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THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

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The Post Office Network of Radio-Relay Stations

Part 1—Radio-Relay Links and Network Planning

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This article, which will be published in two parts, reviews the historical development of microwave radio-relay links and the part that they are now playing in the present rapid expansion of the television and trunk-telephone networks. Part 1 describes typical modern microwave radio-relay links and the network of them that is now being constructed. The problems involved in planning such a network are also discussed. Part 2 will describe the performance, reliability and maintenance of the links.

INTRODUCTION

RADIO waves of wavelength shorter than about 30 cm (microwaves) have been the subject of experiments by radio engineers for many years, and as long ago as 1931 a cross-channel radio link was demonstrated, operating on a frequency of 1,700 Mc/s between St. Margarets Bay and Calais. There followed, in 1934, what was probably the first microwave link operating on a regular commercial basis; this was between the airports of Lympne (Kent) and St. Inglevert (France), a distance of some 35 miles. A halt to further progress was caused by the outbreak of the second World War. However, the advent of special types of valves such as the klystron and the travelling-wave tube, which were developed for radar purposes, was to make a great contribution when hostilities ceased.

The first radio-relay link in the United Kingdom for the transmission of 405-line 3 Mc/s television was installed in 1949 between London and Birmingham to provide a link to the British Broadcasting Corporation (B.B.C.) television broadcasting station at Sutton Coldfield.[1] This link, using earthed-grid triode valves for radio-frequency amplification and operating at a frequency of 900 Mc/s, was the first broadband radio-relay link to be put into commercial service in the United Kingdom. The link was originally designed to employ amplitude modulation of the radio-frequency carrier but, in the event, frequency modulation was chosen, since it was found that the linearity requirements of the transmission performance could be more readily met by this method. The outstanding advantage of frequency modulation was thus recognized at a very early stage in the art.

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In 1952 the first permanent broadband microwave link to be operated in the United Kingdom was put into public service between Manchester and Scotland to carry 405-line 3 Mc/s television signals to the B.B.C. station at Kirk O'Shotts.[2] The link operated in the 4,000 Mc/s frequency band and was the first public-service link anywhere in the world to use the travelling-wave amplifier. At the end of 1952 these links were the only broadband radio links in service and accounted for some 700 broadband-channel miles suitable for the transmission of 405-line 3 Mc/s television signals only.

PRESENT AND PROPOSED RADIO-LINK NETWORKS

Television Links

The early links showed the inherent attraction of microwave links for the transmission of wide-band signals, and in the last 10 years an extensive network has been provided to serve the needs of the Independent Television Authority (I.T.A.) and B.B.C. 405-line monochrome-television services. The network, completed or at present under construction for this purpose, has an aggregate length of 4,000 operational video-channel miles. To meet likely requirements for the new 625-line television networks[3] to be brought into service in the next few years, radio links will be used for city–city routes and for many of the spur routes to the broadcast transmitters. At the present time a network, with an aggregate length of 3,500 operational video-channel miles, is under construction to serve the first 13 B.B.C. Second Program 625-line u.h.f. transmitters.

Telephony Links

Because of their inherent wideband characteristics microwave radio-relay links are also suitable for the provision of large numbers of telephone circuits, arranged in frequency-division multiplex in the baseband* frequency spectrum. Because the transmission linearity requirements for this purpose are more stringent than for monochrome television, it was not until 1956 that the development work carried out both by the Post Office and industry resulted in the provision of a link with a traffic capacity of 240 telephone circuits.[4]

*The term baseband designates the band of frequencies transmitted by the radio system between its input and output terminals.

Up to the present time a total of 1,200 broadband-channel miles have been provided having a traffic capacity of 600 telephone channels per broadband-channel, and currently under provision are 4,300 broadband-channel miles of 960-telephone-channel capacity and 3,000 broadband-channel miles of 1,800-telephone-channel capacity. At the present time the aggregate telephone-channel mileage carried by radio links is 200,000 and by 1966 this will have increased to 2,500,000.

Fig. 1 shows the main radio links at present in service for telephony and for the 405-line television services for the broadcasting authorities, together with new links to

Telephony link, already operational

Telephony link, operational by 1966

Television link for 405-line services, already operational

Television link for 625-line services operational by 1966

FIG. 1—UNITED KINGDOM MICROWAVE RADIO-RELAY TRUNK NETWORK

be provided by 1966 for the B.B.C. Second Program 625-line television network and for telephony.

