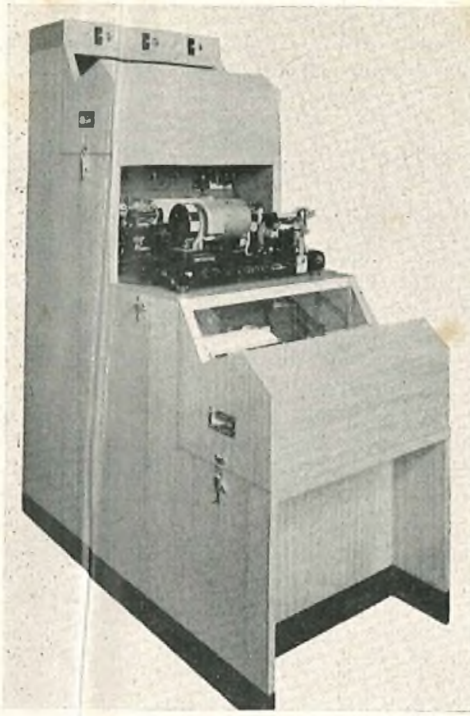

FIG. 5—"STEPPED" MONITORING CONSOLE

(TG 1175) provides this facility, but monitoring is only one of many facilities afforded by this set and to have such a set in use for a considerable time solely for monitoring is inconvenient. Furthermore, it is necessary to be able to monitor a number of circuits simultaneously, and to provide monitor and test sets exclusively for this purpose is costly and, by reason of the space occupied by the tables mounting the sets, wasteful of the limited area available. It was necessary therefore to design and instal a monitoring console which would give the following facilities:

(*a*) Accommodation for three separate monitoring page-printing machines using a minimum of floor area.

(*b*) Each teleprinter to be preceded by a circuit giving a high-impedance input.

(*c*) The ability to monitor both directions of transmission on a simplex basis.

(*d*) The automatic re-rolling of the printed copy.

The "stepped" monitoring console is shown in Fig. 5. The cover has been removed from the second step to show the page-printing teleprinter with keyboard removed. The console is finished in light oak with a band of black plastic sheet at the base. The sound-reducing property of the covers has proved to be most effective. The console has space for three monitoring teleprinters and occupies a floor area of $7\frac{1}{2}$ ft^2, compared with the 42 ft^2 required by three monitor-and-test sets.

Fig. 6 shows the essential features of the monitoring circuit, which is basically the same as that used for the input to the monitor-and-test set. Each of the three monitoring teleprinters is provided with this high-impedance monitoring unit, the send and receive lines that form the input to this unit being connected in parallel with the circuit being monitored by appropriate connexion on the engineering control board. When the monitor key (KML) is operated, the send and receive wires are extended to the grids of the double-triode valve V1, the anodes of which are coupled to a grid of a second double-triode valve, V2. The polarized relay P in the anode of V2 responds to the changes in line polarity, enabling the monitoring teleprinter to give a printed copy of the telegraph traffic passing on the line. The unit prevents racing of the monitoring machine when the idle condition (+80 volts on both send and receive wires) is encountered on the line. The heaters of both valves are permanently operated to ensure instantaneous functioning of the unit and to avoid the recording of spurious characters by the monitoring machine during either the "warming up" or "cooling down" periods of the heaters. Contacts of the key KML are introduced into the grid circuits of valve V1 to ensure that trouble is not caused by voltages induced in the tie lines to the engineering control board by adjacent circuits during the period when the input is left disconnected at the control board.

To provide facility (*d*) it was necessary to develop an attachment for a page-printing teleprinter which would provide for the following:—

(*i*) Automatically re-roll a printed copy of the paper used on a page-printing teleprinter.

(*ii*) Minimize the extent of modifications to the teleprinter required to permit fitting of the attachment.

(*iii*) Maintain a constant tension on the paper to allow for variations in line feed or diameter of the paper roll.

(*iv*) Allow the re-rolled paper to be unwound manually for a reasonable length and re-wound after inspection.

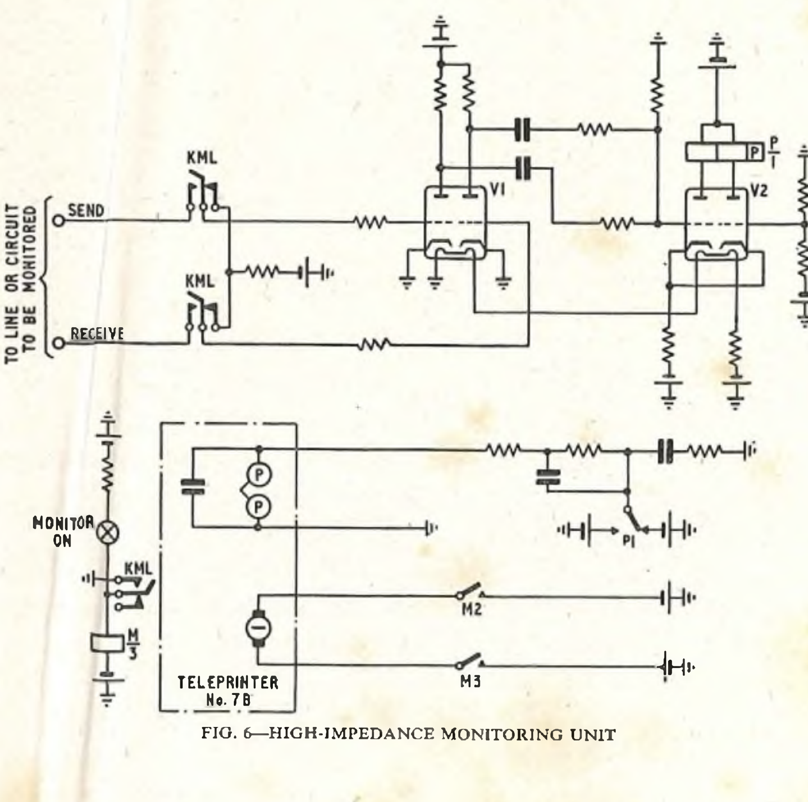

FIG. 6—HIGH-IMPEDANCE MONITORING UNIT

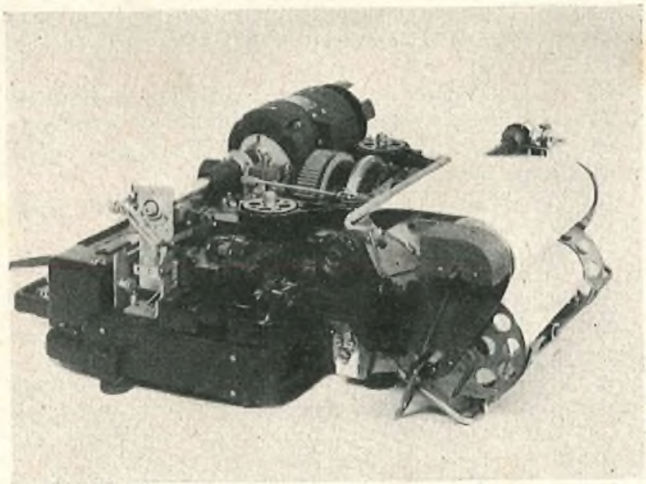

FIG. 7—TELEPRINTER NO. 7B WITH RE-ROLL ATTACHMENT

(*v*) Permit the use of 2-ply paper and allow the second copy to issue from the aperture of the cover, if required.

It was necessary to design an attachment capable of moving in step with the carriage return and line feed of the teleprinter, since the operation of re-rolling the printed copy should be accomplished without risk of tearing the paper. Fig. 7 shows the attachment fitted to a teleprinter. The operation of the attachment can be seen from Fig. 8, which shows an isometric view of the mechanism. The attachment is fixed to the carriage of the teleprinter at each of the cheeks forming the flanges of the paper-roll holder. These are the only modifications required to be made to the teleprinter itself. It is so designed that a forked cam can strike the chariot rail either as the carriage moves from its initial position at the beginning of a line or as it is returned to that position on receipt of the carriage-return signal. In the latter case, the forked cam imparts an upward movement to the connecting link causing the driving pawl to rotate the ratchet wheel, and thus the shaft, a set number of teeth in a clockwise direction. The

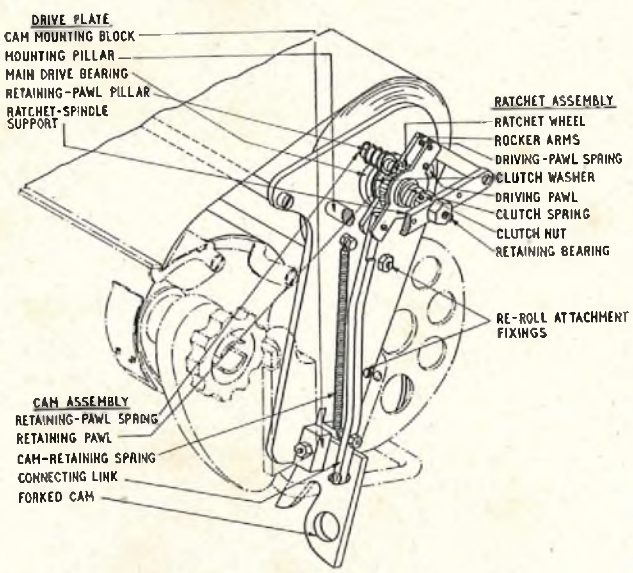

FIG. 8—ISOMETRIC VIEW OF RE-ROLL ATTACHMENT

direction of this movement is againshe action of a slipping-clutch spring, which enablese paper to be kept taut despite variations of lined distance or paper-roll diameter. As the carriageen commences its horizontal feed the forked cam isgain operated, restoring the driving pawl to norm the ratchet-retaining pawl prevents any tendency anti-clockwise movement by the ratchet.

To enable staff to read through theinted text, the paper may be pulled away from the forr-holder fitted to the shaft and manually rewound an extension knob fitted to the shaft on the end note from the ratchet assembly. When a new roll of per is fitted to the machine it is fed through the guidin the normal manner and the free end is secured a cardboard spool by adhesive tape. This spool is en fitted over the former-holder. Tests have shown th it is possible to use 2-ply paper, using a top copy fein the normal way issuing from the top of the cover andeing available to tear off as desired, whilst a comple record on a master copy can be stored on the re-roll tachment.

To enable the copy to be read inchronological sequence the former, complete with reolled paper, is removed and re-wound on a simple maine provided for the purpose. This attachment solve the problem of collecting a printed copy where no facities exist for paper to fall at the back of the machine s in the case of the "stepped" console, and gives ong-duration monitoring at an unattended installation equivalent to the time occupied in using a complete roll of paper.

DISCONNEXION OF RENTER'S D.C. SUPPLY

The telex system requires each renter to have a ±80-volts d.c. supply for operating telegraph machines and providing current for signalling puposes. The public electricity supply is connected to the input of a rectifier, usually mounted below the telepinter table. Investigation of recent fault reports shoved a high proportion classified as "unable to raise renter," and indicated that either intermittent disconnexons in line continuity or accidental or deliberate disconnexions of the a.c. power supply were occurring. Renters would not, however, admit that the power supply had been deliberately disconnected. The "stepped" console was not suitable for observing such conditions and it was considered that the full-time attendance of an engineering officer to detect the absence of line current would be an expensive method of finding the cause of the trouble. A suitable unit was therefore developed, making use of a 4-pen recorder. By connexion on the control board, a relay requiring a low operating current can be connected in parallel with the send line of the renter's circuit under investigation. Whilst voltage of either polarity is present on the line the relay remains operated and the operate coil of one element of the pen recorder is not energized. The relay releases when no current is present on the send line and the pen operates, recording its movement on a paper chart.

A permanent indication is recorded on the chart, which rotates continuously for 168 hours under the action of a clockwork drive. This device enables:

(*a*) A permanent record to be made of interruptions in excess of approximately 1 minute.

(*b*) Interruptions to be correlated to time of occurrence.

(*c*) Economies to be achieved in staffing.

(*d*) Up to four circuits to be observed simultaneously.

The evidence obtained from the use of this device has confirmed that renters were switching off the input to the rectifiers, usually at or about the same times each day. The psychological effect of showing this evidence to renters has been instrumental in preventing recurrences of the trouble.

TESTING OF TELEGRAPH PRIVATE WIRES

Although the majority of circuits controlled by the centralized telex engineering control are naturally those associated with the telex service it has been a constant problem to provide points of access for the association of telegraph equipment on other forms of the telegraph service. In the case of the teleprinter automatic switching network the lines are taken through an engineering control board at the switching centre, and similarly for privately-owned automatically-switched telegraph circuits and manually-switched telex circuits. In the London Telecommunications Region, however, there are approximately 1,000 telegraph private-wire circuits terminated by Post Office apparatus, of which 15 per cent are routed over m.c.v.f.t. channels and test access is possible in the v.f. telegraph terminal, where there is a limited quantity of telegraph testing equipment. Apart from a very small number on the fringe of the London Telecommunications Region the remainder are wholly physical circuits routed through distribution frames in telephone exchanges and not passing beyond the Regional boundary. The tests that can be made on these circuits in telephone exchanges are usually limited to measurement of line resistance and voltage. The provision of adequate telegraph testing equipment at all telephone exchanges involved in the routing of telegraph circuits would be grossly uneconomic.

It is an undesirable but inevitable feature of the present procedure that the initial diagnosis of any reported fault on these private wire circuits is generally made by the telegraph mechanic at the renter's premises. This results in a high proportion of ineffective time, and the ideal arrangement would be for initial testing to be made at the engineering fault reporting centre and the locating of faults on line or termination to be made at that time. The re-routing of these circuits so that they could be taken through the engineering control board of the TLX ENG at the Central Telegraph Office would result in the lengthening of many of the circuits, which would increase fault liability and need a considerable number of cable pairs.

A recent survey has shown that over 70 per cent of these physical circuits pass through distribution frames located in buildings conveniently situated geographically in relation to the Central Telegraph Office. By arranging for a number of 4-wire test circuits to the frame at each such exchange it is proposed that the centralized engineering control should also assume control of these circuits. It is hoped that, by providing a permanently-staffed fault-reporting centre acting as an interception point where the association of adequate telegraph testing equipment is possible, these measures will enable more-stringent testing to be applied and improved maintenance to be attained.

ACKNOWLEDGEMENTS

Acknowledgement is made to colleagues in the Engineering Branch, London Telecommunications Region, in particular to Mr. E. J. C. O'Brien, for assistance in the physical design of the engineering control board, to Mr. F. T. H. Horne for assistance in the adaptation of the teleprinter automatic switching test desk for telex purposes, and to Mr. F. Goldsmith for valuable co-operation in the design of the re-roll attachment. The author is indebted to members of the Telegraph Branch, E.-in-C.'s Office, and to the City Area and Power Section of the London Telecommunications Region.

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Book Review

"Elementary Technical Electricity." L. T. Agger. Longmans, Green & Co. 268 pp. 149 ill. 9s.

This book was first published in 1931, and was written as an introduction to technical electricity for students in evening technical schools and junior day technical schools. The fact that new impressions have since been taken on no fewer than 13 occasions is a measure of its usefulness and popularity.

The original layout has been retained in this revised edition, the first three chapters providing the minimum information on Mechanics and Heat for students commencing a study of electrical science. Magnetism and Electricity are then treated in an elementary manner, followed by chapters on the electric circuit, the various effects of direct current, and the fundamentals of electrical measurements. The concluding chapter on Electromagnetic Induction introduces the basic principles of the d.c. generator and motor.

Although the author claims that, with this new edition, alterations have been made to bring the book up to date, there are several instances where this ideal has not been achieved. A bell-type receiver is given as a modern type of telephone receiver, the Post Office box is still used to illustrate the practical use of the Wheatstone bridge principle, and wireless h.t. batteries are quoted as an example of the use of secondary cells. A more serious fault, however, is the absence of any reference to the M.K.S. system. Most of the students using this book will proceed to more advanced work, where they will certainly be required to use these units, and it is an obvious mistake to base their early studies on the outmoded C.G.S. system.

The presentation of the material is ideal for a primer of this sort; theoretical points are dealt with clearly and concisely, and are amply demonstrated with simple experiments and worked examples. The sets of questions at the end of each chapter are mostly taken from appropriate examination papers of S1 standard. Any teacher who is prepared to make allowance for the few faults mentioned will find this book invaluable for classroom use, and there is no doubt that its popularity in this respect will continue for some years.

G. H. K.

An Electronic Pulse-Duration Analyser

E. NEWELL, B.Sc.(Eng.), A.M.I.E.E., and A. A. MAKEMSON†

U.D.C. 621.317.74 : 621.3.015.3 : 621.395.44

An electronic pulse-duration analyser has been constructed for measuring the duration and frequency of occurrence of transient transmission-path irregularities. The apparatus, which is portable and mains-operated, enables irregularities of longer duration than 2 ms to be recorded, up to four simultaneous recordings being made of irregularities whose durations exceed four pre-determined values.

INTRODUCTION

THE steadily increasing use of diverse signalling systems on circuits carried by multi-channel transmission systems has led to a requirement for more detailed information on transient transmission-path irregularities, their duration and frequency of occurrence. This information could be obtained by means of a device capable of monitoring the false signals resulting from such irregularities, these signals being received on a quiescent channel at the incoming terminal of a communication system, e.g. by direct connexion to the relay contact of a channel signalling receiver.

Such a device would be required to record data from which could be determined the total number of false signals received over a given period of observation and the distribution of these signals in terms of their duration and the manner of their occurrence, i.e. whether the signals were well spaced or occurring in "clusters." From this information an assessment could be made of the severity of transmission-path interruptions and comparisons could be drawn between different signalling paths and different modes of signalling.

The detailed requirements of an electronic pulse-duration analyser capable of producing these data included the following points:

(*a*) The analyser should be portable as opposed to rack mounted.

(*b*) The analyser should be capable of detecting any event of duration longer than 2 ms.

(*c*) In measuring the duration of an event a time unit of, say, 2 ms would be sufficient.

(*d*) In order to determine the distribution of the events as judged by their duration, it should be possible, during any given period of observation, to record simultaneously on four registers those signals having durations exceeding four pre-determined values.

(*e*) It should be possible to choose the four duration times, mentioned in (*d*) above, from suitable values in the range 2–50 ms.

(*f*) The four register totals should be displayed in decimal form and each register should have a manual reset feature.

(*g*) The analyser should be capable of indicating the presence of events occurring in clusters.

(*h*) The accuracy of the data recorded should be a maximum consistent with reasonable economy of circuit design, bearing in mind the other requirements.

GENERAL DESCRIPTION

The following description refers to an analyser built to fulfil the specification given in the previous section. The instrument (Fig. 1) consists of two portable units:

(*i*) The monitoring device (19 in. × 15 in. × 14 in.) containing the main counting circuits, the registers and controls and all associated thermionic-valve and cold-cathode-tube circuits,

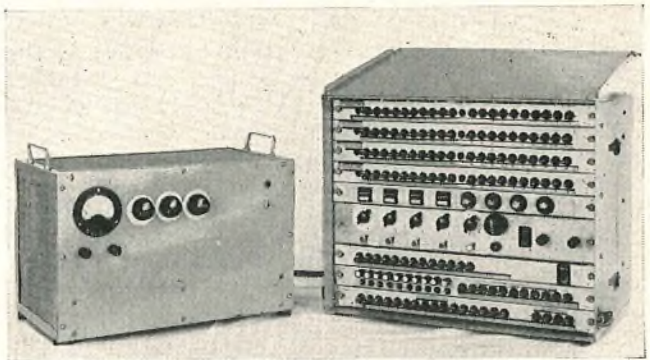

FIG. 1—ELECTRONIC PULSE-DURATION ANALYSER

(*ii*) The a.c. mains-operated power unit (16 in. × 10 in. × 10 in.) providing the various stabilized and unstabilized power supplies for the operation of the monitoring unit.

From the available methods of meeting the required facilities the one selected employs an accurate time-scale against which the incoming signals are measured. This scale is provided by a continuously-free-running multi-vibrator of 1 kc/s basic frequency producing two anti-phase pulse outputs each at 1,000 p.p.s. and designated PX and PY. Careful choice of circuit and the use of suitable components has resulted in a long-term stability, measured during three months' continuous use, of better than ±1·0 per cent.

The required counting rates fall within the range of certain cold-cathode tubes which, for their known reliability, relative cheapness and simpler demands on power supplies, were chosen to fulfil the basic functions of counting, gating and storage. For pulse generation and higher-speed gating, thermionic valves were used. Pulses at 500 p.p.s. (duration 500 μs) are gated into the Main Counter following the start of an event, and blocked from the counter at the end of the event. This counter caters for events of durations in the range 2–50 ms, hence meeting facilities (*c*) and (*e*).

To provide facility (*d*), rotary switches (wafer type) enable from one to four registers to be connected to the cathodes of selected tubes in the counter. Should the duration of an event be such as to cause the main counter to step beyond a selected tube, then a "count-of-one" is effected in the appropriate register. This arrangement allows a simultaneous four-duration analysis to be made. Each register has a maximum storage capacity of 10^6 signals and uses two cold-cathode-tube ring counters for the "tens" and "units" storage, followed by an electro-mechanical meter for the "hundreds" storage. Such an arrangement allows for the individual recording of

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short-duration events occurring in rapid succession.

To meet facility (*g*) it is arranged to integrate those events occurring in clusters by summing their duration times and recording the cluster as one event having a duration equal to this summation. This requires the provision of an auxiliary Pulse-Masking Counter, the main function of which is to generate a reset pulse for the various counting and gating units in the analyser at the end of a pre-selected "masking" period, following the end of an input signal. A masking interval of between 0·5 ms and 10·5 ms is selected by the manual setting of a rotary switch, and, at the end of this period, during which time the main counter ceases to receive pulses at 500 p.p.s., an automatic reset pulse is generated from the cathode circuit of the selected masking counter tube to prepare the analyser for the onset of the next event. If this event matures before the reset pulse is generated then the count continues, this sequence being repeated until the end of the cluster is reached.

Fig. 2 illustrates the main functions of the analyser in block schematic form. The monitored signal on lead *a* is fed into a Signal Control Circuit. This circuit is manually adjusted to receive the two-state input and a change of approximately 10 volts is required for its operation. The amplified, and phase-inverted, signal is then fed on lead *b* to the Start-Gate Control, where it performs a triple gating function, as follows:

(*a*) 1,000 p.p.s. PY pulses from the Pulse Generator are gated into the Frequency Halver on lead *d* to produce two anti-phase pulse outputs, each at 500 p.p.s. and designated P1 and P2, it being arranged that at the start of an event pulse P1 shall occur first.

(*b*) 500 p.p.s. P2 pulses, as they occur, are gated simultaneously on lead *c* to the Main-Counter Control and to the Main Units-Counter, where they operate a cold cathode tube "ring of five."

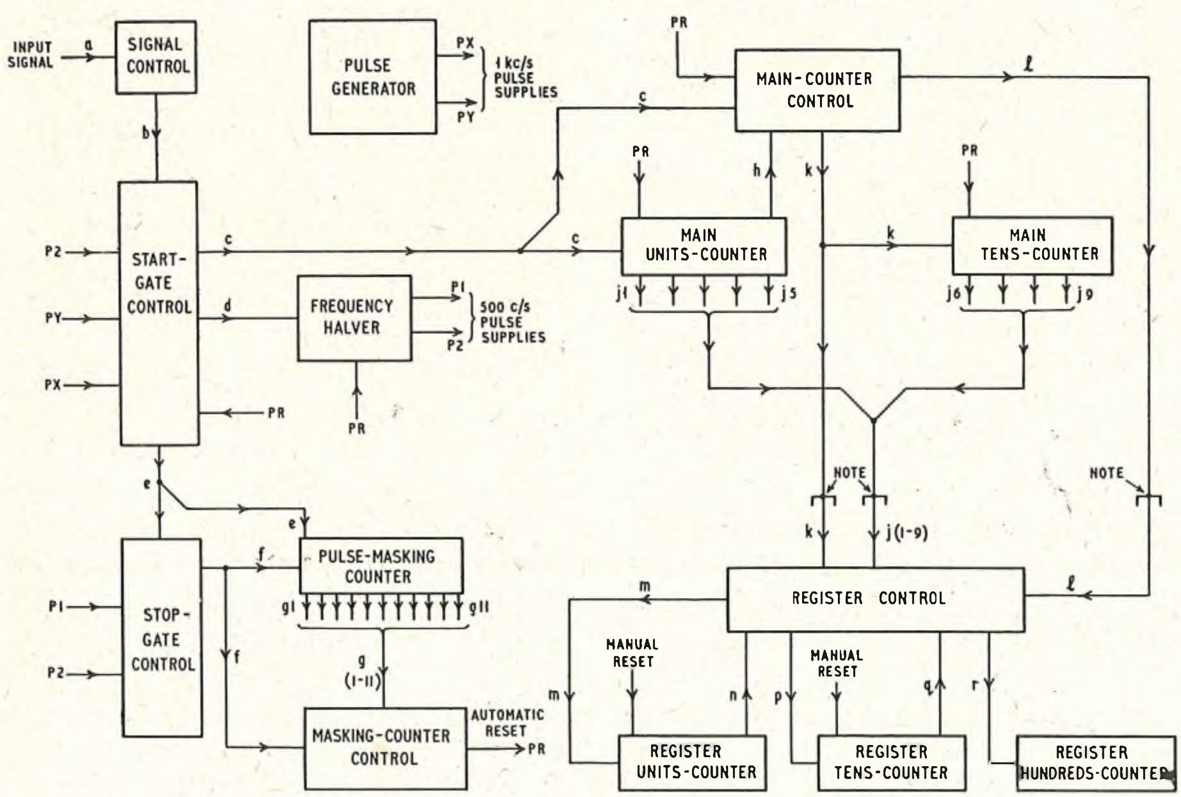
(*c*) 1,000 p.p.s. PX pulses are gated on lead *e* into the Stop-Gate Control, where they are used to reset trigger circuits, whose primary function is to detect the end of an event being monitored. These pulses are also gated into the pulse-masking counter, where the first PX pulse received resets the counter at the beginning of each event.

Should the monitored event have a duration of less than 10 ms, then the main-counter control has no further function to perform, and marking signals appear on the cathodes of the tubes comprising the main units-counter, in sequence, as they are struck by the drive pulses on lead *c*. These marking signals pass to the four Register-Control Circuits on leads *j*1–5. If, however, the monitored event exceeds 10 ms, then the main units-counter continues to cycle for the duration of the event, and extends a signal once every 10 ms on lead *h* to the main-counter control. The first of these signals has a dual function to perform, as follows:

(*i*) The pulse signals fed to the four register-control circuits on lead *l* are inhibited, for the remaining duration of the event, by the operation of a trigger circuit in the main-counter control. This allows any register connected by its control to one of the leads *j*1–5 to register a count-of-one only for any particular event being monitored by the analyser, even though the main units-counter may complete several "rings."

(*ii*) The signal is regenerated and connected to lead *k* to drive the Main Tens-Counter.

Further signals (one every 10 ms) on lead *h* serve only to operate the main tens-counter until a signal duration of 50 ms is reached. Subsequent signals received on



Note.—Commoned to other registers

FIG. 2—BLOCK SCHEMATIC DIAGRAM OF PULSE-DURATION ANALYSER

lead *k* are normally ineffective since the main tens-counter is only connected as a "ring" under routine test conditions. During the operating cycle of the main tens-counter, marking signals appear on the cathodes of the tubes comprising this counter, in sequence, as they are struck by the drive pulses on lead *k*. These marking signals pass to the four register-control circuits on leads *j*6–9.

Each register control contains a manually operated rotary switch, enabling its associated register to be connected to any one of the nine *j* leads. Any register may thus, for a period of observation, record the total number of events exceeding a duration in the range 2–50 ms, as selected by its associated switch. Signals received on the selected *j* lead are gated on lead *m* of the register-control circuit into the Register Units-Counter. The units-counter drives the Register Tens-Counter, and in turn the tens-counter drives the Register Hundreds-Counter, the latter comprising an electromechanical meter. Regeneration takes place in the register-control circuit between each stage. The register tens-counter and units-counter may be manually reset prior to each period of observation. One advantage of this arrangement is that it facilitates routine testing of the registers.

The end of an event is recognized by a change of potential on lead *a*. This removes the gating signal on lead *b* to the start-gate control. This in turn closes two of the three start-control gates thereby inhibiting:

(*a*) The P2 pulses from the main-counter control and main units-counter on lead *c*.

(*b*) The PX pulses from the stop-gate control and the pulse-masking counter on lead *e*.

Inhibiting the P2 pulses ensures accurate measurement of the monitored event, whilst inhibiting the PX pulses prepares the analyser for the generation of a reset pulse. PY pulses continue to operate the frequency halver, in anticipation of the start of a further event within the pre-selected pulse-masking period, i.e. prior to the generation of a reset pulse. Following the disappearance of PX pulses on lead *e*, P1 and P2 pulses are gated as they occur from the stop-gate control into the pulse-masking counter. Since P1 and P2 are 500 p.p.s. pulses in anti-phase, they combine to drive the pulse-masking counter at an effective rate of 1,000 steps/second, and marking signals appear on the cathodes of the tubes comprising this counter, in sequence, as they are struck by the drive pulses on lead *f*. These marking signals pass on leads *g*1–11 to the masking-counter control, which contains a manually operated rotary switch, enabling its Reset-Pulse-Generator circuit to be connected to any one of the 11 *g* leads. Any pre-selected interval (in the range 0·5–10·5 ms) between adjacent events may thus be absorbed by the analyser, which is therefore prepared to treat the onset of a second event as a continuation of the first, i.e. to achieve signal integration. If this should occur during the pre-selected masking period, the reappearance of a signal on lead *b* to the start-gate control will again allow gated P2 pulses to reach the main units-counter and its associated control, and the reappearance of gated PX pulses on lead *e* will block P1 and P2 pulses from the pulse-masking counter. The first PX pulse to appear on lead *e* will also reset the pulse-masking counter in anticipation of the end of the second event.

This process may be continually repeated, without regeneration of a reset pulse, PR, until the end of the last event of the cluster. The start-gate and stop-gate controls and the pulse-masking counter then behave as previously described, except that a marking signal is now extended on the pre-selected *g* lead to the masking-counter control at the end of the requisite masking interval. This signal, gated by the masking-counter control, becomes a PR pulse, which performs the following functions:

(*i*) Resets the main units-counter and tens-counter.

(*ii*) Resets a trigger circuit in the start-gate control, preparatory to monitoring a further event.

(*iii*) Resets a trigger circuit in the main-counter control, ready to gate the next series of pulses received on lead *c* to the four register controls on lead *l*.

(*iv*) Resets the frequency halver, so that the first pulse to be generated by this circuit, when again required to function, is a P1 pulse.

The analyser is now in a position to accept further input signals for monitoring, should they occur, until the end of the period allocated for observation, when a toggle switch in the signal control circuit may be operated to inhibit any further signals received on lead *a*.

CIRCUIT LOGIC

At the commencement of an observation period, the toggle switch in the signal control circuit is restored. This removes the inhibiting condition from the input gate of this control circuit, and any subsequent event appears as a signal on lead *b*. Such a signal passes to the start-gate control (Fig. 3) where it opens gates G1 and G2. With G2 open, the first PX pulse to occur operates the bi-stable trigger TG1. This and subsequent PX

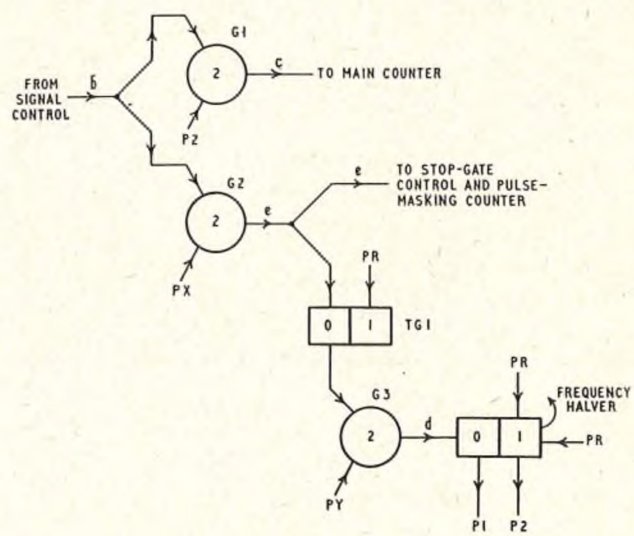


FIG. 3—START-GATE CONTROL AND FREQUENCY HALVER

pulses are also fed on lead *e* to the stop-gate control and to the pulse-masking counter. Trigger TG1 remains operated throughout the duration of the event, and until the receipt of a reset pulse, PR. The trigger controls gate G3, and with this gate open PY pulses are fed to the frequency halver on lead *d*. The continued presence of PY pulses on this lead causes the frequency halver to generate anti-phase P1 and P2 pulses at 500 p.p.s. in synchronism with the 1,000 p.p.s. PY pulses. P2 pulses are gated by G1 and appear as drive pulses on lead *c* to the main counter and its control.

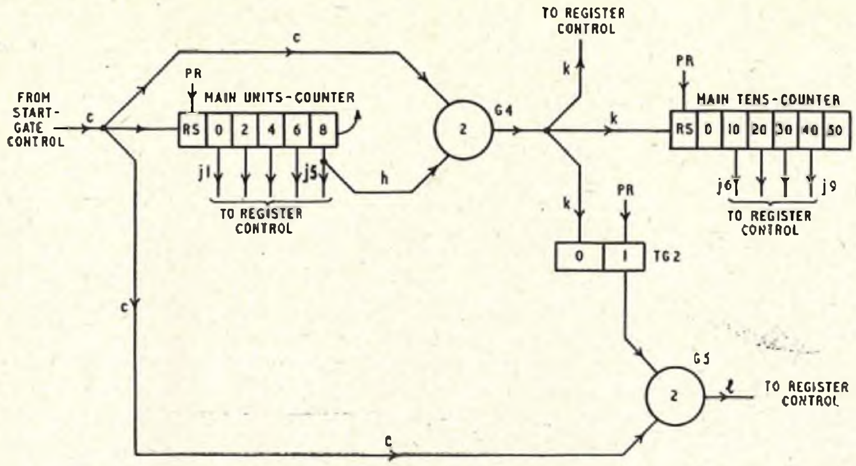


FIG. 4—MAIN COUNTERS AND COUNTER-CONTROL CIRCUIT

The P2 pulses on lead *c* drive the main units-counter (Fig. 4). On receipt of the fourth P2 pulse, this counter steps to position 8 and opens gate G4. The next P2 pulse is gated by G4 and appears as a drive pulse on lead *k* to the main tens-counter. This sequence is repeated on each cycle of the units-counter for as long as the event persists, and the tens-counter continues to step until position 50 is reached. The first pulse appearing on lead *k* also sets trigger TG2. This trigger, like TG1, remains set throughout the duration of the event, and until the receipt of a PR pulse. With trigger TG2 set, gate G5 inhibits further P2 pulses from appearing on lead *l* to the register control.

A switch, SW1 (Fig. 5), associated with each register enables a selection to be made of the two input conditions to gate G6. In positions 1–5 of SW1, marking signals from the main units-counter on leads *j*1–*j*5 open G6 to P2 pulses on lead *l*; in positions 6–9 of SW1, marking signals from the main tens-counter on leads *j*6–*j*9 open G6 to the pulses appearing on lead *k*. Since for positions 1–5 the P2 pulses on lead *l* only appear during the first cycle of the main units-counter, and for positions 6–9 the marking signals on leads *j*6–9 only appear once as the tens-counter steps to position 50, the register cannot record more than a count-of-one for any event, regardless of its duration. Gate G7 generates drive pulses for the register tens-counter, and gate G8 generates drive pulses for the register hundreds-counter.

At the beginning of an event, PX pulses on lead *e* set triggers TG3 and TG4 (Fig. 6). As the P1 and P2 pulses occur, so TG3 and TG4 are reset, only to be set again by succeeding PX pulses. As a result of this sequence, gate

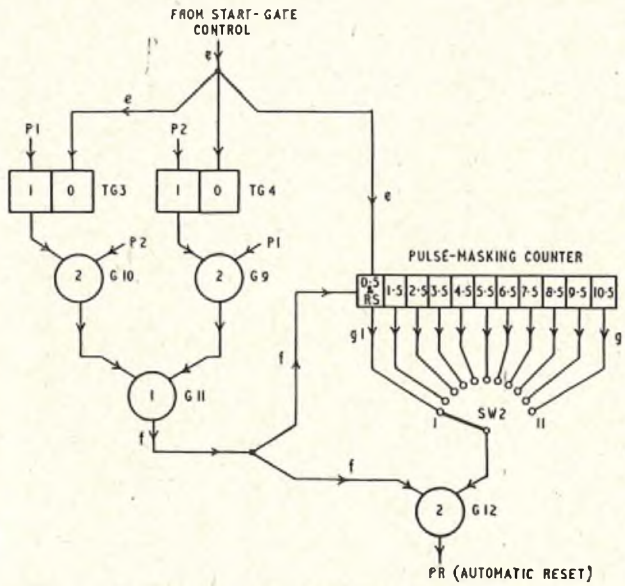
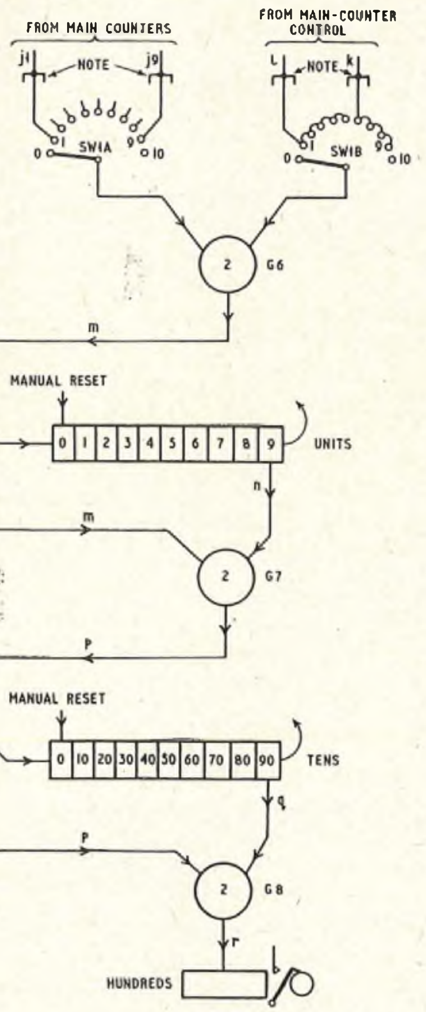


FIG 6—STOP-GATE CONTROL, PULSE-MASKING COUNTER AND MASKING-COUNTER CONTROL

G9 is never open to a P1 pulse nor gate G10 to a P2 pulse. At the end of an event, G1 (Fig. 3) closes to stop the counter and G2 closes to inhibit further PX pulses from lead *e*. Dependent on whether the first inhibited PX pulse follows a P1 or P2 pulse, the circuit is left with trigger TG3 or TG4, respectively, in its reset condition, i.e. with gate G10 or G9 open. With, say, TG3 left in the reset condition, the next pulse to occur is a P2 pulse, which is gated by G10 and by G11 to step the pulse-masking counter. In addition, this P2 pulse resets TG4, and hence the succeeding P1 pulse is also gated by G9 and G11 to step the masking-counter. Alternate P1 and



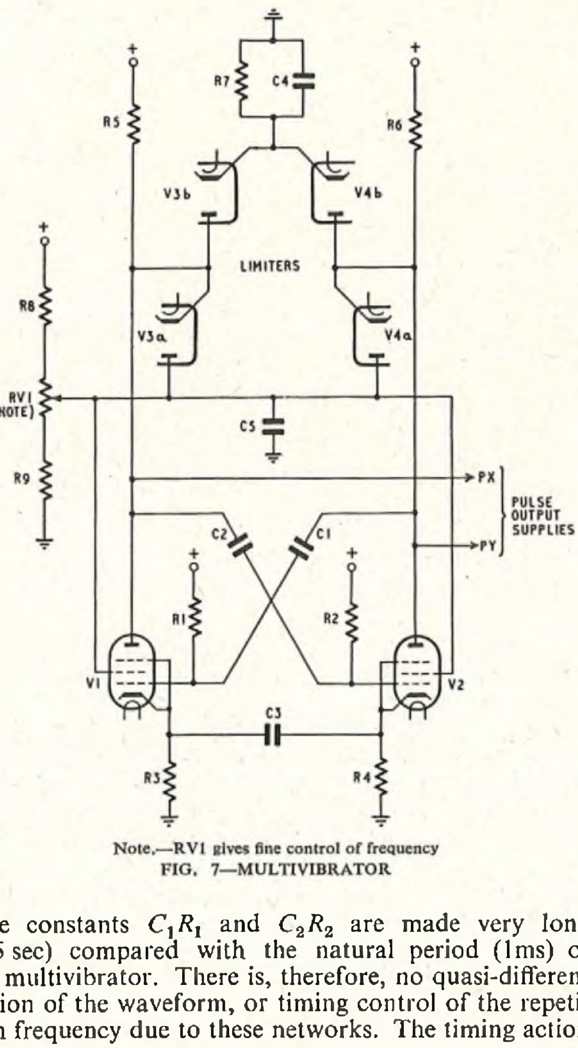
Note.—Commoned to three other registers
FIG. 5—REGISTER AND REGISTER-CONTROL CIRCUIT

P2 pulses continue to drive the masking-counter, until, dependent upon the setting of SW2, gate G12 is opened by a P1 or P2 pulse stepping the counter to the selected position, and the succeeding P2 or P1 pulse is gated by G12 and appears as the reset pulse, PR. The PR pulse resets the main tens-counter and units-counter (Fig. 4), TG1 (Fig. 3), TG2 (Fig. 4), if necessary, and the frequency halver (Fig. 3), if the PR pulse is coincident with a P1 pulse. Should a further event occur during the masking period, however, then gates G2 and G1 reopen (Fig. 3). With G2 open, the first PX pulse to reappear on lead *e* sets triggers TG1, TG3 and TG4 (Fig. 3 and 6), and resets the pulse-masking counter (Fig. 6). Trigger TG1 opens gate G3, and the frequency halver generates P1 and P2 pulses, as previously described. With gate G1 open, P2 pulses reappear on lead *c*, and the main counter drive recommences. This sequence is repeated until the generation of a reset pulse, following the end of the cluster of events.

CIRCUIT ELEMENTS

Pulse Generator

Fig. 7 shows the circuit element used for the generation of the antiphase 1 kc/s (PX and PY) pulses that provide the analyser time-scale. Valves V1 and V2 are a.c. cross-coupled (anode to control grid) in the conventional manner of astable multivibrator circuits. The



Note.—RV1 gives fine control of frequency

FIG. 7—MULTIVIBRATOR

time constants C_1R_1 and C_2R_2 are made very long (0·5 sec) compared with the natural period (1ms) of the multivibrator. There is, therefore, no quasi-differentiation of the waveform, or timing control of the repetition frequency due to these networks. The timing action is confined mainly to the network consisting of capacitor C3 and resistors R3 and R4, modified slightly by valve inter-electrode and stray circuit capacitances. Cathode coupling, using the same capacitor for timing both halves of the operating cycle, maintains frequency stability without recourse to expensive crystal control.

A fine control of the repetition frequency is given by a manual setting of potentiometer RV1, which controls the combined screen-grid voltages of valves V1 and V2. The control grids of both valves are returned to h.t.+ in order to shorten the "recovery time" of these grids following negative voltage excursions, thus improving the slope of the output waveform.

To achieve independence of supply voltage fluctuations and further reduce frequency drift, voltage excursions of the anodes of valves V1 and V2 are limited in both directions, namely:

(*a*) In a positive-going direction by diodes V3b and V4b, which, in conducting, build up a stabilizing voltage across capacitor C4 and resistor R7, the values of which determine the limiting value of the voltage excursion.