TYPICAL RADIO-RELAY LINKS

Microwave radio-relay links now in use operate in radio-frequency bands centred on 2,000, 4,000 and 6,250 Mc/s, and many individual broadband-channels can be accommodated in each band. Radio energy is propagated in narrow beams by highly-directional aerials along "line-of-sight" paths between stations which, in the United Kingdom, have an average separation of about 26 miles.

Single Broadband-Channel Link

Fig. 2 shows, in outline, a single broadband-channel 2-section link for the transmission of either 625-line television signals (baseband frequency-spectrum: 0–5·5 Mc/s; input and output signal levels: 1 volt peak-to-peak*) or 960 telephone conversations (baseband frequency-spectrum: 60 kc/s–4·028 Mc/s; channel test level at input: −45 dbm; channel test level at output −20 dbm).

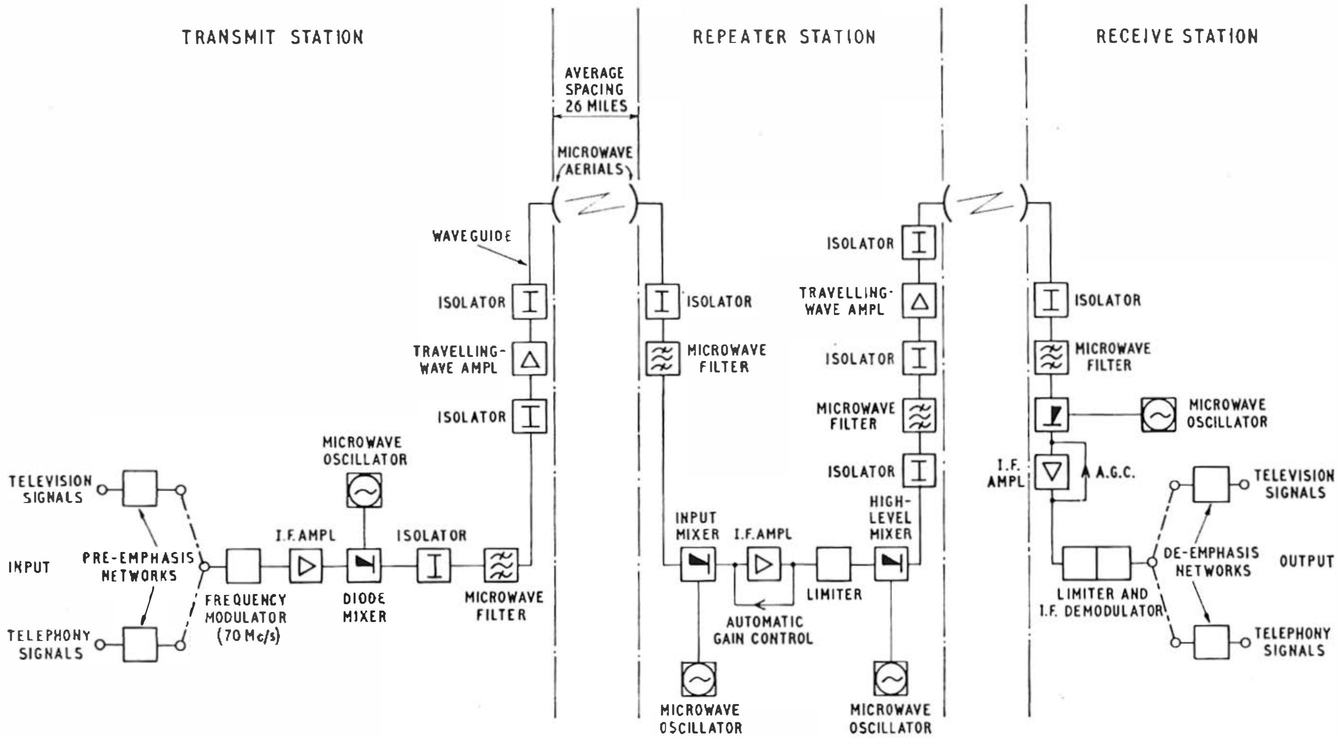


FIG. 2—SINGLE BROADBAND-CHANNEL MICROWAVE LINK FOR THE TRANSMISSION OF TELEVISION OR 960 TELEPHONE CHANNELS

Transmitter. The baseband signal, after suitable pre-emphasis, frequency modulates an oscillator having a mean centre frequency of 70 Mc/s, i.e. the intermediate frequency (i.f.). The peak-to-peak frequency deviation due to a television signal is 8 Mc/s and the maximum (busy hour) r.m.s. deviation due to the multi-channel telephony signal is 1·1 Mc/s. The need for radio links to transmit multi-channel telephony as an alternative to television gave great impetus during the years 1954–1958 to the development of i.f. modulators, demodulators and amplifiers[5,6] of very high standards of performance. The highly-linear voltage/frequency transfer function of the modulators (maximum variation of slope is 0·15 per cent per Mc/s over a 20 Mc/s band) was primarily required to minimize intermodulation noise in telephony systems, but has subsequently enabled the increasingly-stringent requirements of television transmission to be met. An i.f. modulator for the alternative transmission of 960 telephone conversations or of television is shown in Fig. 3.

The frequency-modulated (f.m.) output signal of the modulator has a spectral range of 55–85 Mc/s, and is amplified and applied, together with a signal from a microwave oscillator, to a crystal-diode mixer for conversion to microwave frequency. The mixer output consists of two f.m. sidebands, one above and one below the mean centre-frequency of the microwave oscillator; each sideband carries all the essential information, and one of them is selected by a band-pass microwave filter for application at a level of −29 db relative to one watt (−29 dbW) to a travelling-wave amplifier (t.w.a.) of 36 db gain (Fig. 4). The microwave signal at the output of the t.w.a. (level: + 7 dbW) is connected through a ferrite isolator and low-loss waveguide feeder to the microwave aerial.

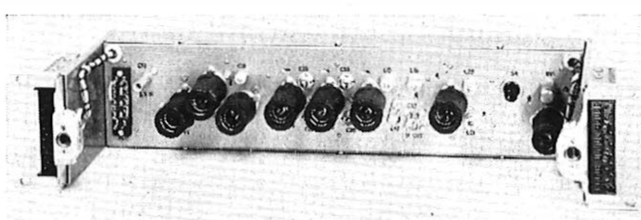


FIG. 3—FREQUENCY MODULATOR (MEAN CENTRE FREQUENCY 70 Mc/s)

*A peak-to-peak television signal extends from synchronizing pulse tip to peak-white level.

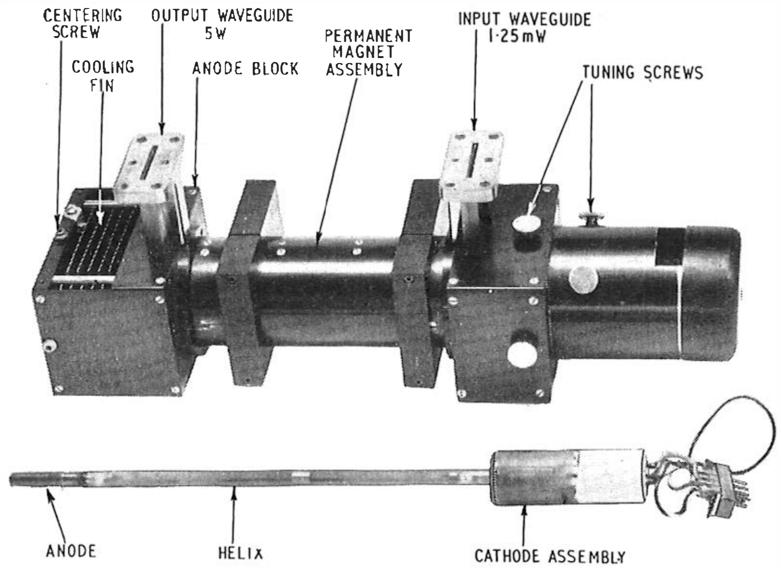


FIG. 4—TRAVELLING-WAVE AMPLIFIER

Echoes in f.m. systems give rise to intermodulation noise in telephony systems and distortion in television systems, and must be reduced to an acceptable level. Ferrite isolators of the resonant or field-displacement type exploit the special properties of ferrite materials[7] to produce a non-reciprocal attenuation characteristic (a forward loss of 0·3 db and a reverse loss of 30 db) and are extensively used to reduce the level of echo signals arising from mis-matches between various microwave elements, e.g. waveguide feeder, transmitter and microwave aerial.