(*b*) In a negative-going direction by diodes V3a and V4a, which, in conducting, virtually clamp the voltage of the anodes to that of the combined screen grids.

With the values chosen for the circuit, the output-pulse amplitudes (PX from the anode of valve V1 and PY from the anode of valve V2) are approximately 30 volts. To ensure long-term frequency stability, resistors R3, R4 and R7 and capacitors C3 and C4 are close-tolerance high-stability components. Other components are not critical in this respect.

Typical Counter Stage

The counter circuit element shown in Fig. 8 is employed in the main and pulse-masking counters and in the

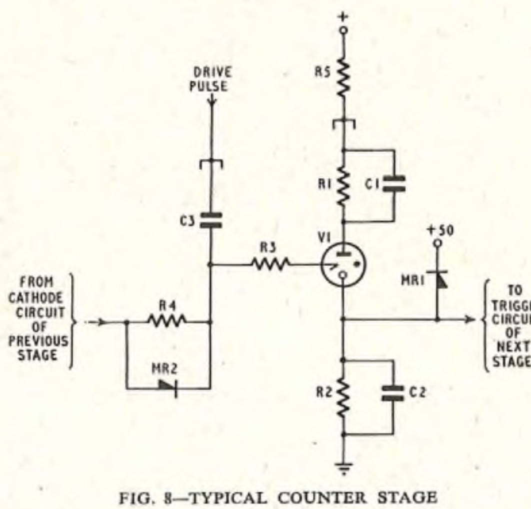


FIG. 8—TYPICAL COUNTER STAGE

register tens-counter and units-counter. These counters all operate on the pulse-plus-bias principle. On striking any tube of a counter, the cathode potential rises exponentially to 50 volts, being clamped at this value by a rectifier (MR1 of the previous stage). This potential charges capacitor C3 in the trigger circuit shown. On receipt of a 50-volt drive pulse through C3, the trigger potential rises momentarily to 100 volts to strike tube V1. With the striking of this tube, the common anode supply falls to the "maintain" voltage of the tube, recovering exponentially as capacitors C1 and C2 charge. This lowering of the common anode-supply voltage, coupled with the individual discharge times of capacitors C1 and C2 of the previous stage, result in the de-ionization of the tube in that stage.

The introduction of a parallel resistor-capacitor combination (R1 and C1) in the anode circuit of each tube, with R_1C_1 greater than R_2C_2, makes it possible to achieve reliable de-ionization, and at the same time improves the cathode waveform. This, coupled with the introduction of rectifier MR2 across resistor R4 to ensure a rapid charging of capacitor C3, enables the element to be used in the high-speed main and pulse-masking counters. For lower-speed operation, rectifier MR2 is omitted.

ACCURACY AND RESOLUTION TIME

At the start of an event, gates G1 and G2 open, and within 0–1·0 ms a PX pulse is gated by G2 to set trigger TG1, which opens gate G3, and in 0·5 ms a PY pulse is gated by G3 to operate the frequency halver, so producing a P1 pulse. Similarly, the following PY pulse, 1·0 ms later, produces a P2 pulse, which steps the main counter. This P2 pulse occurs within 1·5–2·5 ms of the start of the event, and hence the analyser has a "pick-up" accuracy of $\pm$0·5 ms. Subsequent P2 pulses step the main counter with a timing accuracy equal to that of the 1 kc/s multivibrator.

At the end of an event, gates G1 and G2 close immediately. Gate G1 inhibits further P2 pulses from the main counter and G2 inhibits further PX pulses from the stop-gate control. Therefore, within 0–1·0 ms a PX pulse fails to set one of the triggers TG3 and TG4, and 0·5 ms later a P1 or P2 pulse is gated by G9 or G10 to step the pulse-masking counter. With the counter control set for minimum pulse-masking, this pulse is regenerated to form the reset pulse, PR. Hence the PR pulse occurs within 0·5–1·5 ms of the end of an event. This period is referred to as the resolution time of the analyser, and includes an inherent masking time for the device of 0–1·0 ms. The eleven settings of the pulse-masking-counter control are marked 0·5 to 10·5 ms and hence any desired masking period is achieved with an accuracy of $\pm$0·5 ms.

CONCLUSION

The analyser was first used by the staff of the Telephone Development and Maintenance Branch to assist investigation into the general problem of irregularities occurring on circuits on h.f. trunk routes. In this connexion a circuit between London and Birmingham was continuously monitored at the London terminal for the duration of the testing period. The control over both sending and receiving conditions was exercised at London by looping the circuit at Birmingham. A continuous audio-frequency signal, simulating tone-on-idle conditions, was transmitted to line, and operated a signalling receiver connected to the receiving end of the circuit. This receiver provided the necessary conversion of h.f. disconnexions to d.c. signals acceptable to the analyser.

A second application involved the use of the analyser in conjunction with other apparatus on tests preceding the field trial of a carrier system employing built-in signalling facilities (which later became Signalling System A.C. No. 8). On these tests, conducted between Newcastle and Middlesbrough, the degree of speech immunity provided by the signalling system was assessed, the device providing a ready analysis of the false signals received from channel signalling receivers (*a*) under quiescent channel conditions, using tone-on-idle and tone-off-idle signalling codes and (*b*) whilst channels carried pre-recorded known levels of speech.

The analyser was also successfully used by Research Station staff over a considerable period to provide a similar analysis of signal imitations from different types of signalling receivers associated with carrier telephony circuits. No doubt there will be further uses of this instrument as its versatility and the reliability of the recorded data obtainable by this means on "random" signal analyses become more widely known.

Book Review

"V.H.F. Radio Manual." P. R. Keller. George Newnes, Ltd. 216 pp. 194 ill. 30s.

This book is intended for engineers engaged in planning and development, maintenance and servicing of radio equipment operating in the frequency range 30 Mc/s to about 450 Mc/s, and also for advanced amateurs experimenting in this field. The first half of the book is devoted to the principles and techniques of amplification, modulation, demodulation, transmission, radiation, propagation and measurement and the remainder of the book deals with their application to various systems under the headings f.m. broadcast transmitters and receivers, television tuners, single-channel communication equipment, multi-channel communication systems and amateur v.h.f. equipment.

The book deals with a large number of different techniques and systems and contains a great deal of useful practical information. This is presented in a laconic style which, coupled with the very clear printing of the text and diagrams on good paper, makes for easy reading. However, perhaps because the size of the book has been kept to some 200 pages, some of the descriptions of the operation of circuits and some of the explanations of fundamental principles are dealt with in a rather superficial manner which may well confuse those readers who are not already fairly well versed in the subject. Further, there are cases where symbols referred to in the text are not marked on the relevant diagrams. Because of these limitations it is felt that the price of 30s. is on the expensive side.

D. G. J.

I.P.O.E.E. Library No. 2446.

Manhole-Cover Lifters

U.D.C. 621.866:624.027:621.315.233

THE covers fitted to carriageway jointing chambers are necessarily heavy since they are designed to withstand any load that may be applied to them by modern road traffic, and consequently they often present difficulty to the staff who have to lift and move them in order to enter jointing chambers. In the past a number of improvised methods have been adopted to ease the task, but more recently, after discussion with representatives of the Staff Associations, it was decided to explore the possibility of producing a wheeled device for lifting and removing these covers.

A cover-lifting device based on a pair of 6-ton hydraulic jacks, and known as Manhole-Cover Lifter No. 1, is already in use for removing tight covers, and first efforts were directed to making this equipment mobile, so that after a cover had been lifted it could be wheeled away. No suitable method could be devised, however, without rendering the equipment so heavy and cumbersome that it would be unlikely to be used.

The second form of cover lifter considered was one developed by a manufacturer, consisting of a collapsible tripod surmounted by a hydraulic jack. The T-section legs are fitted with castor-type wheels, and the lift is effected via hooks and chains connected to each end of a short bar on the top of the hydraulic jack. The original design, in which the jack was mounted on a platform on top of the tripod, was unsatisfactory as it was found to be unstable under load. The makers were asked to lower the jack so that it was within the tripod, the side thrust from the legs being taken on a steel sleeve surrounding the jack body. This was done, and proved satisfactory. The equipment is designed to work at a maximum load of 3 tons; if this figure is exceeded the yield point of the chain material is exceeded and permanent deformation results.

FIG. 1—MANHOLE-COVER LIFTER No. 2

A third equipment, also developed by a manufacturer, was brought to notice by the Regional Director's Office, South Western Region, and, as may be seen from Fig.1, consists essentially of a lever, the fulcrum of which is the axle of a pair of wheels.

The cover-lifting keys are suspended from a square-section cross-bar, fixed to the end of a flat steel strip which is suitably angled at its other end to accommodate a tubular steel handle. The flat strip fits into slots at the top of a V-shaped member which is welded to the axle. The strip is secured in place by chained pins through suitably drilled holes, and three pairs of holes are provided in the strip to allow adjustment for different cover sizes. The tubular handle is also secured to the strip by a chained pin. The axle is made from angle iron, reinforced by a length of steel rod welded in the angle. Two sets of keys are provided, one for manhole covers and the other for joint-box covers. The pins at the end of the cross-bar are to prevent the keys and cover from slipping off the bar. The equipment may be easily and quickly dismantled into four main parts by removing three pins.

Comparative trials were carried out with the tripod and lever devices, from which it was concluded that the latter was the more suitable for Post Office use. The tripod needs greater care in setting up, is slower in operation and is more difficult to wheel away when the cover is suspended from it. There is also the danger of one leg slipping into the jointing chamber, although this may be overcome by running the castors in suitable lengths of channel iron placed alongside the opening.

It is proposed to introduce the lever device, under the title of Manhole-Cover Lifter No. 2, for underground gangs and jointers whose work entails the frequent lifting of heavy covers. The device is not intended to lift very tight or jammed covers, which should be dealt with by the jacking device mentioned earlier (Manhole-Cover Lifter No. 1).

S. L.

Book Review

"Radio Receiver Design (Part I)," Second Edition. K. R. Sturley, Ph.D., B.Sc., M.I.E.E., Sen.M.I.R.E. Chapman & Hall, Ltd. 667 pp. 56s.

In producing a second edition of Part I of his "Radio Receiver Design," Dr. Sturley has rewritten Chapter 1 and added new sections to some of the other chapters, increasing the number of pages from xiii+435 to xx+667. The treatment remains largely mathematical, and descriptive sections dealing with current practice are relatively short; in fact no circuit diagram or detailed description of a typical sound broadcast or general-purpose receiver is included.

After an introductory chapter, there are chapters giving very detailed treatments of valves, the aerial, and the stages of a receiver for amplitude-modulated signals, up to the detector; a.f. amplification, receiver testing and the design of frequency modulation and television receivers form Part II.

Chapter 1, much enlarged, now includes fuller consideration of double-sideband amplitude-modulation, frequency-

(Continued on p. 77).

Notes and Comments

New Year Honours

The Board of Editors offers congratulations to the following members of the Engineering Department honoured by Her Majesty The Queen in the New Year Honours List:

Edinburgh Telephone Area	Lowe, M. M.	Technical Officer	British Empire Medal
Engineering Department	Thwaites, J. E.	Senior Executive Engineer	Member of the Most Excellent Order of the British Empire
Liverpool Telephone Area	Wright, F. C.	Assistant Engineer	Member of the Most Excellent Order of the British Empire
Reading Telephone Area	Collins, H. F.	Technical Officer	British Empire Medal
Reading Telephone Area	Sharp, L. W.	Assistant Engineer	Member of the Most Excellent Order of the British Empire

Journal Changes

With this issue, which is the first part of Volume 51, the appearance of the Journal is appreciably changed, the object being to make it easier to read and to improve its appearance. Several changes of type face have been made, including a change in the type used for the main body of each article from Old Style (Roman) to Times. The headings of the articles have been rearranged and a number of other minor changes have been included. Lastly, the cover has been radically altered, the new design following the modern trend towards simplicity and clean lines.

Board of Editors

Mr. W. A. Humphries is resigning from the post of Managing Editor of the Journal because of a change in official duties and the Council of the Institution has appointed Mr. E. Davis, formerly an Assistant Editor, to take his place with effect from 1 May 1958. The new Assistant Editor is Mr. A. G. Leighton.

The Board of Editors takes this opportunity of thanking Mr. Humphries for his services to the Journal, and in particular for his work on the Jubilee and Transatlantic Telephone Cable Numbers.

Mr. R. H. de Wardt has recently left the Post Office and as a consequence has resigned from the Board of Editors. The Board would like to express their appreciation of his services. Mr. A. H. C. Knox has been appointed by the Council of the Institution to fill the resulting vacancy.

Premiums Awarded by the Radio Industry Council for Published Technical Articles

Each year the Radio Industry Council awards up to six premiums of 25 guineas each to writers of published technical articles which, in the opinion of the Council's panel of judges, are likely to enhance the reputation of the Industry and make more widely known British achievements in radio, television and electronics.

Any writer will be eligible who is not paid a salary wholly or mainly for writing and is not earning 25 per cent or more of his income from fees for articles or from book royalties.

Writers are invited to submit published articles (six copies of the journal, or of the relevant pages, proofs or reprints), together with signed declarations of eligibility, to the Secretary of the Radio Industry Council, 59 Russell Square, London, W.C.1, requesting consideration for an award. Articles will be considered for awards at the end of each year and the results announced early in the new year. Writers are, however, urged to send in their entries during the year as soon as possible after publication; all entries must reach the Radio Industry Council's offices before the end of the year.

Articles published in this Journal are eligible for the awards; it will not, however, be necessary for writers of articles published in this Journal to send copies to the Secretary of the Radio Industry Council when requesting consideration for an award, because copies of each issue of the Journal are sent to the members of the panel of judges.

Institution of Post Office Electrical Engineers

Retired Members

The practice of publishing in the Journal each year the names of those members who, on retirement from the service, have retained their membership of the Institution under Rule 11(*a*) was discontinued some years ago but it is now to be resumed. The following members, who retired during 1957, have retained their membership:—

G. Batho, Hirdie, Pentre Celyn, Nr. Ruthin, N. Wales.
W. West, 39 Peter Avenue, Willesden, London, N.W.10.
R. C. Davies, 14 Hillview Road, Irby, Heswall, Wirral, Cheshire.
A. Whiteley, B.E.M., 319 Edgeley Road, Cheadle Heath, Stockport, Cheshire.
H. H. Dell, 115 Shelford Road, Trumpington, Cambridge.
A. MacDonald, 420 Leagrave Road, Luton, Bedfordshire.

S. Welch, *Secretary*

Reprint of Library Catalogue

A new Library Catalogue is now being printed and should be ready during April 1958. Members have already been asked to let their Honorary Local Secretaries know if they require a personal copy, and Associate Section members may obtain copies at a nominal price of 6d. from their Associate Section Honorary Local Secretaries.

Additions to the Library

2462 *Applied Mechanics for National Certificate.* J. D. Walker (Brit. 1957).

Covers the requirements of students taking Mechanical and Electrical Engineering courses in Technical Colleges. Corresponds to the Applied Mechanics portions of the O.N.C. in Mechanical and Electrical Engineering.

(*Continued on p.* 74).

Regional Notes

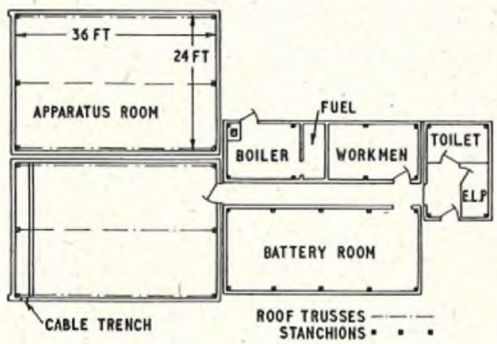
Midland Region

TELEPHONE EXCHANGES IN AREAS LIABLE TO SUBSIDENCE

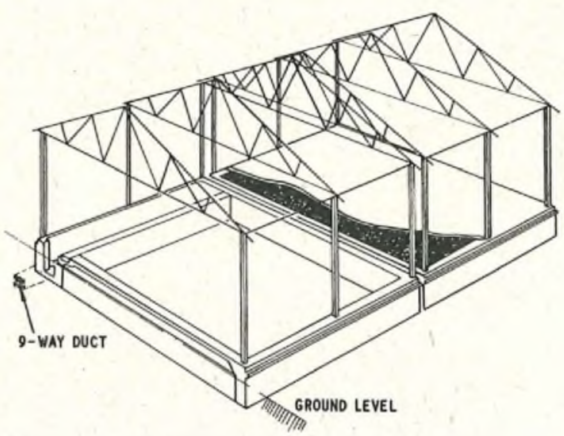
A special type of construction has been employed in two exchange buildings in the West Midland Area in an attempt to avoid serious damage to plant if subsidence should occur. The exchanges, Brierley Hill and Cradley Heath, are both in mining areas where subsidence is not uncommon.

The foundations, consisting of reinforced concrete slab beams approximately 4 ft deep, are sunk into the soil in rectangular formation, and on this structure is laid a reinforced concrete slab, which forms the floor of the section. The sections are knit together with weak concrete, the whole foundation virtually consisting of a number of inverted concrete boxes.

The building is erected on this foundation in sections corresponding to the foundation sections, with the walls and roof members so constructed that subsidence of any section need not affect an adjacent section. A plan of one of the buildings and a sketch of part of it are shown in the illustrations.



PLAN OF BUILDING



SKELETON OF CONSTRUCTION OF PART OF BUILDING (APPARATUS ROOM)

Internal racking and cabling are arranged so that slack cable is left at any points where joints in building sections occur. Any differential movement of the sections will take up the slack cable, and the electrical working of the exchange will, it is hoped, be unaffected. A. D. O.

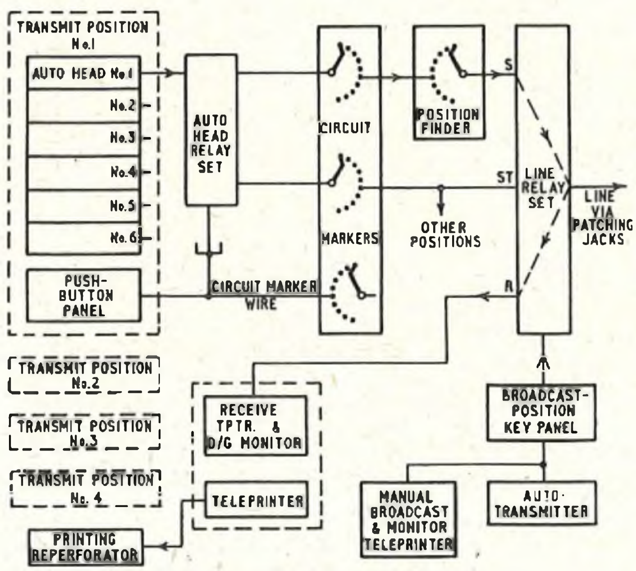
London Telecommunications Region

BRITISH ROAD SERVICES PUSH-BUTTON TORN-TAPE RELAY SYSTEM

The trend towards automatic working of large private renters' teleprinter installations continues. A recent noteworthy addition is the introduction of push-button torn-tape relay working by British Road Services at 238 City Road, London. This is the main switching centre of a teleprinter network operated by British Road Services. It previously worked on a manual basis with the addition of a small tape-relay system, which served 12 long-distance duplex circuits. On 13 January 1958 the whole network was changed over to the new push-button torn-tape relay system with 31 simplex and 11 duplex working circuits.

The installation consists essentially of four transmit/receive operating positions, each position comprising eight printing reperforators mounted in three 3-tier console cabinets and one push-button panel, the lower position of which accommodates two triple-headed automatic transmitters. The four operating positions are arranged in two units, each of two positions, the layout of each unit being in the form of a half-octagon with the push-button panels in each angle.

BRITISH ROAD SERVICES TAPE RELAY CENTRE



TAPE RELAY CENTRE SIMPLEX CIRCUIT

A general view of the tape relay centre is shown in the photograph, which illustrates the method of operating. An operator is seen taking a tape from a console preparatory to loading it into one of the automatic transmitters associated with the push-button panel on her immediate right. Each push-button panel can accommodate 48 circuits, the circuit designation being engraved on its associated button. The diagram gives a general outline of the method of working. The six automatic transmitter heads shown are common to the panel and each one has its own relay set and associated uniselector, termed the Circuit-Marking Uniselector. Each line is terminated on a relay set which also has its own uniselector, termed the Position-Finder Uniselector.

When an operator loads a tape on to an automatic transmitter head and presses the button of the appropriate circuit a "marked" condition is placed on a contact on the bank of the circuit-marking uniselector, which drives to the marked position; this corresponds to the outgoing line relay set of the line required. The Demand-Stored lamp (green), which is on the panel, associated with the loaded head will now glow steadily, indicating that the demand has been stored by the equipment.

The operator can now release the button. If the circuit is free a start signal is given to the position finder associated with the line relay set causing it to hunt for the calling head. When the head is found the uniselector drive is cut and the line is switched to the automatic transmitter and transmission commences, this being indicated by the demand-stored lamp changing from a steady glow to a flashing signal. When all the tape has passed through the transmitter the transmission is complete and all relays restore to normal.

The receive lines of simplex circuits are terminated on teleprinters via the line relay sets. This is for checking and editing. Messages are retransmitted to a local printing reperforator, and subsequently transmitted via the automatic transmitters to any depot in the network. For duplex lines the send line is similar to the simplex line except that it is terminated at the outstation on a teleprinter instead of a Unit Signalling TG3069, and the receive line at the tape relay centre is routed via the patching-jack field direct to a local printing reperforator (not shown in the diagram). The patching-jack field, on a table between the seated operators at the left of the photograph, gives monitoring facilities, flexibility and supervision on the whole system.