Inter-Station Transmission Loss. The total transmission loss between hypothetical aerials that radiate power uniformly in all directions (isotropic aerials) and are 25 miles apart in free space is 140 db. Practical microwave aerials are highly directional (± 1° to the 3 db power points) and have a gain of 42 db relative to isotropic aerials. The use of such aerials results in an overall transmission loss (including losses in waveguide feeders) of about 67 db under normal propagation conditions. For all practical purposes this loss is constant over the radio-frequency (r.f.) channel bandwidth of 30 Mc/s.

Repeater. The normal r.f. signal level at the repeater input mixer is about −60 dbW, and this may fall to −90 dbW during periods of severe fading. It has been found convenient, in the majority of links installed in the United Kingdom, to provide most of the fixed gain and all of the reserve gain to overcome the inter-station transmission loss at the intermediate frequency, although some repeaters are in use in which all the amplification is carried out at the radio frequency.[8]

The low-noise input mixer (noise factor 10 db) serves to convert the signal to i.f. for application to an amplifier of 80 db maximum gain and with automatic gain control to ensure constant output level (0·5 volts) for wide variations of input-signal level. The amplifier bandwidth is ± 20 Mc/s to the 3 db points, and linear variations in group-delay do not exceed 0·05 nanoseconds per megacycle over the central 20 Mc/s of bandwidth. The high-level mixer reconverts the signal to a microwave frequency that differs by 252 Mc/s (as described later) from the signal frequency at the input to the repeater. Fig. 5 (*a*) shows a 6,000 Mc/s repeater equipment currently in use for the transmission of either 960 telephone channels or 625-line television, and Fig. 5 (*b*) shows in detail the transmit/receive panel of the repeater.

Receiver. At the receiver the signal is converted to i.f., amplified to a fixed level, and fed to a limiter that serves to remove all residual amplitude-modulation components from the frequency-modulation signal. Frequency/voltage conversion is carried out in a highly-linear i.f. demodulator, the output of which is passed to an appropriate de-emphasis network (either for television or telephony) whose characteristic is the inverse of the pre-emphasis network at the transmit station.

Multi-Broadband-Channel Link

General Arrangement and Channel Frequencies. The establishment of multi-channel radio routes has demanded the development of branching filters to combine a number of r.f. channels for connexion to one aerial feeder.

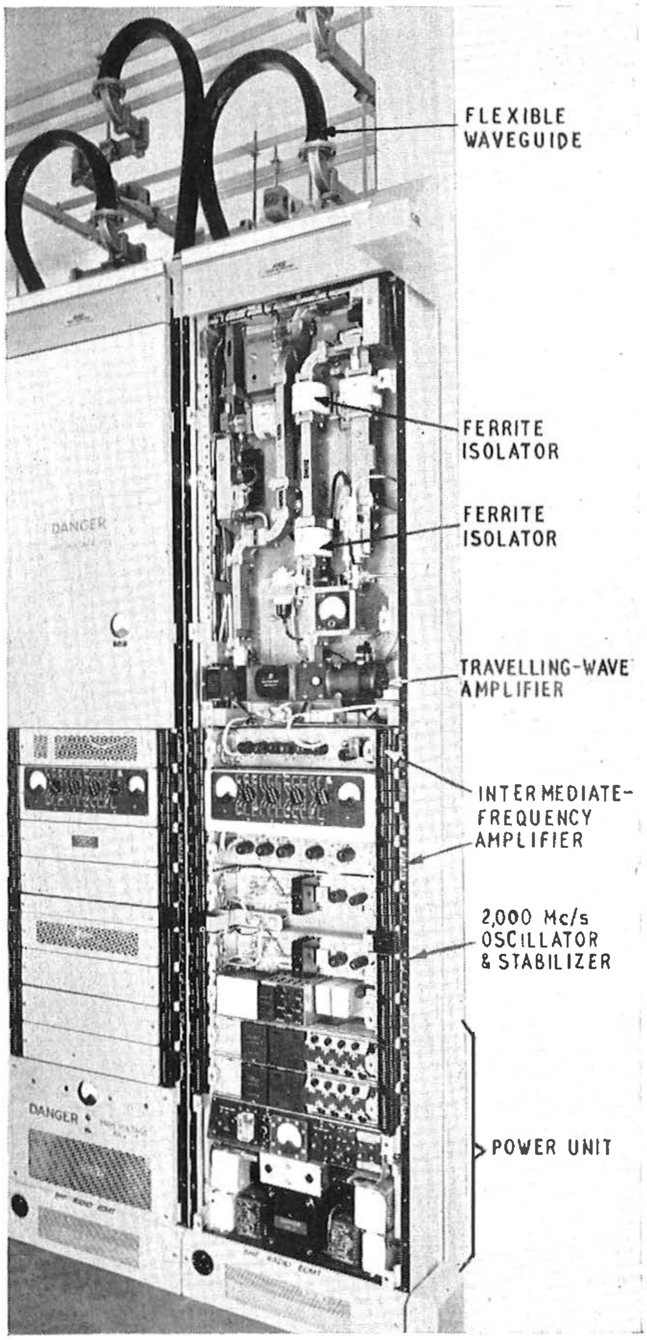
Present techniques, using conventional mono-polar parabolic-type aerials will allow for the connexion to a single aerial of up to four transmitters and four receivers using channel-frequency assignments within a single frequency band. For systems now in course of provision the element of common sharing will be increased by the availability of a new type of microwave aerial[9] whose wide frequency-band characteristics will allow one aerial to be shared by several different frequency bands. This new wide-band aerial, called a horn reflector, has been designed to transmit and receive two signals of dominant TE_{11} mode, polarized at 90° to each other, when used in conjunction with a low-loss (0·5 db/100 ft at 6,000 Mc/s) circular waveguide. Fig. 6 shows the general arrangement of a multi-r.f.-channel link using aerials of this type, together with the preferred frequency-channelling plan for the 6,000 Mc/s common-carrier band; the general arrangement is also typical of the 2,000 and 4,000 Mc/s bands.

The communication band, 500 Mc/s wide, is subdivided into two adjacent blocks of 250 Mc/s, designated "high" and "low" for convenience. Each block contains eight radio-frequency channels spaced 29·65 Mc/s apart, and at any one station all transmit channels are allocated to one block (high or low) and all receive channels to the other (low or high). Thus, at station B all go and all return transmit channels (f1–f8) are in the low band while all receive channels (f1′–f8′) are in the high band. Channels are interchanged from the high band to the low band or vice-versa by a frequency shift of 252 Mc/s during transmission through a repeater station. This arrangement results in considerable economy in the use of the frequency spectrum but is only possible under certain conditions. For example, as a side effect of the transmission of radio-frequency energy transmitted from repeater station B to terminal station C (go channels f1–f8), some energy will be transmitted in the direction of terminal station A; this unwanted energy must be reduced to a very low level in the direction of terminal station A if interference with the return channels (f1–f8) received at station A from station B is to be avoided. In general, this entails the use of highly-directional aerials and careful planning of the station to avoid unwanted local reflections.

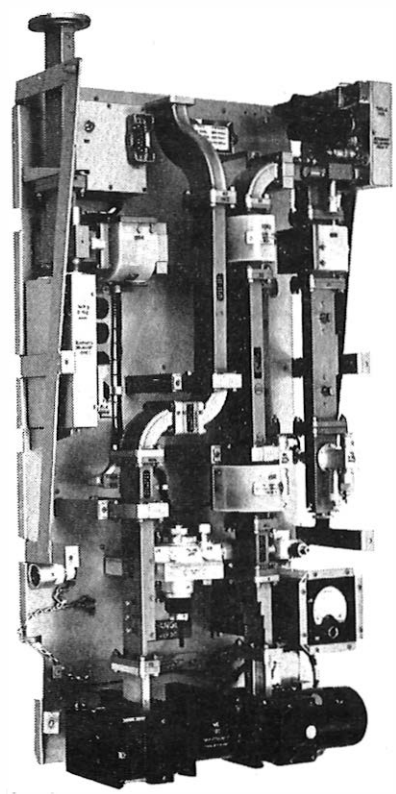
To enable channels to be separated more easily adjacent channels are given orthogonal polarizations so that the minimum frequency spacing between two channels of the same polarization is 59·3 Mc/s. A frequency gap of 44·5 Mc/s is provided between the transmit/receive blocks to facilitate the reduction of transmit-to-receive crosstalk. Two aerials are used for each direction of transmission, each aerial being used for simultaneous transmission and reception of four channels.