The broadcast-position key panel shown in the diagram provides access to all lines, and transmission takes place via the electronic broadcast units located in the apparatus room. A feature of the broadcast unit is the visual indication (white lamp) that a line is busy at one of the automatic transmitter panels; another lamp (green) glows when it is free and available for broadcast. When this condition obtains the associated lamp on all push-button panels on transmit positions will glow, indicating that the line is engaged. Another feature is the facility whereby, after the automatic clear down, the same arrangement can be retained by the operation of the Camp-On key and another broadcast transmitted immediately.

There is also a service bank of printing reperforators which are available for reception on any line by patching at the jack field. The messages received may be retransmitted by running the tape through an automatic-transmitter on a telex position.

This push-button tape relay scheme was designed and developed by the Engineering Department. The apparatus used is of standard Post Office type.

Power for the installation is supplied from two conventional telegraph motor-generator sets; each set is driven by a 14 h.p. 3-phase motor at 1,440 r.p.m.; the generators have an output of 4 kW at 80/110 volts and are equipped with Isenthal regulators. There is no battery; the generator outputs supply the power board directly and are used alternately. The power board was designed and produced by the London Telecommunications Region's Power Section and the general installation was carried out by the City Area teleprinter construction staff.

The system is working satisfactorily and during one day recently handled approximately 4,000 messages.

E. J. C. O'B.

External Telecommunications Executive

REPLACEMENT OF STANDBY GENERATING PLANT AT ONGAR RADIO STATION

For some years past the standby generating plant at Ongar Radio Station has fallen rather short of the required standard of performance and it has recently been necessary to replace it by new plant. The recovered standby generating plant consisted of a rather odd assortment of equipment and it may be of interest to describe how it came to be installed.

In 1921 when the station was first opened there was no electricity supply in the district and three Vickers-Petters semi-diesel engines with direct-coupled dynamos were installed, with a maximum output of 144 kW at 240 volts d.c. A storage battery was later provided to float on the busbars and assist the generators when the load was heavy, the battery being recharged when the load was light. It also provided emergency lighting for the buildings and masts when all the supplies failed.

In 1929, when the station was enlarged, four Belgian engine-generators (ABC, Ghent), each of 120 kW capacity, were installed. At about the same time the public mains supply at 11 kV was extended to North Weald and the radio station, so the Electricity Board's supply then became the normal source of power, while the engine-generators remained as a standby against power failures. They were also used regularly to reduce the maximum demand on the mains supply. A link between a.c. and d.c. supplies was provided by two 250 kW synchronous-motor-generators. Under normal conditions one of these machines motored from the a.c. busbars and, by over-exciting the field windings by means of a Brown-Bouverie automatic regulator, the power factor was maintained at 0·97 at all times. Under emergency conditions the synchronous-motor-generators worked in reverse with the d.c. side acting as the motor and the a.c. side as the alternator. Providing it was known in advance that the supply would be cut at a stated time, the d.c. generation could be built up by stages until all seven engine-generators delivered power to the busbars. Once the station load was taken by the engine-generators, the mains supply could be disconnected. The operation of running-up the engine-generators occupied a considerable time as the ignition tubes that formed hot spots on the cylinder-heads had to be heated by blowlamps until they attained red heat before compressed air could be injected to commence movement of the pistons. It was an impressive sight to see all seven of the engines running with the two motor-alternators in parallel converting the d.c. power to 3,350 volts, 3-phase alternating current.

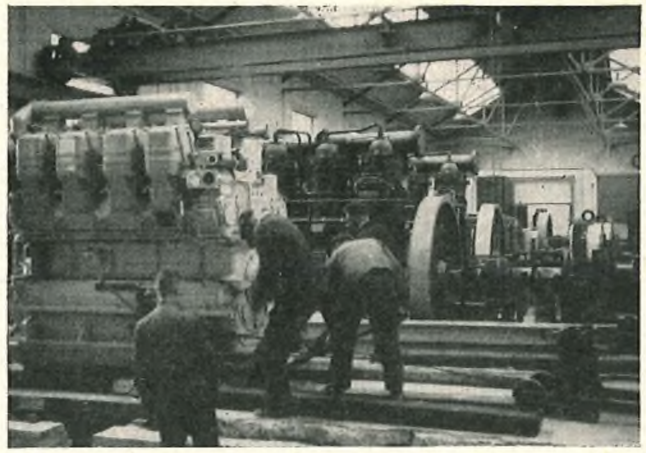
For some time it had been realized that, with the station load increasing, this antiquated plant did not provide adequate protection against mains failures, strikes, or

BREAKING UP THE OLD FOUNDATIONS

lock-outs, which could put the complete radio station out of action. The beginning of the end came in 1954 when the crankshaft of one of the ABC engine-generators fractured. As an interim measure an 8-cylinder Paxman diesel engine, directly coupled to a 275 kW alternator, was installed. Before the installation had been completed a second ABC engine-generator broke down beyond repair. Drastic action was then called for so it was decided to scrap all the existing engine-generators and to install two English-Electric 750 kVA diesel-alternators of modern design.

The engine-room became a scrap merchant's paradise as the old machines were dismembered, only the foundations, an example of which is shown in the first photograph, showing any passive resistance. They testified to the craftsmen who made them and resisted pneumatic drills, hammers and wedges in their stubborn refusal to make way for the new foundations. The concrete was finally cut through and the pits constructed in which the new foundation blocks were to rest. These were completely insulated from the concrete-lined pits by a 2 in. layer of cork slabs in order to reduce vibration to a minimum. This insulation continues round the sides of the blocks up to floor level, as shown in the second photograph. The long life and smooth running of an engine depends to no small extent on the design and strength of this block and the accurate lining up of the packing pieces on which the engine rests.

The new standby generating plant consists of two English-Electric V8-cylinder turbo-blown diesel engines running at 750 r.p.m., coupled to 750 kVA alternators and exciters. The third photograph shows an engine-alternator being moved into position. An important feature of the plan is a change-over of the locally generated voltage to 11 kV, which will eventually be the voltage for distribution to the whole radio station. Space has been allowed for a third engine set, if required. The switchgear is installed in three fireproof cubicles and so arranged that the station would not be completely out of action following a catastrophic failure in any one of the three switchrooms or associated supplies. Automatic carbon-dioxide apparatus is installed to safeguard against fires.



MOVING A NEW ENGINE-ALTERNATOR INTO POSITION

LINING ONE OF THE NEW PITS WITH CORK

To avoid the risk of the engine freezing up under extreme conditions of low temperature the complete cooling system is filled with an anti-freeze liquid, which circulates on a closed system similar to that of a motor car, except that the radiator is equipped with a 25 h.p. fan.

The new plant is very easy to operate, which is most important as it is only required for occasional use. Whereas it was necessary in the past to maintain a continuous rota of switchboard attendants and engine drivers, it is hoped in the future to treat a diesel-alternator in a similar way to an unattended radio transmitter. When required for service it will be run up and when the emergency is over it will be closed down and the power house locked up until the next emergency.

A.R.L.

I.P.O.E.E., Additions to the Library—(*continued from p.* 71).

2463 *The Principles of Telecommunications Engineering.* H. R. Harbottle and B. L. G. Hanman (Brit. 1957).
Covers the first-year syllabus of the C. & G. curriculum in Telecommunications Principles.

2464 *Understanding Hi-Fi Circuits.* N. H. Crowhurst (Amer. 1957).
An explanation of the various sections that go to make up an integrated hi-fi system.

2465 *Services Textbook of Radio and Electrical Engineering, Vol. 1: Electrical Fundamentals.* G. R. Noakes (Brit. 1956).
Covers the material common to both Radio and Electrical Engineering. Employs the rationalized M.K.S. system of units.

2466 *Transistor A.F. Amplifiers.* D. D. Jones and R. A. Hilbourne (Brit. 1957).
Deals systematically with the design of transistor a.f. amplifiers, and gives circuitry and design details of a versatile range of amplifiers, including high-fidelity and public address systems.

2467 *F. M. Radio Servicing Handbook.* G. J. King (Brit. 1957).
Provides the theoretical and practical knowledge necessary to the service engineer, and for the amateur enthusiast interested in the construction of f.m. equipment.

2468 *Transistor Circuit Engineering.* Ed. R. F. Shea (Amer. 1957).
Shows how transistor theory can be put to work in typical circuits, and gives the necessary knowledge for circuit design and developing usable circuits in all fields of application.

W. D. FLORENCE, *Librarian*

Associate Section Notes

Ipswich Centre

The forming of an Ipswich Centre resulted from a gathering of 25 interested engineering staff at the telephone exchange on 3 October 1957.

After a short talk by the Area Liaison Officer, Mr. L. A. Farrow, and two of our colleagues from the Colchester Centre who kindly came along to give their help, the following officers and committee were elected: *Chairman:* Mr. P. E. Buck; *Vice-Chairman:* Mr. E. W. Cattermole; *Secretary:* Mr. A. F. Green; *Treasurer:* Mr. K. C. Bristo; *Committee:* Messrs. J. E. Walden, M. S. P. Wicks, C. G. Pilgrim and R. J. Shelton; *Auditors:* Mr. F. B. Kerry and Mr. P. Havard.

An inaugural meeting under the chairmanship of Mr. P. E. Buck was held in November. Mr. Buck introduced the Deputy Chief Regional Engineer, Mr. A. H. C. Knox, the Area Engineer, Mr. F. K. Radcliffe, and the Regional Liaison Officer, Mr. H. W. Harrison. Mr. Harrison gave a short talk on the aims of the Associate Section, and Mr. Knox then followed with a detailed and much appreciated talk on "Promotion," after which the floor was open for questions and discussion.

The December meeting took the form of a challenge from the Colchester Centre to a general knowledge quiz at Colchester, which was enjoyed by all and resulted in a victory for the home team.

The winter program has also included a demonstration of coaxial cable jointing and testing by Messrs. J. Albins and I. Grainge, and a talk entitled "What are Plastics?" by Mr. E. Couzens.

For the summer months visits have been arranged to a variety of places, including Imperial Chemical Industries, Stowmarket; East Anglian Daily Times, Ipswich, and Cliff Quay Power Station.

The membership now stands at 160, which is most encouraging, and the success of the Centre has been due in a large measure to the efforts of our Liaison Officer, Mr. L. A. Farrow.

A. F. G.

Hastings Centre

As during last summer diesel-electric main-line trains had been introduced locally and the bus company had decided to scrap the town's trolley-bus services, we opened the season topically with films on diesel-electric trains and trolley-buses.

Thanks to the efforts made by members in attending meetings, all have been a success. Four members of the Centre contributed papers:

"Fuel Economy in the Home," by K. Noakes.
"The New P.A.B.X.s," by L. R. Hills.
"Group Charging," by S. E. C. Theobold and T. W. Whitmore.

The other paper read during this session was on "Air Navigation," by Mr. Guest of the Brighton Associate Centre.

During October a day visit to Ford Motor Works, Dagenham, was well supported.

Events scheduled to take place during the remainder of this session include a talk on yachts and boat building, by a member of the local sailing fraternity, and the annual contest with our neighbouring centre, Tunbridge Wells.

L. J. S. W.

Medway Centre

January's meeting was undoubtedly one of the highlights of the current session, when our speaker was Mr. W. L. Newman of the London television network switching centre. The writer would like to express thanks on behalf of the above Centre to those members of the television outside broadcasts staff and network switching centre at Museum Exchange who, although behind the scenes, made this meeting possible.

E. J. R. S.

Bradford Centre

At the time of writing we are midway through our program for the current session, which has to date included visits to a waterworks undertaking, a brewery, and the Bradford City Police Headquarters. In addition, a paper entitled "Post-War Developments in Telecommunications" has been read to the Centre by one of our members.

Looking back, one of the most pleasing features of the session has been the joint meeting with the Leeds Centre to celebrate the Associate Section's Silver Jubilee, when a paper on "The Overland Section of the Transatlantic Telephone Cable" was given by Messrs. Robinson and Ash of the Engineer-in-Chief's Office.

We in Bradford look forward to these joint meetings, which give an opportunity to meet fellow members in other local centres.

Other items in the session's program have been:

27 January: Joint meeting with Leeds Centre. Talk on Valve Manufacture, by C. H. Gardner of Mullards.
26 February: "The Man in the Middle," a talk given by Mr. J. Sunderland, T.T.S. Bradford Area Traffic Division (Work in an Area Traffic Division).
20 March: "Holidays Abroad," by J. Redfearn.

The remaining items in our current program are:

16 April: All-day visit to Calder Hall atomic power station.
8 May: Annual general meeting and film show.

The membership of the Centre stands at 159 and we hope to increase this figure before the end of the session. We shall be pleased to hear from other Centres on any topic. Please contact the Secretary, Bradford Telephone Exchange, Manchester Road, Bradford, 5.

W. J. H.

Leeds Centre

Since the publication of the last Journal, the Leeds Centre has commemorated the Silver Jubilee Year with a talk and film entitled "Overland Section of the Transatlantic Cable, Newfoundland". This was given by Mr. H. E. Robinson and Mr. B. Ash of the Engineer-in-Chief's Office (External Plant and Protection Branch). The meeting was held at the Hotel Metropole, Leeds, with a record attendance of 108 members. The visiting members included members from the Bradford, Huddersfield and Sheffield centres.

The introduction was most clearly given by Mr. H. E. Robinson, who described in detail the routing of the cable and some of the preliminary difficulties experienced on this project. The description of the cable laying, jointing and testing was very clearly given by Mr. B. Ash, who made his commentary most interesting with occasional reference to the more humorous moments, which were depicted on coloured film. It was generally agreed to be a most interesting talk and much benefit was derived by all.

On 14 December 1957 a party of 10 members paid a visit to the British Railways signal box at York station and the Large Exhibits Section of the Railway Museum. Much interest was shown in the workings of the control console showing trains approaching and leaving York station. The visit ended with a demonstration of the operation of electro-pneumatic points on the track outside York station. It was agreed that further visits would be arranged due to the large number of requests.

On 27 January 1958 an illustrated talk was held at the Griffin Hotel, Leeds, entitled "Radio and Special Quality Valves," by Mr. R. Webb of Mullard, Ltd. There was a good attendance, those present including visiting members from the Bradford and Huddersfield Centres. Mr. Webb gave a most interesting introductory talk, supported by two excellent films, on the design and application of radio and special quality valves. It is hoped in the near future to visit the Blackburn factory of Mullard, Ltd., where all the interesting details illustrated in the talk may by seen.

Other items arranged for this session were:

21 February 1958: A return visit to British Insulated Callender's Cables, Ltd., Prescot, for another 30 of our members.

10 March 1958: An illustrated talk entitled "Television By Wire," by Mr. Oakly of West Riding Relay, Ltd.

Arrangements were made to hold a Jubilee Telecommunications and Electronics Exhibition at the Department of Electrical Engineering, University of Leeds, on 26, 27 and 28 March.

It is hoped to report on these events in a future issue of the Journal.

C. B.

Edinburgh Centre

In November the Centre held a dinner to celebrate the Silver Jubilee of the formation of the Associate Section. Thirty members were present and a special welcome was accorded to the Telephone Manager, Mr. I. Matheson, to Lt.-Col. F. Lucas from Post Office Headquarters, Scotland, and to Mr. J. J. McKichan, O.B.E., who was the first Centre chairman in 1932. During the course of the evening Lt.-Col. Lucas presented Mr. J. R. Haggart with an I.P.O.E.E. certificate of merit for his success in the essay competition.

Once again Mr. D. Plenderleith presented an excellent film show during December. The program was devoted to technical and general films and to the enjoyment of those present ended with an old-time comedy favourite.

"Maintenance of the Grade of Service" was the subject chosen by Mr. W. Carr for his talk in January and though the attendance of members was disappointingly small Mr. Carr was called upon to answer numerous questions.

There are three more interesting talks before the end of the present session and the committee appeals to members to support the section activities so that more ambitious programs can be arranged in the future.

T. J. P.

Sheffield Centre

On 14 November Mr. J. M. Willmott of the Lincoln Area gave us a most interesting lecture on "Printed Circuits." He brought with him a car-load of exhibits, ranging from basic raw materials to a transistorized printed-circuit record-player. These were all excellently displayed on stands, and with a set of lantern slides they really "put us in the picture." Mr. Willmott's subject and presentation were so fascinating that he was besieged by questions afterwards and the hour was late when he left for Lincoln.

Our Leeds colleagues invited us to join them at the Hotel Metropole on 25 November. On that occasion Messrs. Ash and Robinson of the Engineer-in-Chief's Office were lecturing and showing a colour film entitled "Overland Section of the Transatlantic Cable, Newfoundland." The response was so enthusiastic that a large coach-load went from Sheffield and a most enjoyable evening was spent at Leeds.

The meeting on 5 December was a family evening, when our speaker was Mr. A. Faulkner-Taylor, a local naturalist, photographer, author and broadcaster. He brought us his colour film on "A Derbyshire Dale," which showed various aspects of the local countryside through the four seasons. Besides the excellent pictures of birds, flowers and fish life we saw one of the well-known Derbyshire caverns and a workshop where the Blue John stone, quarried there, is fashioned into souvenirs. We also had a close-up view of the patient and intricate work that goes into the preparation of a well-dressing.

Our Telephone Manager, Mr. E. S. Loosemore, visited us again on 19 December. His subject "Telephone Charging Systems" was very topical, following the announcement of the new call charges. He traced the various tariffs from the take-over by the Post Office in 1912 to the present day, and then dealt in detail with the group charging system which now operates. Then, looking ahead, he suggested some methods of charging which might be used with subscriber trunk dialling.

We were pleased to welcome the Telephone Manager and Mrs. Loosemore as guests at our last meeting, together with our Area Engineers, Messrs. A. M. Hunt and J. W. Spooner, and their wives. It was another of our popular family gatherings. Our program started with an excellent show of travel films by British Railways, and then we adjourned to the refreshment club for a first-class supper, which had been jointly organized by our Secretary and Chairman.

J. E. S.

Sunderland Centre

On 29 November, Mr. F. M. Inglis of Siemens Edison Swan, Ltd., once again paid us a visit to give his talk on "Television Tubes." The speaker supported his talk with numerous exhibits ranging from a 9 in.-tube set through other sizes up to the large 21 in.-tube models. The interest of the Centre was reflected in the size of the audience, it being the largest to date, 29 members being present.

Numbers at the subsequent visit to the cathode ray tube factory on 4 December 1957 were, however, below expectations, only 14 members touring the works. As on a previous visit to the same firm, the tour was well organized, extremely interesting and informative.

30 December, was our next meeting, and on that occasion the following films were shown:

"Six Days Scottish Motor Cycle Trial"
"Mirror in the Sky"
"Echo Whalefinder"

The film projection was excellent and the best to date, due entirely to our colleague R. Rodda.

D. A. C.

Scarborough Centre

The Scarborough Centre held its annual dinner in the Salisbury Hotel, Scarborough, on the evening of Friday, 6 December 1957.

Among those present from the Senior Section were the Chief Regional Engineer, Lt.-Col. J. Baines, O.B.E., T.D.,; Mr. H. A. Clibbon, Telephone Manager, York Area; Mr.

Standing (left to right):—Lt. Col. J. Baines, Chief Regional Engineer, Mr. H. A. Clibbon, Telephone Manager, York; Mr. E. Speechley, Executive Engineer, York and Mr. A. S. Major, Assistant Engineer, Scarborough.
Seated (left to right):—Mr. G. E. T. Thomas, Area Engineer, York; Mr. W. Bradley, Secretary, Scarborough Associate Centre and Mr. D. A. Rivis, Chairman, Scarborough Associate Centre.

G. E. T. Thomas, Area Engineer, York Area; Mr. E. Speechley, M.B.E., E.R.D., Executive Engineer, York and Mr. A. S. Major, Assistant Engineer, Scarborough.

The dinner was followed by a cabaret and dance and all members, wives and friends had a really jolly evening.

W.B

Aberdeen Centre

In the current session, 1957–58, three of our members have given papers, as follows:

"The Norwegian Cable," by J. M. Kidd. Mr. Kidd gave a very interesting talk on the Norwegian cable and its associated terminal equipment. He referred to the American and other submarine cables and had a sample of the transatlantic cable laid in 1956 to show. He spoke about the problems met and the measures taken to overcome the various difficulties that have arisen in the provision of submarine cable from our island to other countries. The techniques developed and the costs of laying and maintaining the cable also featured in his talk. A lively discussion followed and Mr. Kidd very competently dealt with questions.

"Television and Radio Investigations," by D. White. A very interesting and informative talk on television and interference was given by Mr. White. He indicated the technical difficulties involved and the human relation aspect in dealing with the public on technical matters. Mr. White ably answered the questions put to him and gave us some indication of the legalities applying to suppression of interference from electrical equipment.

"P.A.B.X. No. 3," by J. H. Lawrence. Mr. Lawrence gave a general outline of the P.A.B.X. No. 3. He indicated some of the novel circuit features and his talk was well illustrated by the use of an epidiascope. A lively question time followed which was ably dealt with by Mr. Lawrence.

Also this session we have had talks by guest speakers under the following titles: "Transistors", "Your Television Weather Chart Explained", "Royal Signals Communication", "Operating with Co-Operation" and "Developments, including subscriber trunk dialling.

To mark the occasion of our Silver Jubilee we are to issue a bulletin and hold a dinner at which it is hoped to have a representative gathering of past and present members.

J. G. P.

Glasgow and Scotland West Centre

It is with regret that we announce the death of our Treasurer, Mr. A. H. Wallace. Alex, who was in his early fifties, was one of those rare creatures—an enthusiast. In all that he undertook, in work and play, in the Post Office and out of it, he put his whole heart and could be depended upon to finish all that he had started.

It was typical of the man that a close and mutual friend handed his books and monies over to the Chairman in less than a week, complete in every detail and balanced to the last penny.

Alex was one of the founder members of the Centre and will be greatly missed.

J. F.

Book Reviews

"Radio Receiver Design (Part 1)"—*continued from p.* 70

modulation, phase-modulation and pulse-modulation, dealing with their spectra and properties. Unfortunately the detection of a.m. waves is dealt with only by reference to a detector suppressing alternate half cycles instead of the common type of envelope follower, although the latter type is very fully treated in a later chapter. A section on signal-to-noise ratio and noise factor is included.

In Chapter 2, sections have been added on noise in valves and its effect on noise factor, while Chapter 3 has a new section on "signal-to-noise ratio and the aerial" and Chapter 5 includes one on noise in frequency-changers.

The aerials considered in Chapter 3 are those for broadcast reception, including the dipole and folded dipole, but excluding the dipole with reflector and the Yagi.

Chapter 4, on r.f. amplification, remains mostly a consideration of tunable amplifiers up to 50 Mc/s, with a short section on amplifiers at higher frequencies.

An extensive treatment of crystal filters has been added to the chapter on i.f. amplifiers, and appendices are provided on equivalent T and π sections, lattice network equivalents, and Foster's reactance theorem.

A very useful feature of the book is the extensive list of references at the end of each chapter.

The emphasis throughout the book is on the mathematical approach to the electrical design of the various parts of (mainly) sound broadcast receivers, and telecommunication engineers may be disappointed to find that no reference is made to receivers for single-sideband telephone systems or to telegraph receivers.

W. H. R. L.

"An Introduction to Semiconductors." W. R. Dunlap, Jr. Chapman & Hall: London. pp. xxi + 417. 260 ill. 94s.

The discovery of transistor action in 1948 did more than herald a new active device for the electronic engineer. It resulted in profound changes in solid-state physics and in new technologies for the preparation of single crystals of semiconductors containing minute but controlled amounts of impurity. As with most important new subjects, the supply of text books has lagged behind the need. Every new book must be examined more to see whether it is going to fill some of the gap rather than to see whether it contains new ideas, or new approaches; that by W. R. Dunlap, whose original contributions to the subject are well known, does fill some of the gap even though it is limited, largely, to the physics and preparation of semiconductors, with much briefer attention to transistors and other structures based on p–n junctions.

The first few chapters condense much of modern physics; crystal structure, wave mechanics, the parts played by electrons in solids, particularly in metals and semiconductors, and imperfections in solids receive special attention. Basic ideas are stated and important consequences derived with the minimum of intermediate steps. Descriptions of the properties of surfaces, contacts and p–n junctions, of the measurement of some of the key properties of semiconductors and of methods of preparation follow rather briefly. The properties of the two elemental semiconductors, germanium and silicon, are described in considerable detail in one of the best parts of the book, and are followed by an introduction to semiconducting compounds. One chapter is then devoted to rectifiers, one to transistors—describing their mechanisms and key properties in broad terms only—and a final one to other applications of semiconductors.

There can be little doubt about the value of the book to the people to whom it is addressed—graduates entering the fields of development and applications of semiconductors, and students wishing to augment their reading of solid-state physics. Those electronic engineers who are not prepared to accept new components without enquiring into the physical basis for their behaviour, are particularly recommended to study the first half of the book. Their opinion of the final quarter may well be, however, that there is insufficient connexion made with the first half. So many problems of the design, properties and reliability of the transistor depend directly on the physics of semiconductors that this connexion could hardly have been overstressed.

The book is well presented, but, alas, contains many misprints—some serious—in the mathematical expressions; one can but hope that they will be corrected in the future editions which the book seems assured to have.

J.R.T.

Staff Changes

Promotions

Name	Region	Date
Reg. Engr. to Chief Reg. Engr.		
Barker, P. L.	N.I. to W.B.C.	3.6.57
Telephone Manager to Reg. Engr.		
de Jong, N. C. C.	N.W. Reg. to N.I.	17.7.57
Area Engr. to Telephone Manager		
Birnie, R. C.	Scot	24.12.57
Senr. Exec. Engr. to Asst. Staff Engr.		
Harding, T. C.	E.-in-C.O.	21.10.57
Forty, A. J.	E.-in-C.O.	21.10.57
Richards, D. L.	E.-in-C.O.	17.10.57
Humphries, W. A.	E.-in-C.O.	1.11.57
Thompson, A. J.	E.-in-C.O.	9.12.57
Exec. Engr. to Area Engr.		
Halton, T. J. V.	N.W. Reg.	11.7.57
Chapman, S. D.	S.W. Reg.	18.11.57
Radcliff, F. K.	H.C. Reg.	4.11.57
Hudson, G. K.	N.I. to N.W. Reg.	7.1.58
Exec. Engr. to Senr. Exec. Engr.		
Croft, E.	L.T. Reg.	1.6.57
Long, H. W. N.	S.W. Reg.	16.10.57
Breary, D.	E.-in-C.O.	28.10.57
Rubin, M. J.	E.-in-C.O.	28.10.57
Marriott, P. E.	E.-in-C.O.	29.10.57
Hills, E. G.	E.-in-C.O.	11.11.57
Lane, G. W. H.	N.I. to H.C. Reg.	11.11.57
Sims, A. E. J.	L.T. Reg. to U.S.A.F. Liaison Officer.	25.11.57
Chapman, K. J.	E.-in-C.O.	16.10.57
Winkley, W. J. F.	E.-in-C.O.	23.12.57
Walker, R. R.	E.-in-C.O.	16.12.57
Bailey, N. G.	E.-in-C.O.	1.12.57
Hare, A. G.	E.-in-C.O.	1.12.57
Kelly, P. T. F.	E.-in-C.O.	11.12.57
Rogers, M. J.	E.-in-C.O.	1.1.58
Arthur, J. C. C.	L.T. Reg. to E.-in-C.O.	13.1.58
Cook, A. E.	E.-in-C.O.	20.12.57
Asst. Engr. to Exec. Engr.		
Fell, H. J. P.	E.T.E.	25.9.57
Campbell, A.	E.T.E.	25.9.57
Stafford, L.	Scot.	9.9.57
Irvine, W. T. L.	L.T. Reg.	28.8.57
Chapman, R. W.	L.T. Reg.	15.8.57
Arnold, A. E.	L.T. Reg.	1.10.57
Hales, A. C.	Scot.	21.10.57
Jeffery, D. A.	E.-in-C.O.	15.10.57
Owen, B. H.	N.W. Reg. to Scot.	11.11.57
Campbell, G. R.	Scot.	31.10.57
Bennett, D. G.	Scot.	22.10.57
Reeve, C. W.	H.C. Reg.	7.11.57
Jones, W. A.	E.T.E.	21.11.57
Awberry, W. A.	E.-in-C.O.	25.11.57
Benford, H.	Mid. Reg.	15.11.57
Punshon, R. W.	L.T. Reg.	21.8.57
Irving, L. J.	L.T. Reg.	15.11.57
Chappell, S. H. J.	E.-in-C.O.	8.1.58
Asst. Engr. (Open Competition)		
Bardouleau, D. A. W.	E.-in-C.O.	13.1.58
Barfoot, D. W.	E.-in-C.O.	13.1.58
Edmonds, L. S. J.	E.-in-C.O.	13.1.58
George, A. A.	N.E. Reg.	13.1.58
Godwin, B. M.	E.-in-C.O.	13.1.58
Higgs, D.	E.T.E.	13.1.58
Johns, P. B.	E.-in-C.O.	13.1.58
King, P. G.	E.-in-C.O.	13.1.58
Muir, W. W.	E.-in-C.O.	13.1.58
Ninnim, N. J. H.	E.-in-C.O.	13.1.58
Phillips, R. H.	E.-in-C.O.	13.1.58
Price, C. D. E.	E.-in-C.O.	13.1.58

Name	Region	Date
Asst. Engr. (Open Competition)—continued		
Ralph, S. T.	H.C. Reg.	13.1.58
Rintoul, D. A.	E.-in-C.O.	13.1.58
Sands, M. J. E.	E.-in-C.O.	13.1.58
Slater, B. O.	N.E. Reg.	13.1.58
Soanes, S. T.	E.-in-C.O.	13.1.58
Stanbrook, J. A.	H.C. Reg.	13.1.58
Inspector to Asst. Engr.		
Pinn, A. W. J.	H.C. Reg.	23.9.57
Lewis, G. M.	H.C. Reg.	16.9.57
McPherson, J. B.	S.W. Reg.	12.8.57
Meneely, J.	N.I.	31.10.57
Williams, D.	W.B.C.	25.11.57
McQuaid, J.	N.I.	1.11.57
Potts, J. R.	Scot.	14.11.57
Brown, W. E.	S.W. Reg.	11.7.57
Twydell, H. J.	H.C. Reg.	4.11.57
Fowler, G. H.	H.C. Reg.	1.12.57
Osborne, W. J.	H.C. Reg.	20.11.57
Burton, J. R.	L.T. Reg.	7.12.57
Buckingham, J. J.	L.T. Reg.	28.10.57
Rickards, H. C. S.	H.C. Reg.	2.1.57
Hartley, W.	Mid. Reg.	27.1.58
Gibson, A. L.	Mid. Reg.	3.2.58
Mann, J. F.	Mid. Reg.	23.7.57
Tech. Offr. to Asst. Engr.		
Hewett, J. W.	L.T. Reg. to E.-in-C.O.	26.10.57
Keel, L. F.	S.W. Reg. to E.-in-C.O.	26.10.57
Yeadon, N. B.	S.W. Reg. to E.-in-C.O.	26.10.57
Paine, N. J.	L.T. Reg. to E.-in-C.O.	26.10.57
Miller, J. E.	L.T. Reg. to E.-in-C.O.	26.10.57
Bain, A. J. R.	S.W. Reg. to E.-in-C.O.	26.10.57
Taylor, S. C.	L.T. Reg. to E.-in-C.O.	26.10.57
Hubble, R. A.	L.T. Reg. to E.-in-C.O.	26.10.57
Hutchings, F. S. P.	E.-in-C.O.	28.9.57
Willis, A. G.	E.-in-C.O.	28.9.57
Rushby, A. C.	L.T. Reg. to E.-in-C.O.	26.10.57
Lidbetter, E. J.	L.T. Reg. to E.-in-C.O.	26.10.57
Huggins, G.	L.T. Reg. to E.-in-C.O.	26.10.57
Quartly, J. P.	L.T. Reg. to E.-in-C.O.	26.10.57
Watson, A. L.	N.E. Reg. to E.-in-C.O.	9.11.57
Cleaver, R. D.	N.W. Reg. to E.-in-C.O.	26.10.57
Davies, J. A.	E.-in-C.O.	19.10.57
Dickenson, P.	N.E. Reg. to E.-in-C.O.	26.10.57
Jones, D. H.	L.T. Reg. to E.-in-C.O.	26.10.57
French, R. F. G.	E.-in-C.O.	28.9.57
Perrins, E. V. T.	E.-in-C.O.	2.11.57
Longden, T. E.	N.E. Reg. to E.-in-C.O.	9.11.57
Curtis, D.	N.E. Reg. to E.-in-C.O.	9.11.57
Winn, L. A.	L.T. Reg. to E.-in-C.O.	26.10.57
Ainsworth, C. N. L.	E.-in-C.O.	28.9.57
Perry, R. H. W.	S.W. Reg. to E.-in-C.O.	26.10.57
Bohannon, T. D.	L.T. Reg. to E.-in-C.O.	26.10.57
Rapley, N. S.	E.-in-C.O.	2.11.57
Cripps, G. E.	L.T. Reg. to E.-in-C.O.	26.10.57
Callcut, K. L.	L.T. Reg. to E.-in-C.O.	26.10.57
Cuncliffe, H.	E.-in-C.O.	12.10.57
Kingcombe, A. C.	S.W. Reg. to E.-in-C.O.	26.10.57
Dunn, W. A. J.	S.W. Reg. to E.-in-C.O.	26.10.57
King, W. T.	E.-in-C.O.	2.11.57
Williams, J. R.	E.-in-C.O.	28.9.57
Brown, R. J.	E.-in-C.O.	2.11.57
Gard, R. L.	W.B.C. to E.-in-C.O.	2.11.57
Dyer, R. W.	L.T. Reg. to E.-in-C.O.	26.10.57
Green, W. B.	N.E. Reg.	6.8.57
Starling, D. W.	H.C. Reg.	1.10.57
Murray, D.	Scot	30.10.57
Thornton, R. H.	E.T.E.	1.10.57
Allen, B. N. S.	N.W. Reg. to E.-in-C.O.	30.11.57
Pizey, H. J. E.	E.T.E. to E.-in-C.O.	9.11.57
Whitchurch, H.	Mid. Reg. to E.-in-C.O.	20.11.57
Proffitt, C.	N.W. Reg.	7.10.57
Jackson, D. A. N.	N.W. Reg.	7.10.57
Hatton, H. R.	S.W. Reg.	15.7.57

Promotions—*continued.*

Name	Region	Date
Tech. Offr. to Asst. Engr.—continued		
Lord, T. K.	E.T.E.	18.11.57
Trotter, T. M.	E.T.E.	18.11.57
Jones, A. M.	E.T.E.	18.11.57
Ramsey, G. J.	Scot.	9.9.57
Hopkins, J.	N.E. Reg.	7.8.57
Smith, W. H.	S.W. Reg.	31.8.57
Ord, J. A.	N.E. Reg.	1.9.57
Ashworth, C.	N.W. Reg.	14.10.57
Hawkins, R.	Mid. Reg.	27.5.57
Parkes, A. J.	Mid. Reg.	7.12.57
Price, R. J. (*In absentia*)	E.-in-C.O.	30.4.57
Cavill, J. S.	S.W. Reg.	24.10.57
Dove, K. H.	E.T.E.	2.12.57
Parke, W. K.	L.T. Reg.	29.7.57
Davis, A. G.	L.T. Reg.	6.12.57
King, J. A.	L.T. Reg.	25.9.57
Sharpe, J. E. M. (*In absentia*)	L.T. Reg.	10.12.57
Evans, D. T.	L.T. Reg.	27.9.57
Croughan, K. N. E.	H.C. Reg.	18.11.57
Metcalfe, N.	N.W. Reg.	24.12.57
Neil, W. W.	Scot. to E.-in-C.O.	4.1.58
Yeates, B. L. E.	S.W. Reg. to E.-in-C.O.	4.1.58
Goodwin, A. W. R.	L.T. Reg. to E.-in-C.O.	4.1.58
Wilkes, J. T.	E.-in-C.O.	4.1.58
Scott, D. D.	Scot. to E.-in-C.O.	4.1.58
Turner, D. W.	E.-in-C.O.	11.1.58
Goss, C. E. G.	L.T. Reg. to E.-in-C.O.	4.1.58
Ripley, A. L.	E.-in-C.O.	4.1.58
Batty, J. S.	E.-in-C.O.	4.1.58
Swynnerton, D. C.	E.-in-C.O.	4.1.58
Goodwin, E. F.	L.T. Reg. to E.-in-C.O.	28.1.58
Stewart, J. D.	Scot. to E.-in-C.O.	28.1.58
Graham, D. R.	N.E. Reg. to E.-in-C.O.	28.1.58
Aiken, A. D.	L.T. Reg. to E.-in-C.O.	28.1.58
Blois, A. H.	E.-in-C.O.	28.1.58
Heys, E.	Mid. Reg.	12.4.56
Arnold, D. E. L.	Mid. Reg.	3.9.56
Pickles, J.	N.W. Reg.	2.1.58
Tech. Offr. to Inspector		
Bevan, B.	L.T. Reg.	5.10.57
Bayly, F. J.	L.T. Reg.	5.10.57
Burnham, J. T.	L.T. Reg.	21.10.57
Sellars, L. P. W.	L.T. Reg.	21.10.57
Moorman, E. E.	L.T. Reg.	14.1.58
Connell, P.	L.T. Reg.	15.11.57
Rolls, L. W.	L.T. Reg.	16.12.57
King, G. A.	L.T. Reg.	7.12.57
Giltinan, F. T. I.	W.B.C.	28.8.55
Warne, F. W.	L.T. Reg.	1.1.58
Wallace, W. V.	Scot.	20.1.58
Tech. I to Inspector		
Dainty, L. M.	L.T. Reg.	5.8.57
Henwood, S. G.	L.T. Reg.	10.6.57
Munn, W. W.	L.T. Reg.	29.7.57
Purrott, H. E.	L.T. Reg.	14.9.57

Name	Region	Date
Tech. I to Inspector—continued		
Martin, A. W.	L.T. Reg.	14.9.57
Johns, H.	L.T. Reg.	28.7.57
Hayward, E.	H.C. Reg.	16.8.57
Hall, R.	H.C. Reg.	19.8.57
Horlock, A. P.	H.C. Reg.	23.9.57
Jones, J. G.	W.B.C.	1.11.57
Jarrett, R. W.	H.C. Reg.	26.9.57
Groom, J. H.	H.C. Reg.	30.10.57
Foster, K. R. S.	H.C. Reg.	26.9.57
Niven, J. M.	Scot.	4.11.57
Foxton, A. E.	N.E. Reg.	1.9.57
Bywater, H.	N.E. Reg.	11.1.56
Machin, H. E.	Mid. Reg.	18.5.55
Herbert, E.	L.T. Reg.	26.11.57
Brake, C. A. C.	H.C. Reg.	23.9.57
Wright, J. W.	E.-in-C.O.	14.11.57
Howard, C. W.	L.T. Reg.	21.2.58
Cooper, A. R.	L.T. Reg.	1.11.57
Snr. Sc. Offr. to Prin. Sc. Offr.		
Parkes, E. S.	E.-in-C.O.	27.1.58
Snr. Sc Offr. (Open Competition)		
Poole, P. H.	E.-in-C.O.	18.10.57
Exptl. Offr. (Open Competition)		
Hand, T. G.	E.-in-C.O.	9.12.57
Griffin, E. J.	E.-in-C.O.	3.2.58
Asst. Exptl. Offr. (Open Competition)		
Eustace, J. C. G.	E.-in-C.O.	3.10.57
Ravenscroft, M. J. (Miss)	E.-in-C.O.	14.11.57
Asst. (Sc.) (Open Competition)		
Guthrie, A. G. A.	E.-in-C.O.	4.12.57
French, M. J. G. (Miss)	E.-in-C.O.	3.12.57
Blyth, W.	E.-in-C.O.	3.12.57
Gilbert, B. C.	E.-in-C.O.	24.12.57
Cross, A. C.	E.-in-C.O.	14.1.58
Snr. Dsman. to Chief Dsman.		
Jury, R. J.	E.-in-C.O.	16.12.57
Ldg. Dsman. to Snr. Dsman.		
Keeping, H. W. L.	H.C. Reg. to S.W. Reg.	2.9.57
Dsman. to Ldg. Dsman.		
Sayer, A. J. H.	E.-in-C.O.	11.10.57
Burgess, R. R.	L.P. Reg.	1.11.57
Denton, F. E.	L.T. Reg. to L.P. Reg.	18.11.57
Hargrove, K. L.	L.T. Reg. to L.P. Reg.	18.11.57
E.O. to H.E.O.		
Diamond, W. B.	E.-in-C.O.	2.12.57
C.O. to E.O.		
Aaron, F. C.	E.-in-C.O.	16.9.57
Garner, J. F.	E.-in-C.O.	16.9.57
Webb, H. W.	E.-in-C.O.	30.9.57
Wheeler, W. S.	E.-in-C.O.	2.12.57

Deaths

Name	Region	Date
Exec. Engr.		
Tipple, J. W.	Mid. Reg.	29.12.57
Asst. Engr.		
Allen, T. F. H.	L.T. Reg.	2.11.57
Smith, R.	H.C. Reg.	6.11.57
Glover, G.	W.B.C.	10.11.57
Smith, C. V. G.	Mid. Reg.	19.11.57
Marshall, H. N.	N.E. Reg.	4.12.57

Name	Region	Date
Asst. Engr.—continued		
Bell, R. F.	E.-in-C.O.	19.12.57
Dodds, J. W.	N.E. Reg.	5.1.58
Gibson, D. S.	Scot.	23.1.58
Hall, V.	N.E. Reg.	31.1.58
Inspector		
Burkhill, R. W.	N.E. Reg.	23.12.57
Spicer, A. R.	L.T. Reg.	1.1.58