Channel Combination and Separation. In the arrangement shown by Fig. 6, four transmit channels (f1, f3, f5 and f7 with vertical polarization) and four receive channels (f1′, f3′, f5′ and f7′ with horizontal polarization) are combined in a polarization filter, P6. Ferrite circulators, illustrated in Fig. 7, are used to combine or to separate the individual broadband radio-frequency channels. The circulator consists of a junction of four waveguides, fitted internally with ferrites. As a result of the Faraday rotation effect[7] that occurs in ferrites, non-reciprocal phase-shifts occur in the arms of the circulator. This effect is used to direct the energy of each channel into the appropriate outlet. Full use of the eight channels available in both the go and return directions of transmission in the 6,000 Mc/s band is achieved by the use of a second horn aerial for each radio-relay link, as shown for channels f2′–f8′. Where traffic growth on a route is sufficiently rapid it may be economical to erect both aerials at the outset. In such cases, and where bi-polar aerials (e.g. horn-reflector type) are used, it is possible to connect all transmit channels to one aerial and all receive channels to the other. This arrangement has certain advantages, e.g. greater freedom from transmit-to-receive crosstalk and intermodulation noise, and is often used on British Post Office routes.

Horn-Reflector Aerial. The main advantages of the horn-reflector type of aerial lie in its wide transmission bandwidth, good matching properties and the low level of energy propagated in directions other than the wanted direction. The wide transmission bandwidth of the aerial allows the simultaneous transmission of r.f. channels in the 4,000, 6,000 and 11,000 Mc/s common-carrier bands. The polarization filters P4 and P11 shown in Fig. 6 are for this purpose. By this method up to 20

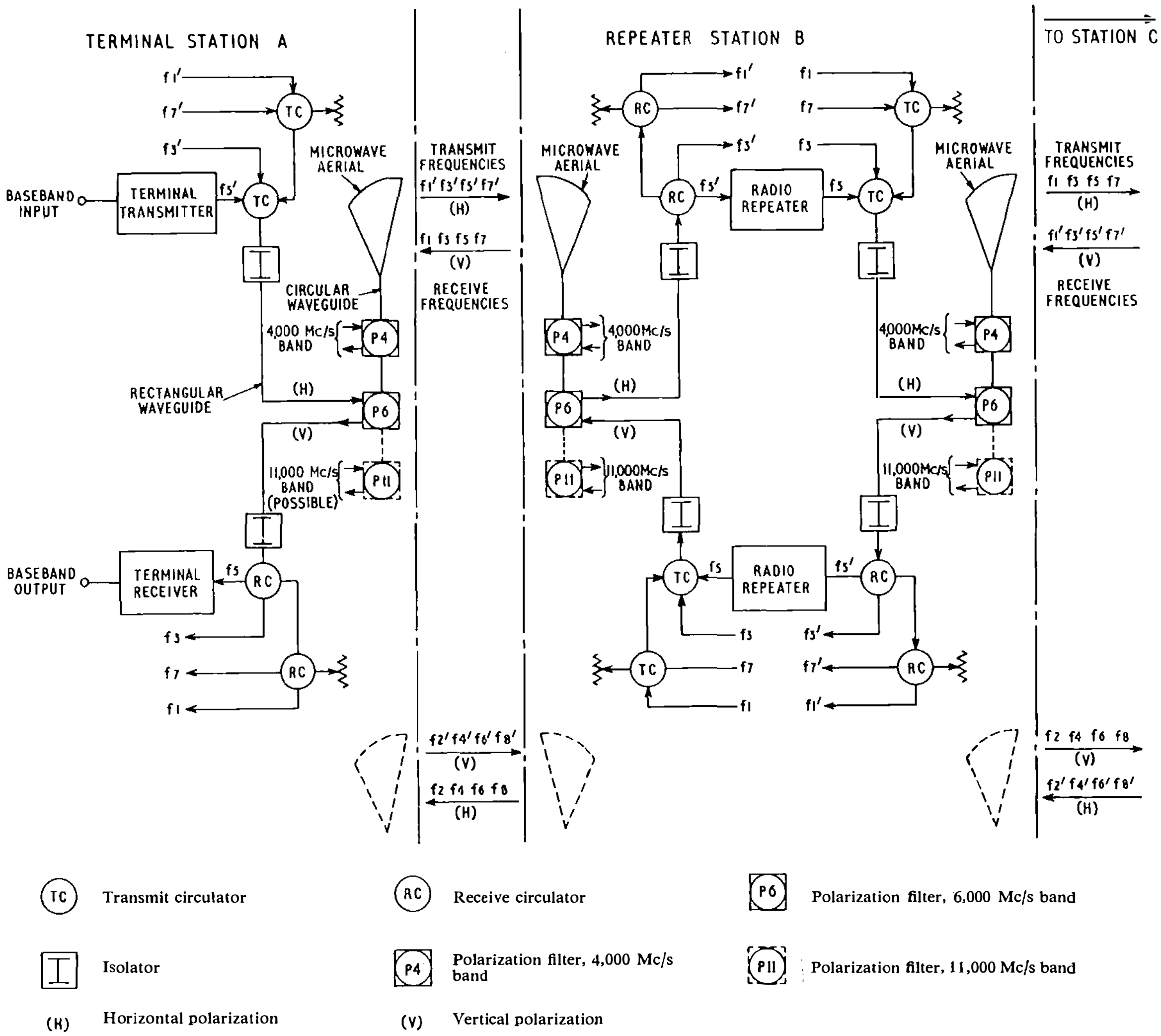


(*a*) Repeater Racks

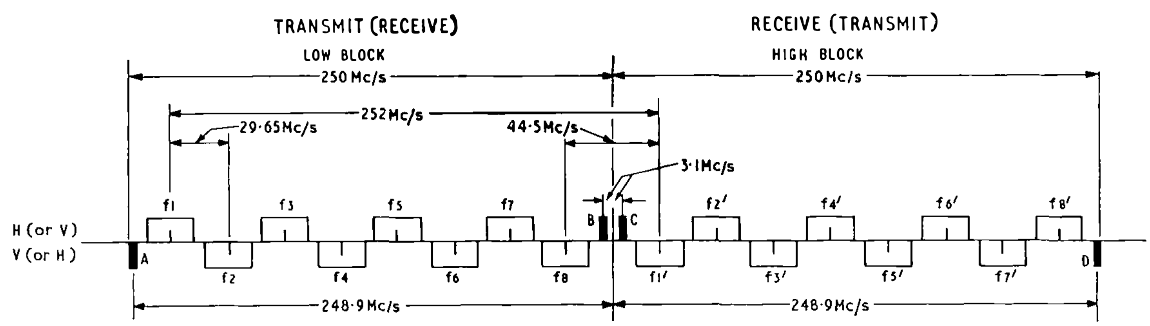


(*b*) Transmit/Receive Panel

FIG. 5—6,000 Mc/s REPEATER EQUIPMENT



(*a*) Arrangement of Multi-Channel Link

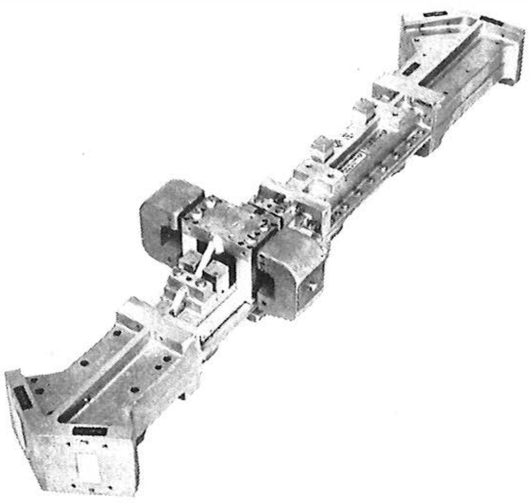


(*b*) Channel Assignments for Common-Carrier Frequency Band 5,925–6,425 Mc/s

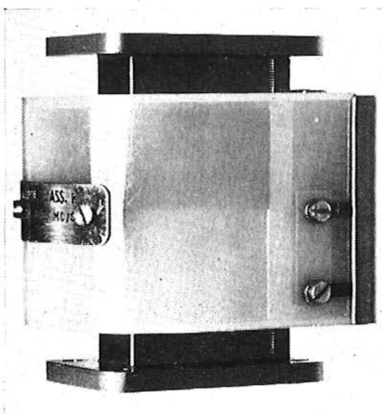
FIG. 6—MULTI-BROADBAND-CHANNEL MICROWAVE SYSTEM

broadband communication channels in both the go and return directions of transmission can be accommodated on one pair of horn-reflector aerials. It has yet to be decided whether adequate security of communication could be maintained with such a concentration of broadband channels through common items of equipment.