Retirements and Resignations

Name	Region	Date
Staff Engr.		
West, W.	E.-in-C.O.	31.10.57
Reg. Engr.		
Chapman, F. B.	L.T. Reg.	30.11.57
Snr. Exec. Engr.		
Biddlecombe, A. W.	E.-in-C.O.	31.12.57
Exec. Engr.		
Davidson, J. W. Q. (*Resigned*)	E.-in-C.O.	31.10.57
Greenwald, H. H. (*Resigned*)	E.-in-C.O.	3.11.57
Fagg, G. K.	E.T.E.	7.10.57
Grainger, C. H.	Scot.	11.10.57
Burrows, C. T.	H.C. Reg.	8.11.57
Asst. Engr.		
Grindley, A. E.	L.T. Reg.	19.6.57
Goldsack, F. J.	L.T. Reg.	4.10.57
Steed, F. G. P.	S.W. Reg.	25.10.57
Train, R. F.	Scot.	30.10.57
Johnson, F. D. (*Resigned*)	E.-in-C.O.	25.10.57
Whisson, S. T.	E.T.E.	31.8.57
Dell, H. H.	H.C. Reg.	19.10.57
Carroll, T. H.	N.W. Reg.	5.11.57
Jones, O. H.	W.B.C.	10.11.57
Grogan, A.	Scot.	14.11.57
Rice, A. W.	H. C. Reg.	15.11.57
Coleman, J. S.	L.T. Reg.	23.11.57
Sharp, L. W.	H.C. Reg.	30.11.57
Thornhill, E.	Mid. Reg.	30.11.57
Hurlock, B. T.	E.-in-C.O.	10.12.57
Drew, F. G.	S.W. Reg.	4.12.57
Bevan, J.	L.T. Reg.	5.12.57
Blunt, C. E.	L.T. Reg.	6.12.57
Richards, B.	Mid. Reg.	8.12.57
Diprose, W. H.	L.T. Reg.	10.12.57
Whitfield, L.	E.T.E.	11.12.57
Clark, W. E.	W.B.C.	13.12.57
Batt, J. J. G.	N.W. Reg.	14.12.57
Burnley, J.	N.I.	31.12.57
Brierley, J. W. C.	N.W. Reg.	26.12.57
Miller, P.	Scot.	2.1.58
Cockhill, H. G.	L.T. Reg.	6.1.58
Neville, J.	N.W. Reg.	17.1.58
Brown, C. H.	L.T. Reg.	25.1.58
Page, W. F.	E.-in-C.O.	27.1.58
Boadella, J. W.	E.T.E.	31.1.58
John, W. L.	E.T.E.	31.1.58
Brown, W.	N.W. Reg.	1.2.58
Worthy, P.	E.-in-C.O.	6.2.58
Asst. Engr.—continued		
Crowe, V. E. (*Resigned*)	E.-in-C.O.	10.1.58
Ackerman, P. M. (*Resigned*)	H.C. Reg.	10.1.58
Boardman, S. (*Resigned*)	E.-in-C.O.	31.1.58
Buisseret, P. J. (*Resigned*)	E.-in-C.O.	31.1.58
Inspector		
Eaves, A.	H.C. Reg.	29.10.57
Tucker, A. E.	L.T. Reg.	14.11.57
Monahan, D. W.	L.T. Reg.	25.11.57
Clements, J. V.	Mid. Reg.	16.7.54
Graham, R. H.	L.T. Reg.	15.12.57
Allen, F.	Mid. Reg.	31.12.57
Brown, W. H.	H.C. Reg.	31.12.57
Pannell, F. C.	S.W. Reg.	31.12.57
Ockmore, S. C.	L.T. Reg.	3.1.58
Wright, W. F.	L.T. Reg.	13.1.58
Machin, W. H.	L.T. Reg.	15.1.58
Allison, W.	H.C. Reg.	22.1.58
Renouf, C. J.	L.T. Reg.	24.1.58
Campbell, D. M.	Scot.	27.1.58
Mills, F. C.	S.W. Reg.	29.1.58
Prin. Sc. Offr.		
Hourigan, H. F. (*Resigned*)	E.-in-C.O.	31.12.57
Exptl. Offr.		
Lee, M. A. (*Resigned*)	E.-in-C.O.	10.1.58
Asst. (Sc.).		
Beswick, C. A. (*Resigned*)	E.-in-C.O.	22.11.57
Donovan, D. E. (*Resigned*)	E.-in-C.O.	27.12.57
A.R.M.T.O.		
Lakey, J.	H.C. Reg.	31.12.57
Ldg. Dsman.		
Payne, E. C.	Mid. Reg.	17.7.57
Pratt, B.	N.W. Reg.	2.12.57
H.E.O.		
Baker, F. S.	E.-in-C.O.	1.10.57
E.O.		
Cartwright, A. M.	E.-in-C.O.	30.9.57

Transfers

Name	Region	Date
Chief Reg. Engr.		
Moffatt, C. E.	W.B.C. to S.W. Reg.	3.6.57
Asst. Staff Engr.		
Maddison, W. H.	Factories Dept. to E.-in-C.O.	4.11.57
Snr. Exec. Engr.		
Gilbey, P. D.	E.-in-C.O. to N.E. Reg.	1.12.57
Exec. Engr.		
Windell, S. R.	E.-in-C.O. to Nigeria	31.10.57
Partridge, J. G.	India to E.-in-C.O.	31.10.57
Boggis, R. J.	E.T.E. to M.B.D.	2.9.57
Whittaker, J. W.	E.-in-C.O. to L.T. Reg.	25.11.57
Dormer, D. J.	E.-in-C.O. to I.T.U. Geneva	1.12.57
Asst. Engr.		
Eason, D. J.	W.B.C. to Nigeria	2.11.57
Price, R. J.	E.-in-C.O. to Pakistan	30.4.57
Asst. Engr.—continued		
Davis, K. C.	E.-in-C.O. to E.T.E.	9.12.57
Bayley, M. W.	E.-in-C.O. to S.W. Reg.	16.12.57
Tankard, A. H.	E.-in-C.O. to E.T.E.	16.12.57
Sheldon, W.	E.-in-C.O. to Pakistan	25.1.58
Osborne, W. J.	H.C. Reg. to Singapore	1.1.58
Inspector		
Chappell, J. J.	H.C. Reg. to Singapore	1.1.58
Snr. Dsman.		
Haley, H. H. J.	S.W. Reg. to L.T. Reg.	2.9.57
Ldg. Dsman.		
Cradduck, F.	Mid. Reg. to H.C. Reg.	31.1.58
H.E.O.		
Priestley, R. E.	War Damage Commission to E.-in-C.O.	4.11.57

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Designed for the outdoor connection of Specialized Remote Control Units, Centimetre Radio Links, Ground Radar, Television Camera and Industrial Electronic Equipment.

Moulding techniques ensure a tough, permanent, moisture-resistant assembly which virtually eliminates the possibility of conductor breakages at the coupler.

Screwed lock rings provide forced engagement and withdrawal. The overall metal housing is replaceable if damaged.

The cable itself is designed with a symmetrical cross section to provide the greatest reliability during handling.

The conductors are embedded in the moulding in the same geometric formation as in the cable so that each contributes to the strength of the connection.

Both panel mounting and cable couplers can be supplied, with insulated tails and cable lengths respectively cut to meet individual requirements.

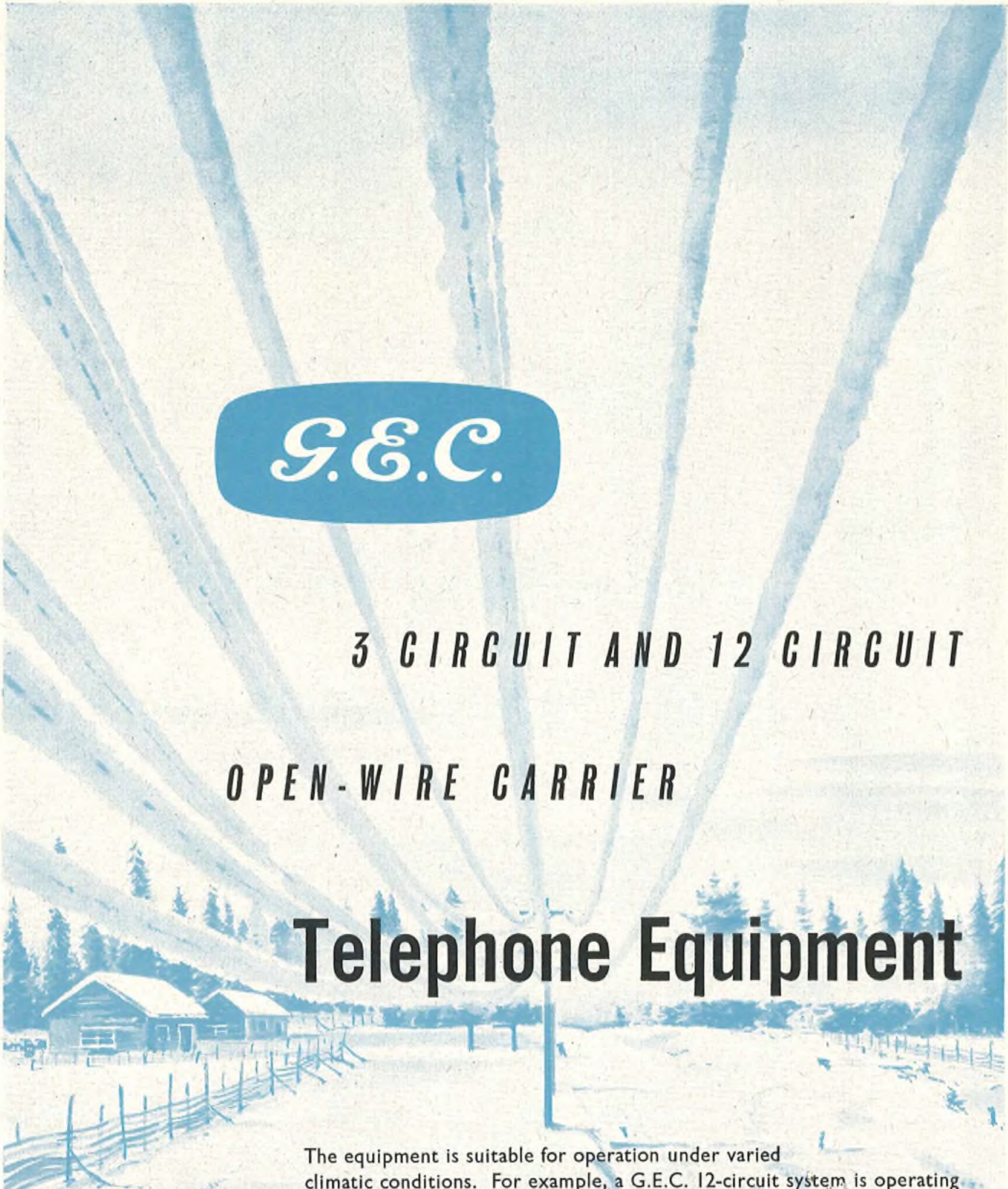
Full details of our standard range of Polypole Couplers and Cables are available on request.

BICC are always glad to advise on the use of Polypole Couplers and Cable to meet customers' special requirements.

BI Callender's

BRITISH INSULATED CALLENDER'S CABLES LIMITED

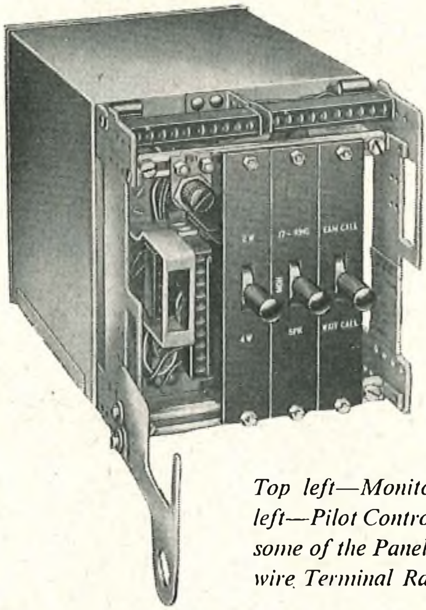
21 BLOOMSBURY STREET, LONDON, W.C.1

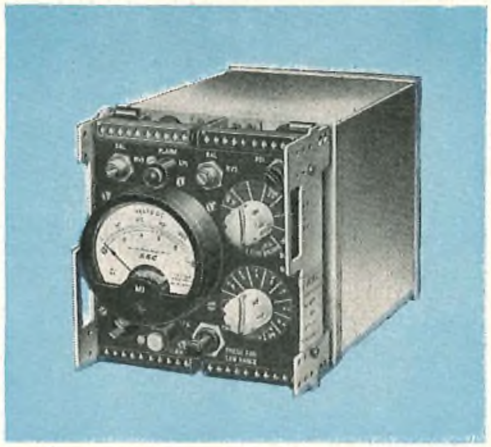


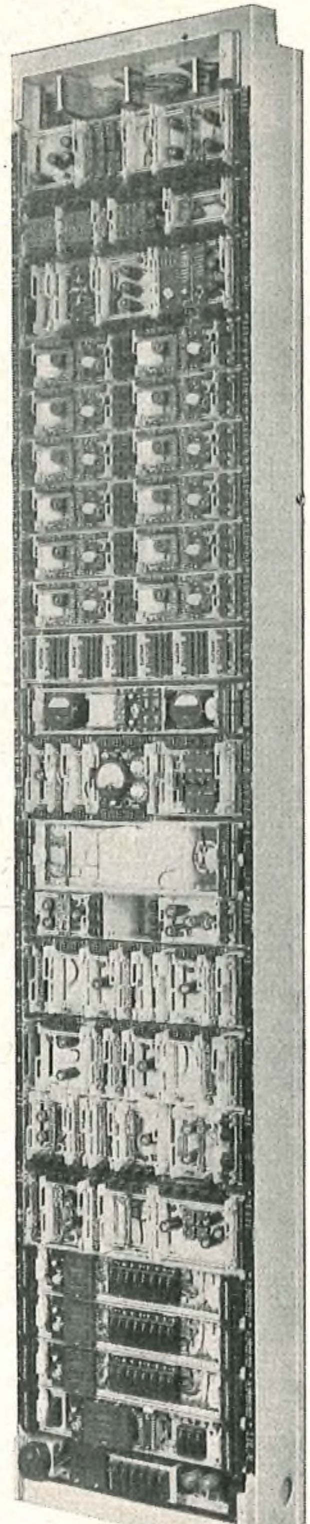
Everything for Telecommunications by open-wire line, cable and radio; single and multi-circuit

G.E.C.8

THE GENERAL ELECTRIC COMPANY LIMITED OF ENGLAND







Top left—Monitor, top right—Alarm, bottom left—Pilot Control and bottom right—Amplifier, some of the Panels used in the 12-Circuit Open-wire Terminal Rack shown on the right.

G.E.C. 3-circuit and 12-circuit carrier telephone equipment provides for the transmission of three and twelve high-quality speech circuits, respectively, over an open-wire route. Each speech circuit effectively transmits the frequency band 300 c/s to 3400 c/s. Signalling is effected at the out-of-band frequency of 3825 c/s on each circuit.

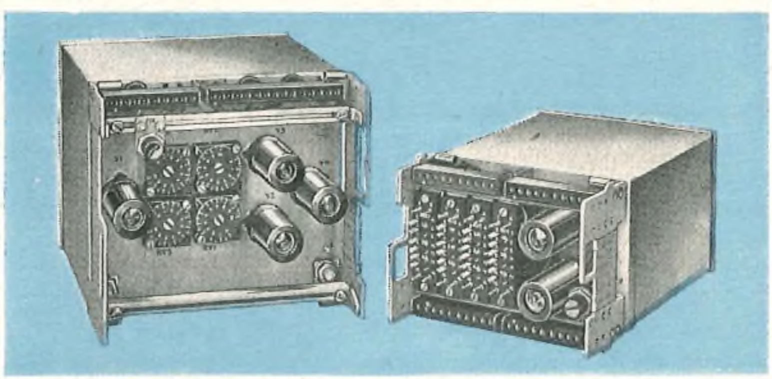
The signals transmitted to line in the 12-circuit system are within the frequency band 36 to 143 kc/s, and in the 3-circuit system within 3.16 to 31.1 kc/s in accordance with the recommendation of C.C.I.T.T.
Thus a 3-circuit and a 12-circuit system can operate over the same open-wire pair. Several systems can operate along the same route.

When required, a broadcast programme circuit of approximately 10 kc/s bandwidth can be inserted at the intermediate frequency of 84 to 96 kc/s, in place of three speech circuits in either system. In addition, twenty-four voice-frequency telegraph channels can be provided over any speech circuit.

By suitably spacing repeaters along the route, a system may be operated over distances of many hundreds of miles, the exact distance and spacing of repeaters depending on local conditions.

The equipment itself is the latest G.E.C. Type 56. A complete 3-circuit terminal or a complete 12-circuit terminal is accommodated on one single-sided rack.

For further information please write for Standard Specifications
SPO1011
and
SPO1025



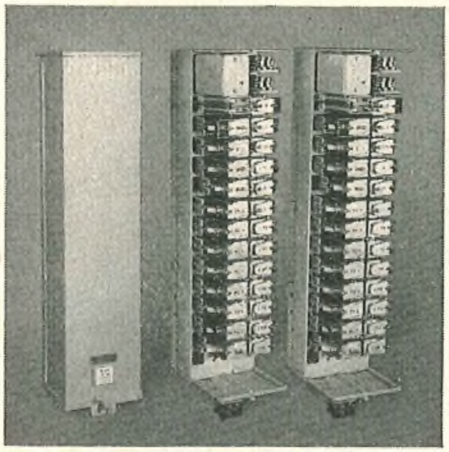
and TV link; short, medium and long haul. Automatic and Manual exchange.

G.E.C.

TELEPHONE, RADIO & TELEVISION WORKS · COVENTRY · ENGLAND

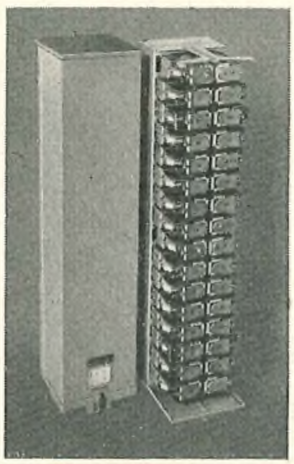
SUBSCRIBERS' LINE CONCENTRATOR

An all-relay communication system which provides Telephone Service for TEN subscribers over TWO connecting links to an EXCHANGE

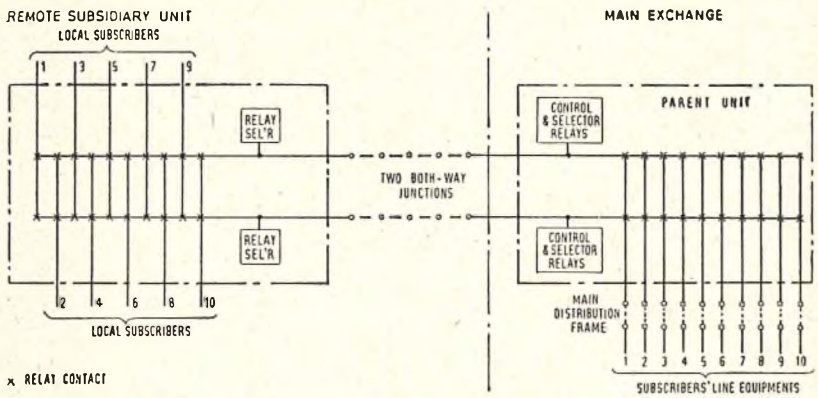


Parent Unit (cover removed)

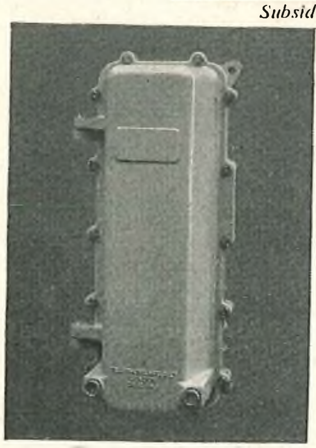
The TMC Subscribers' Line Concentrator is *not* a Party Line — subscribers are operationally indistinguishable, in all respects, from directly connected lines. It is fully secret and standard subscribers' telephone sets are used.
Plant costs are drastically reduced by its use, without any sacrifice of facilities. A complete system can be installed in a few hours, with a minimum of internal construction work, whether for permanent or temporary installation.
Batteries or power leads are not necessary at the remotely located Subsidiary Unit, nor are premises required for housing it.
Maximum reliability, with negligible maintenance requirements, is ensured by the use of 3000-type relays throughout. Visual and audible alarms are provided in the Parent Exchange to indicate line faults, and a faulty junction is automatically taken out of service.
The system is supplied to the British Post Office and the Corporation of Kingston-upon-Hull, in England. Overseas it is in use in Australia, British Guiana, Jamaica, Nyasaland, Singapore and Hong Kong.



Subsidiary Unit



A call at either end of the system causes the selecting relays to hunt. The corresponding outlets at each end of the junction are selected simultaneously and tested for *calling* and *busy* conditions. When the calling condition is located the hunt action is arrested, and interconnection between the subscriber and the subscribers' line equipment is provided by the junction. The call then proceeds in the normal manner according to the type of Parent Exchange.



Weatherproof case for subsidiary unit

The scheme can also be used to provide a variety of services, e.g.—
Night service for selected subscribers connected to an Exchange with restricted hours of attendance . . . Release of cable pairs to fully loaded D.P.'s . . . Release of pairs on cable routes pending provision of new plant . . . Service to blocks of residential Flats, as an alternative to a P.B.X. . . . Service for short duration events such as Exhibitions and Race Meetings by making pairs available without additional plant.

Write for full technical data to:

TELEPHONE MANUFACTURING CO LTD

HOLLINGSWORTH WORKS · DULWICH · LONDON S.E21

TELEPHONE: GIPSY HILL 2211

A cut-away view of a typical submerged repeater

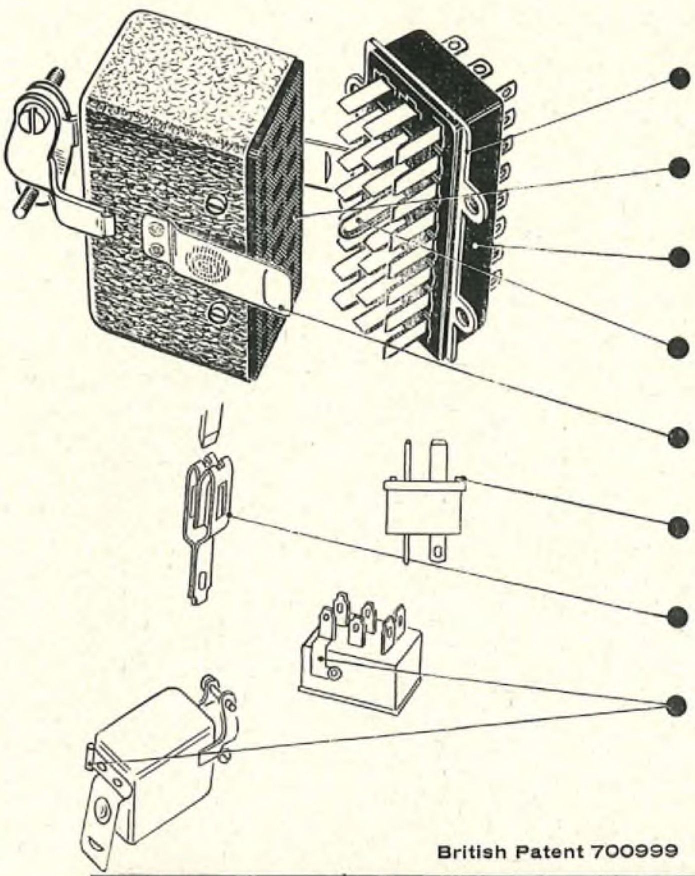
"MULTICON" PLUGS AND SOCKETS

The full range consists of 2, 4, 6, 8, 10, 12, 18, 24 and 33-pole sizes. Illustrated is the 24-pole size.

Working voltage: 1,000 volts D.C. or A.C. (peak) or 500 volts D.C. or A.C. (peak) in tropical use.

Current rating: 5 amps. D.C. or A.C. (R.M.S.) per contact.

Average contact resistance: below 0·002 ohms.

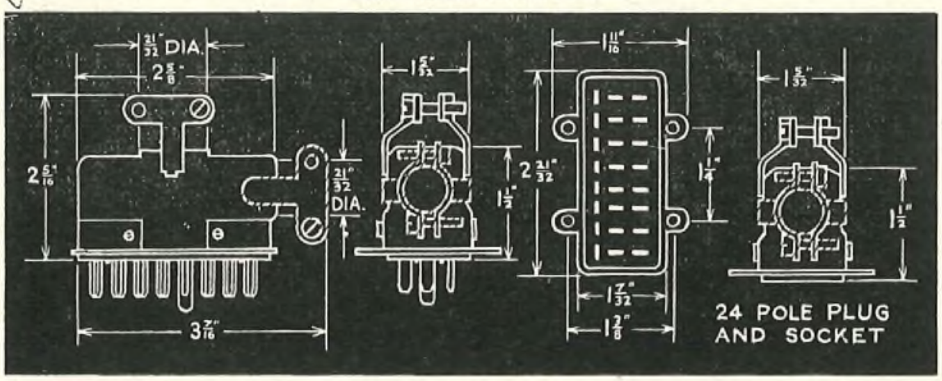


- Metal flanges moulded into the body to ensure flush mounting and to avoid alignment difficulties.
- Terminal numbering moulded into plug and socket bodies to facilitate wiring and cableform testing.
- Single-piece nylon-filled body mouldings provide high insulation and tracking resistance.
- Large pin locator contact facilitates engagement, especially in unitor applications.
- Optional vibration-proof retaining blades to secure the unit to panel or chassis.
- Four distance pips keep mating faces apart and eliminate moisture traps between plug and socket faces.
- Socket clips have split limbs with four areas in contact with each plug blade ensuring absolute reliability of contact.
- Earthing of plug or socket covers is achieved by either:

  Internal connecting link from a contact to cover, OR

  rivetted earth tag to outside of cover.

British Patent 700999



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Painton & Co. Ltd.

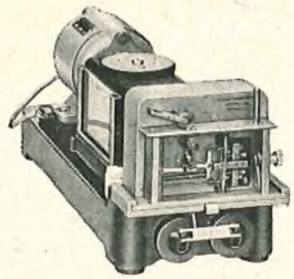
KINGSTHORPE NORTHAMPTON

Tel: 32354-5-6 Telegrams: 'Ceil' Northampton

HIGH SPEED AUTOMATIC MORSE EQUIPMENT

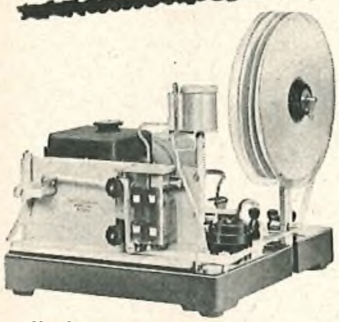
Keyboard Perforator Model 50

Provided with locking device which prevents the simultaneous depression of two keys. Max. operating speed 750 characters per minute.



Transmitter Model 112

Speed range 13-250 words per minute. For training schools model 113 having a speed range of 5-35 words per minute is recommended.



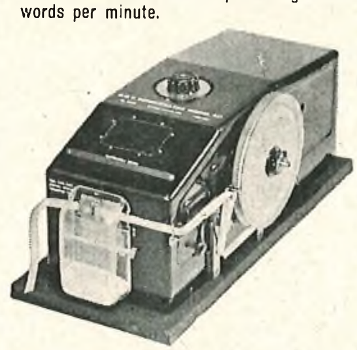
Undulator Model 309

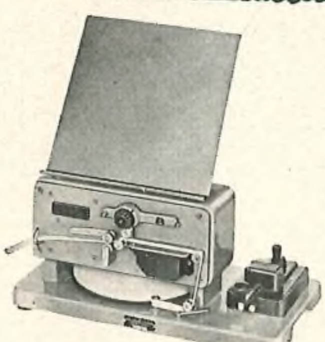
Max operating speed 300 words per minute. Other models available with double recording part and with amplifier/rectifier for tone frequency signals.

G.N.T.

Reperforator Model 451

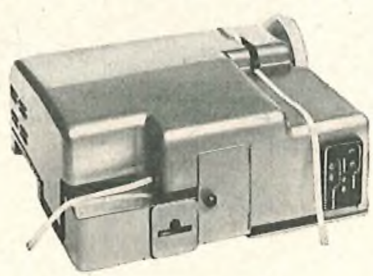
A truly synchronous receiver which produces a perforated tape similar to the one used for transmission. Normal speed range 40-200 words per minute.





Morseinker Model 1515

Used for training purposes, Motor-driven. Also available with built-in amplifier/rectifier for tone frequency signals. Spring-driven models also available.

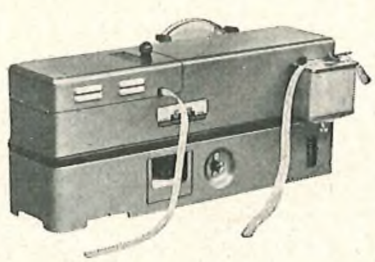


Converter Model 2201

For the conversion of a perforated Morse Code, or Cable Code, tape into a perforated 5-unit Code tape or into 5-unit signals at standard teleprinter speed.

Converter Model 2206

For the conversion of a perforated 5-unit Code tape into a perforated Morse Code, or Cable Code, tape.



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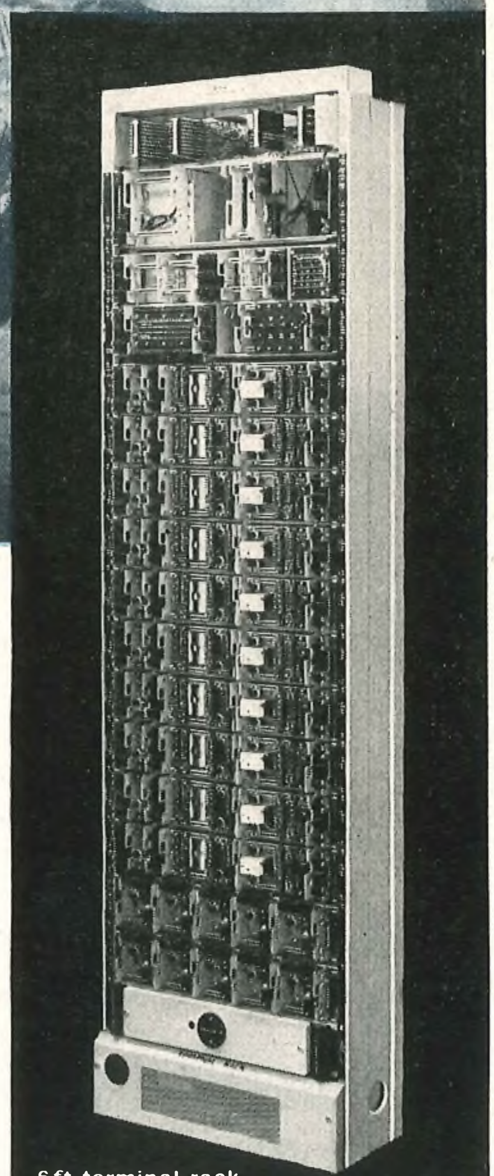
LONDON E. C. 3.

TELEPHONE EQUIPMENT

FOR OPEN-WIRE LINES



6 ft terminal rack
(without covers)
accommodating up to ten circuits

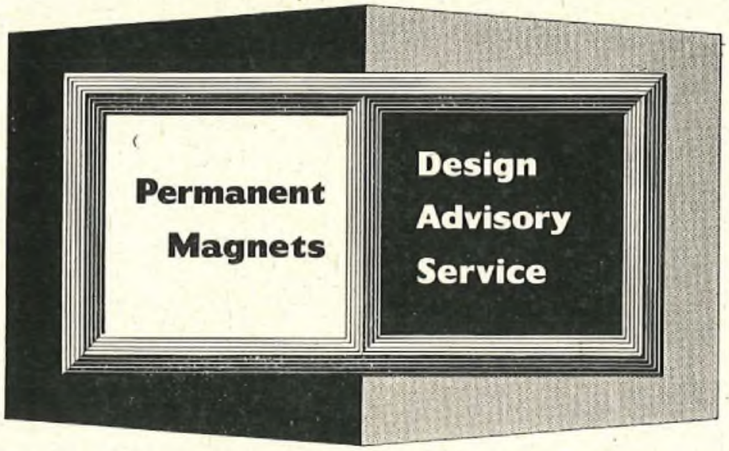
- ★ Capital cost less than that of providing the equivalent facilities by adding physical pairs to the pole route.
- ★ High degree of reliability with the minimum of maintenance.
- ★ Low power consumption, and capable of operation in locations where mains supplies are unreliable or non-existent.
- ★ Capable of working on the same pole pair in conjunction with either a physical circuit up to 2,700 c/s, a single-circuit system employing a carrier frequency of either 6 kc/s or 13 kc/s, or a three-circuit system.
- ★ Capable of working on the same pole route with either another rural carrier system, a three-circuit system or a twelve-circuit system.

EQUIPMENT

and TV link ; short, medium and long haul. Automatic and manual exchanges.

AND TELEVISION WORKS · COVENTRY · ENGLAND

GEC 9



The Modern Theory of Permanent Magnets

No. 1

Advertisements in this series deal with general design considerations. If you require more specific information on the use of permanent magnets, please send your enquiry to the address below, mentioning the Design Advisory Service.

This article is designed to help towards a better understanding of the changes that take place inside a permanent magnet when it is placed in a magnetic field.

According to present theory a magnetic material consists of a number of elemental magnets known as domains. If the material is unmagnetised the magnetic fields from the domains cancel out, due to their random arrangement, so that the collective field is zero.

To magnetise the material, it must be subjected to a magnetic field of sufficient intensity to rotate the domains and bring them into line with the direction of the field. This is known as magnetic saturation and is indicated in Fig. 1 as $B_{sat.}$

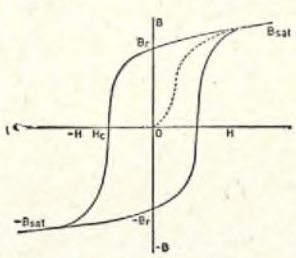


Fig 1

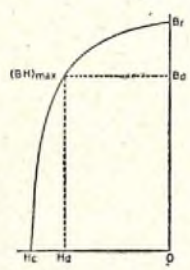


Fig 2

Fig. 1 shows the familiar hysteresis loop of a ferromagnetic material. It represents a cyclic change in magnetic flux density due to the change in magnetising force.

The area of the hysteresis loop is a measure of the energy stored in the material and for permanent magnets the loop should be as large as possible.

Point O represents a magnet material unmagnetised and the dotted curve shows the increase in magnetic flux density with the increase in magnetising force H.

Saturation, denoted B_{sat} is the degree or saturation which will produce the maximum area of hysteresis loop. When the magnetising force is reduced to zero, the magnet retains a high proportion of the flux set up and this value, which is the remanant induction in the magnet, is shown as B_r.

If the magnet is then subjected to a de-magnetising force (a magnetising force in the reverse direction) the value of flux will reduce as the de-magnetising force increases, until the flux falls to zero, at H_c. This value H_c is known as the coercive force of the magnet and is the highest value of H to which the magnet can be subjected before the flux in the magnet reverses. By increasing the de-magnetising force still further the magnet will become saturated in the reverse direction at $-B_{sat.}$

If the magnetising force is once more reversed, the flux density will follow in a manner as indicated on the graph.

The second quadrant (Fig. 2) of the hysteresis loop is the curve usually shown to indicate the characteristics of a permanent magnet. The maximum external energy obtainable from a magnet is obtained where the product of the corresponding values of B and H are maximum. These values are usually designated B_d and H_d and are the values recommended for design purposes.

Partial de-magnetisation of the magnet will occur if ferromagnetic objects come into contact with its sides. This treatment not only alters the direction of magnetisation of the domains, thus decreasing the useful flux at the pole faces, but is liable to cause instability. It is important, therefore, that ferromagnetic objects are kept away from magnetised magnets.

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'MAGNADUR' CERAMIC MAGNETS
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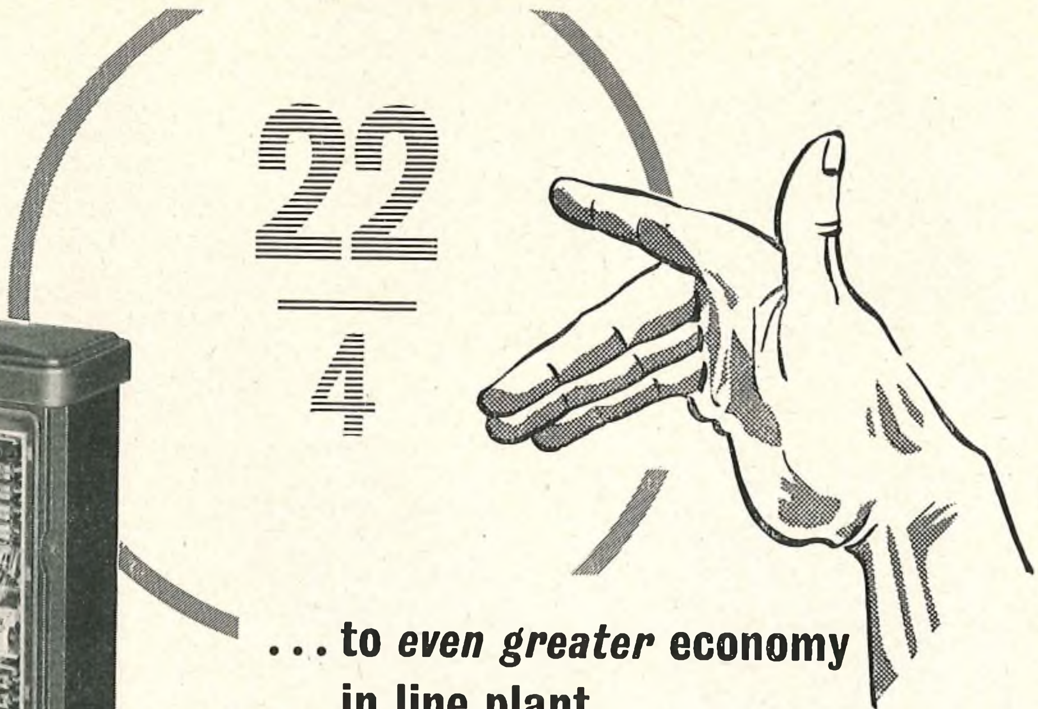
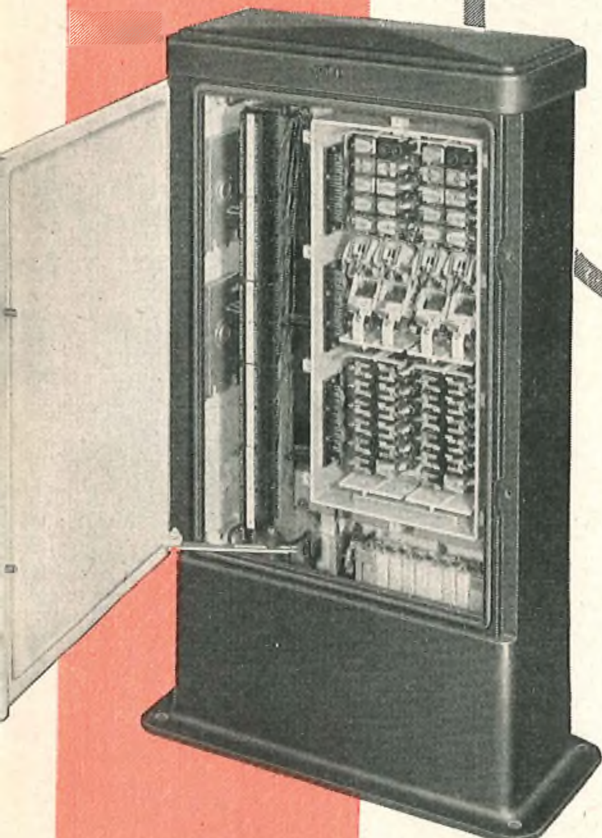
MC264

ERICSSON LINE CONNECTORS

point the way . . .





. . . to *even greater* economy in line plant

- SERVICE FOR 22 SUBSCRIBERS
- 4 EXCHANGE LINES ONLY
- NO CONTROL LINES
- SAVING IN CALLING EQUIPMENT
- COMPLETE SECRECY
- EASE OF MAINTENANCE
- JACK-IN RELAY SETS
- INDIVIDUAL METERING
- STANDARD EQUIPMENT
- FULLY TROPICALIZED

The Ericsson Line Connector solves your cabling problems by providing service for 22 subscribers over 4 pairs only, as well as effecting a considerable saving in exchange equipment. Whilst being primarily of use in relieving external line plant shortages, it may also be used as an exchange in rural areas as an alternative to a P.B.X. or P.A.B.X. Another application may be an economical service given to blocks of flats etc.

The remote unit and exchange equipment comprises telephone relays and uniselectors similar to those supplied to the British Post Office and no special maintenance problems are introduced. Equipment is not bridged across, nor left in series with, the line; thus, subscribers on the line connector enjoy exactly the same facilities as those with normal direct lines. Intercommunication between subscribers is achieved by dialling the normal directory number, and all connections to and from subscribers are set up via one of the four pairs. Providing at least one of these pairs remains serviceable, connections between subscribers and the exchange can be maintained.

The remote equipment is sealed within a desiccated container which may be fitted into a standard B.P.O. cross connection cabinet as illustrated, or alternatively, arrangements can be made to meet customer's requirements.

The Ericsson Line Connector has been supplied to the B.P.O. and orders are in hand for overseas administrations. Full particulars are available on request.

T E L
ENGLAND

ERICSSON TELEPHONES LIMITED

HEAD OFFICE: 22 LINCOLNS INN FIELDS, LONDON, W.C.2. TEL: HOLBORN 6936

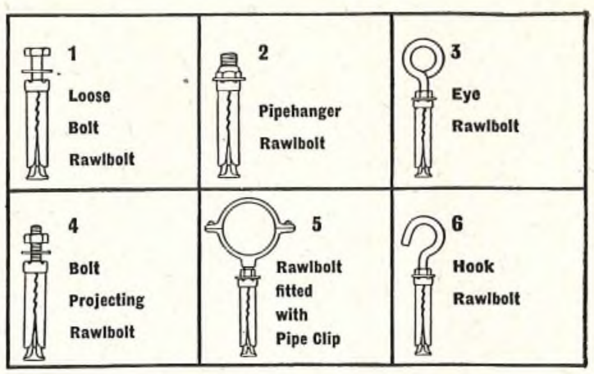
WORKS: BEESTON, NOTTINGHAM & SUNDERLAND

Rawlbolt charts showing full range of sizes and types with illustrated literature available on receipt of letter-heading or business card.

6 HEADS are better than one!

You never need to improvise with Rawlbolts. There are types exactly right for every bolt-fixing job, No. 5, for example, for the support of pipe-work, and No. 2 for use with Pipe-hangers and other gas fittings. Hook and Eye Rawlbolts (Nos. 3 and 6) have many uses, such as providing anchorage for guy ropes and cables, supporting suspended ceilings, etc. There's the Loose Bolt Rawlbolt (No. 1), inserted after the machine is slid into position, and the Bolt Projecting Type (No. 4), ideal for wall-fixings.

Rawlbolts give you bolt-fixings of enormous strength in a fraction of the time taken by any other method.



Every bolt-fixing job is far quicker with

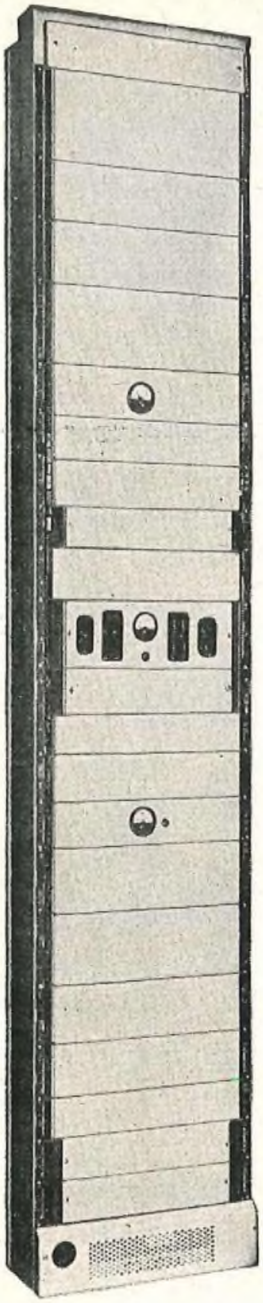
RAWLBOLTS

THE RAWLPLUG CO. LTD., RAWLPLUG CROMWELL RD., LONDON, S.W.7

B580

Standard

Transistorised regenerative repeater equipment
FOR TELEGRAPH SYSTEMS



Typical Rackside Assembly

- ★ **Reforms signals having up to 49% distortion.**
- ★ **Crystal-controlled oscillator ensures effective tandem working.**
- ★ **Signalling speeds up to 100 Bauds with 7, 7½ or 8 unit codes.**
- ★ **Fully transistorised.**
- ★ **Printed circuits & improved mechanical construction.**
- ★ **36 repeaters on one 9ft. rackside.**

FACILITIES

Rejection of start signal elements of a duration less than $\frac{1}{8}$, $\frac{1}{4}$, $\frac{3}{8}$ or $\frac{1}{2}$ of a signal element, as required.

Automatic insertion of stop signal element in the re-transmitted code regardless of its presence or not in the received signal.

Automatic re-synchronisation after the regeneration of each signal.

The minimum signal length of 138.125 ms (at 50 Bauds) allows for the transmission of both 7 and 7½ unit code signals, in accordance with C.C.I.T.T.

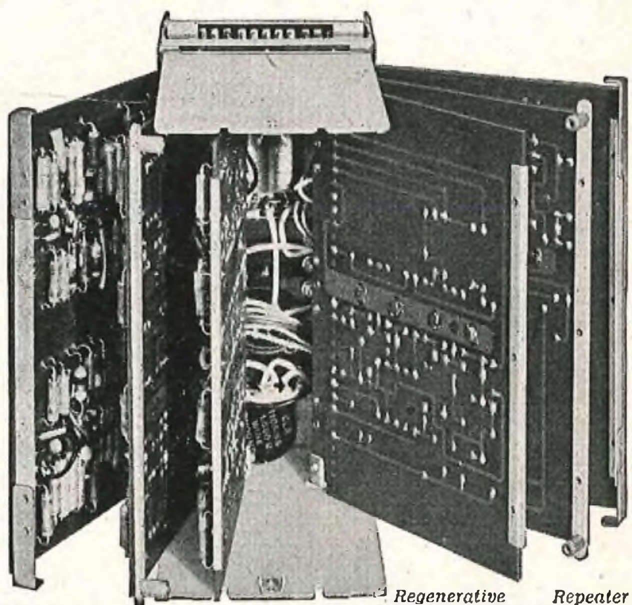
The repeaters can be made to operate at signalling speeds of up to 100 Bauds.

The degree of distortion experienced by start-stop telegraph signals during transmission can be so great as to render them unintelligible to a teleprinter.

Such distortion can occur in radio links, in switched telegraph networks employing a number of tandem connections and on land lines where long distances separate the terminals.

Standard Transistorised Regenerative Repeater Equipment will recreate, or reform, telegraph signals with zero distortion for retransmission either directly into a receiving teleprinter or over a further telegraph link.

The equipment will receive, examine and regenerate start-stop telegraph signals which may be suffering distortion of up to 49%. Distortion of the signal transmitted by the equipment never exceeds 1%.



Regenerative Repeater showing printed circuits and component assemblies

Standard Telephones and Cables Limited

Registered Office : Connaught House, Aldwych, London, W.C.2

TRANSMISSION DIVISION: NORTH WOOLWICH · LONDON E.16

Precision Measuring Instruments and Electronic Measuring Equipment

AS leading manufacturers of precision instruments for specific requirements and applications, Ernest Turner have over 35 years of experience in dealing with the problems of instrumentation in a rapidly advancing industry. In radio, television, nucleonics, air and marine navigation, medical research, telecommunications, atomic power; in Britain and in many other parts of the world—in tropical and temperate climates—on land, sea and in the air Ernest Turner instruments are giving reliable service.

ERNEST TURNER ELECTRICAL INSTRUMENTS LTD.

HIGH WYCOMBE BUCKS ENGLAND

Tel: HIGH WYCOMBE [illegible] Cables: GORGEOUS, HIGH WYCOMBE

Full details of all Turner instruments and equipment are contained in Catalogue No. 85, available on request.

Photograph by courtesy of Imperial Chemical Industries Ltd.

The pipelines in this 1,765-ft. tunnel under the River Tees between the I.C.I. Works at Wilton and Billingham were wrapped with DENSO TAPE some years ago. A recent inspection showed not a sign of corrosion !

DENSO TAPE is but one of a whole family of anti-corrosive products—each engineered for specific uses.

Have *your* corrosion problem solved *once and for all* by :

DENSO REGD. ANTI-CORROSION PRODUCTS
TRADE MARK

WINN & COALES LTD.

DENSO HOUSE, CHAPEL ROAD, LONDON, S.E. 27

'Phone: GIPsy Hill 4247 (PBX). 'Grams: Denselte, Westnor, London

world-wide approval

Pye Telecommunications Limited are now marketing the widest and most modern range of V.H.F. fixed and mobile radio-telephone equipment available in the world. This range of equipment has been designed to expand the application of Pye Radio-Telephones already in constant use all over the world.

Pye Ranger V.H.F. equipment has now received approval from the British G.P.O. for Land and Marine applications employing A.M. or F.M. systems, type approval from the Canadian D.O.T., and type acceptance of the F.C.C. of the United States of America.

Pye V.H.F. equipment is designed to meet the approval of authorities throughout the world. No other Company holds so many approvals for this range of equipment, which now covers every conceivable requirement.

We can offer

FREQUENCY RANGE
All frequencies from 25 to 174 Mc/s

POWER RANGE
All powers up to 1 Kilowatt.

CHANNEL SPACING
All channel spacings including 20 and 25 kc/s in full production.

MODULATION
A.M. or F.M.

No matter what your V.H.F. requirements are, Pye Telecommunications Ltd., can fulfil them. Your enquiries are invited.

PYE

Leading the world in V.H.F. RADIO-COMMUNICATION

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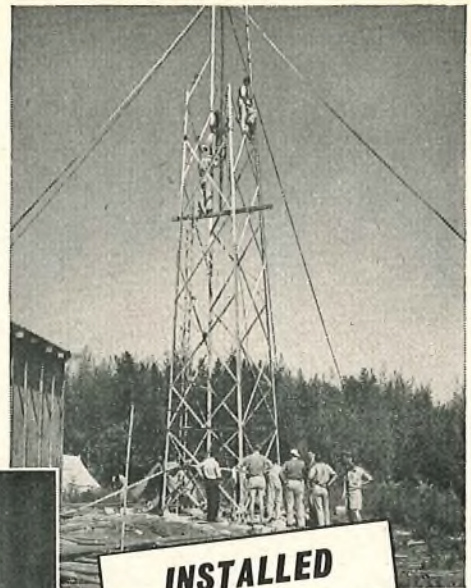
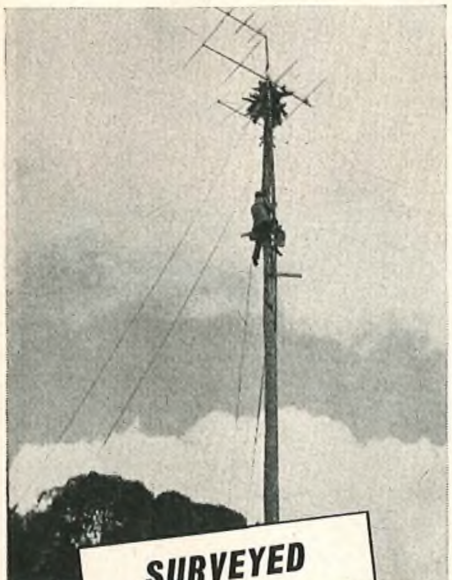
COMPLETE COMMUNICATION SYSTEMS

—all the world over





LONG-DISTANCE H.F. TELEGRAPH SYSTEMS

High Frequency systems form a major part of world-wide radio telegraph communication services. Marconi's have recently designed new equipment for such systems incorporating the latest electronic developments to save time and labour, reduce operating costs and eliminate faults. The company is unique in the resourcefulness and skill it can bring to the complete engineering of a system from the surveying stage onwards to the maintenance after it has been installed, and the training of the staff to operate it at maximum efficiency.

The Lifeline of Communication is in experienced hands

MARCONI

Complete Communication Systems

MARCONI'S WIRELESS TELEGRAPH COMPANY LIMITED, CHELMSFORD, ESSEX, ENGLAND

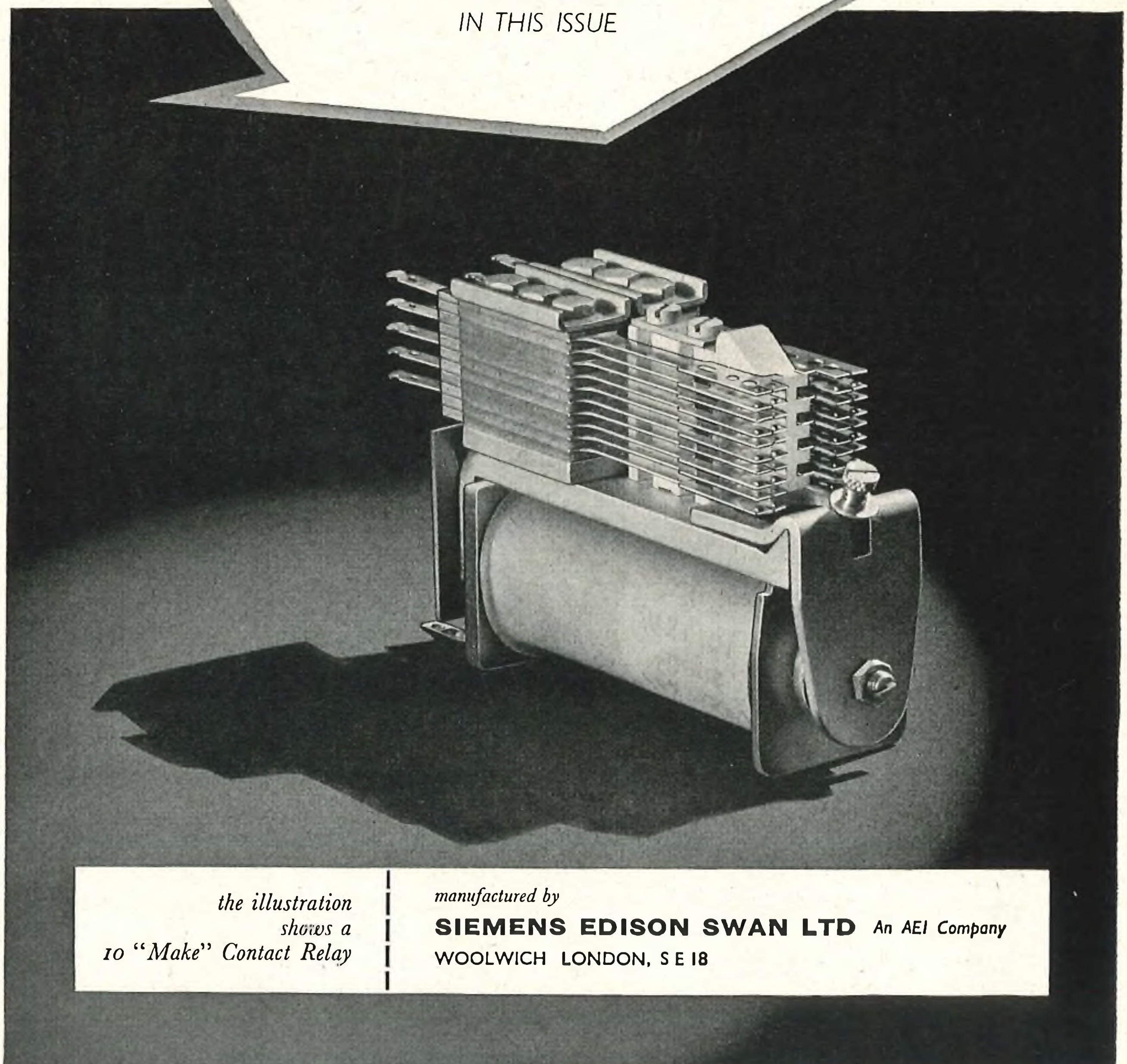
LC 15

The **NEW** SIEMENS EDISWAN

Long Life Relay

POST OFFICE TYPE 10

AS DESCRIBED IN THIS ISSUE



the illustration shows a 10 "Make" Contact Relay

manufactured by

SIEMENS EDISON SWAN LTD *An AEI Company*

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THE CENTENARY NEOPHONE

A quality instrument at an economical price, especially suitable for use overseas.

circuit telephone

This entirely new instrument, a product of the designers of the world-famous "Neophone" which established new standards in telephone performance and appearance in the nineteen-thirties, incorporates the following attractive features —

Improved performance, using latest design of components.
Lower first cost, achieved by the most modern manufacturing methods.
Lower maintenance cost.
Suitably finished for tropical use. Sealed case keeps out dust and insects.
Reduced size and weight – handset weight halved – only 7 ounces.

21 COLOUR COMBINATIONS

7 different handset shades and a choice of 3 case colours. The case can be changed WITHOUT DISTURBING THE DIAL SWITCH.

The centenary NEOPHONE

THE NEW INSTRUMENT WITH NEW FEATURES

Complete technical details are available on request.

subscribers

Radio Telephone

The A.T.E./Marconi v.h.f. f.m. battery operated subscriber set provides radio telephone service where no mains exist and a land line could not be built. It is compact and economical and provides transmission of a quality equal to line or carrier working.

Chief characteristics are:-

Frequency bands: 156-184 Mc/s or 54-84 Mc/s.
12v. d.c. supply from accumulator.
Fully tropicalized.
2-wire connection to telephone.
300-3000 c/s audio bandwidth.
Frequency modulated transmitter and receiver.
Range 20 miles (approximately).

Weight 27 lb. 12.27 kg.
Dimensions 15″ x 10″ x 6″ (.38m. x .25m. x .15m.).
Power consumption: transmit 1.15A, receive 1.10A.
Cyclic switching for listening out reduces average drain to 110 mA.

ATE MARCONI

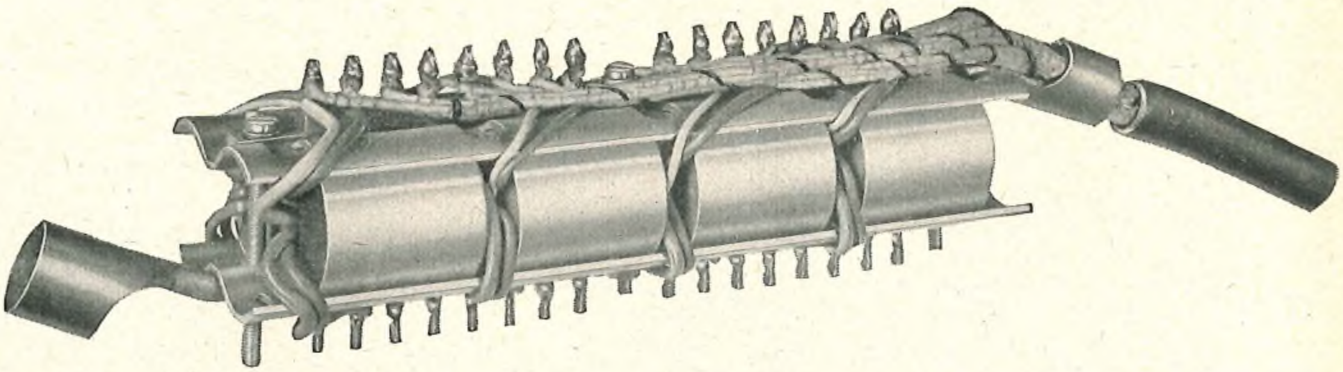
AUTOMATIC TELEPHONE & ELECTRIC CO. LTD.
STROWGER HOUSE, ARUNDEL STREET, LONDON, W.C.2.

MARCONI'S WIRELESS TELEGRAPH COMPANY LIMITED
MARCONI HOUSE, CHELMSFORD, ENGLAND.

AT14681


Cells Secondary Stationary Nos. 12, 13, 14
Cells Secondary Stationary Nos. 9, 10, 11
POWER BEHIND THE LINES
TUNGSTONE Batteries have been designed to conform fully with G.P.O. and British Standard Specifications.
These illustrations show the very wide range and type of Cells in regular production for Telephone Exchange work in Great Britain, Australia, New Zealand, India, South Africa, West Indies, etc.
Open Type Cells can be supplied in capacities from 50 a.h. to 700 a.h. in Glass Containers, and from 400 a.h. to 5,000 a.h. in Lead-lined Wooden Boxes — Enclosed Type Cells in capacities from 10 a.h. to 200 a.h.
Battery Secondary Portable No. 10
Battery Secondary Portable No. 14
Cells Secondary Enclosed Nos. 1 to 5
TUNGSTONE
REGD TRADE MARK
BATTERIES

Improved splice loading with the L219

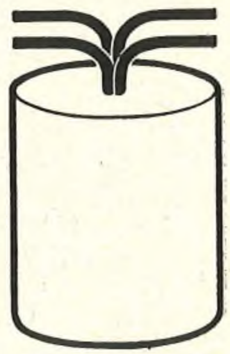


The new economical loading coil

Arising from the increasing demand for a smaller coil which can be employed in splice loading, Mullard have developed the L219. In the design Mullard were assisted by their own production experience and information given by overseas users. The result is a simple, low cost component (to grade 3 spec.) suitable for small or large splice loading units.

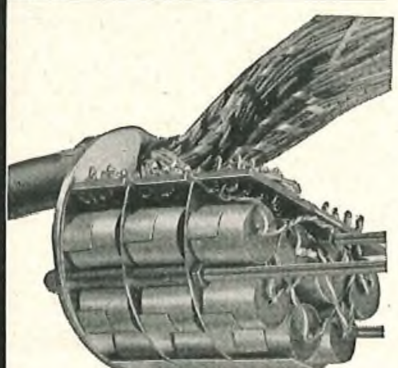
Smaller construction

By using a new grade of Ferroxcube pot core the overall volume of the coil is considerably reduced. The coil is resin sealed in a small cylindrical aluminium canister ensuring complete protection from climatic effects. The windings of the coils are brought out on flying leads.



LIFE SIZE COIL
L219

Permits smaller splices



Key factors in this development are the clamping arrangements which, with the new coil, permit much smaller splice housing. On small cables, coils are mounted lengthways in pairs with great compactness. For larger cables, coils are mounted radially, each mounting plate accommodating up to seven coils. Clamping plates, coils, etc. can be supplied as kits.

Please write for full details of the new Mullard loading coils

Mullard
SPECIALISED ELECTRONIC EQUIPMENT

MULLARD LIMITED
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ME614a

Momental! Monumentous!

'This is an old Roman way, built about 150 A.D., I believe, by Roman rabbits,' said Baron Rabbit. 'Perhaps those pipes on which you stand are Roman remains.'

'No, no, sir,' replied the Constable. 'These are not pipes, they are called conduits and are quite modern. Been here only 50 years or so. They are made of vitrified clay.'

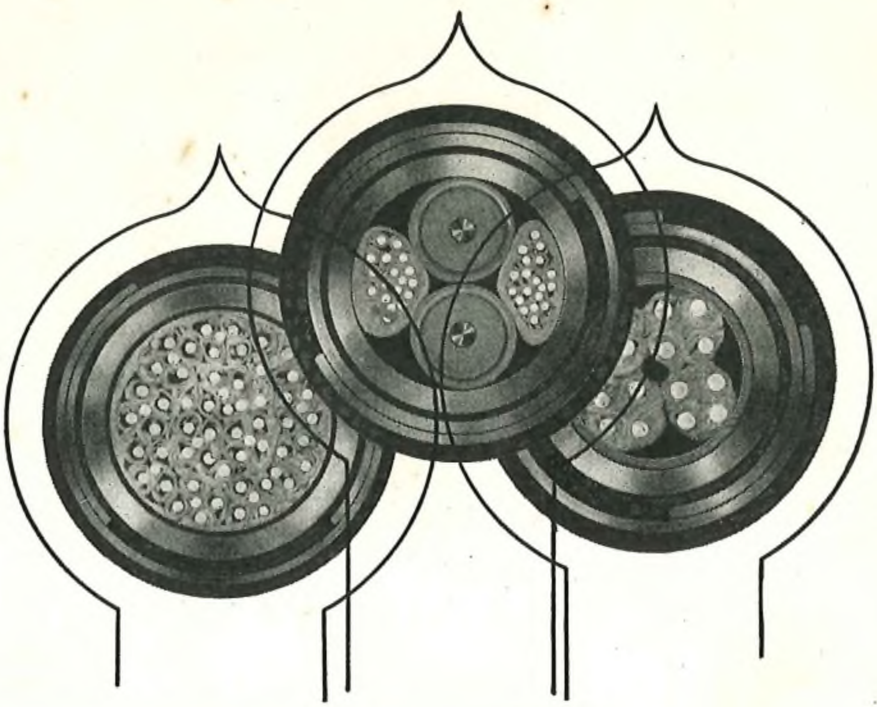
'That,' said the Baron, 'is precisely the stuff the Romans used, too. Long-lasting, money-saving, acid-resisting stuff. And smooth. Cables slide easily through that kind of conduit.'

'Salt glazed vitrified clay conduits are momental,' said the Constable.

'Salt glazed vitrified clay conduits are monumentous!' agreed the Baron.

Put down Salt Glazed Vitrified Clay Pipes and Conduits — they stay down for centuries!

NATIONAL SALT GLAZED PIPE MANUFACTURERS' ASSOCIATION



Sections of the three cables ordered by the Department of Posts and Telegraphs of the Government of India from Standard Telephones and Cables Limited. *These installations are indicative of S.T.C.'s lead in communication cable engineering.*

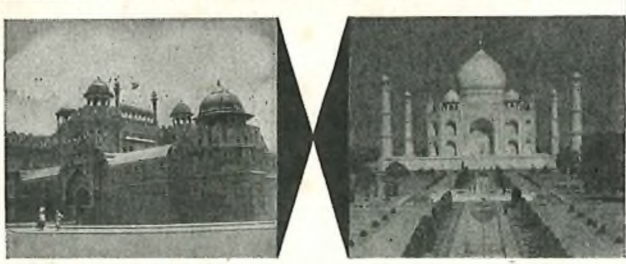
THREE 'FIRSTS' IN INDIA

BOMBAY-THANA 24-CHANNEL CARRIER CABLE

Two parallel cables completed in 1954.
The first 24-channel carrier cables in India.

CALCUTTA-ASANSOL 60-CHANNEL CARRIER CABLE

Two cables completed in 1957.
The first 60-channel carrier cables in India.



DELHI-AGRA COAXIAL CABLE

One cable of two coaxial tubes (960 channels) with additional carrier and audio circuits.
Now being manufactured.
The first coaxial cable in India.

Standard Telephones and Cables Limited

Registered Office : Connaught House, Aldwych, London, W.C.2

TELEPHONE CABLE DIVISION: NORTH WOOLWICH · LONDON · E.16

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