Fig. 8 shows a horn-reflector type aerial in course of erection at a Post Office radio-relay station. The aerial shown has a radiating aperture area of 140 ft^2 and a gain at 6,000 Mc/s of 45 db relative to an isotropic aerial; it is used on main routes for the transmission of 1,800 telephone conversations per r.f. carrier. A smaller version, with an aperture area of 70 ft^2 and a gain of 42 db, is used for certain routes where the transmission capacity need not exceed 960 telephone channels per r.f. carrier, or where inter-station transmission loss is small.



(a) Channel Combination/Separation Ferrite Circulator



(b) Ferrite Isolator

FIG. 7—FERRITE CIRCULATORS

NETWORK PLANNING

Frequency Bands Available

The frequency bands currently available to the Post Office for broadband point-to-point communications in the United Kingdom are:

1,700–1,900 Mc/s (2,000 Mc/s "spur" band)
1,900–2,300 Mc/s (2,000 Mc/s band)
3,790–4,200 Mc/s (4,000 Mc/s band)
5,925–6,425 Mc/s ("lower" 6,000 Mc/s band)
6,430–7,110 Mc/s ("upper" 6,000 Mc/s band)
10,700–11,700 Mc/s (11,000 Mc/s band)

The 2,000, 4,000 and 6,000 Mc/s bands are generally used for main links connecting large centres of population. The bands are channelled to give six r.f. broadband channels in both the go and return directions of transmission in the 2,000 and 4,000 Mc/s bands and eight r.f. channels in the lower 6,000 Mc/s band. The radio-frequency spacing between broadband channels is about 30 Mc/s, and this spacing is theoretically sufficient to give a capacity of 1,800 telephone channels in each broadband channel as an alternative to television. Lower-band 6,000 Mc/s equipment having this capacity is now available, and 4,000 Mc/s equipment with a similar capacity should become available in the near future; the telephone-traffic capacity of current 4,000 Mc/s equipment is 960 circuits. The alternative transmission capacity of the 2,000 Mc/s equipment is unlikely to exceed 960 telephone circuits for some time.

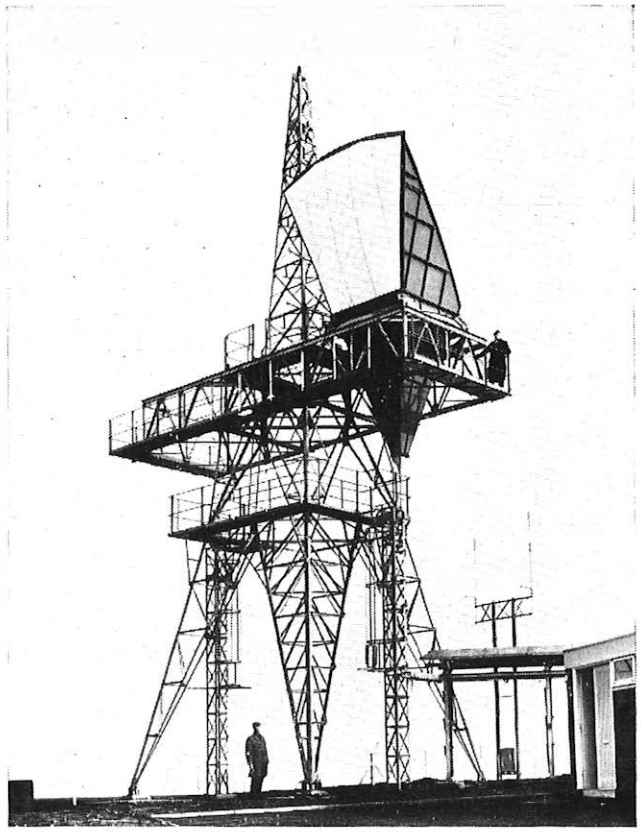


FIG. 8—HORN REFLECTOR AERIAL

In all three bands the equipment is suitable for the transmission of 625-line colour television, including the sound program that is associated with the video signal. It is often more economical to carry the sound program in this way, and it may have operational advantages compared with the use of separate land-line for this purpose. The method of transmitting the sound program is to use a sub-carrier located in the baseband above the video signal and to frequency modulate this sub-carrier by the audio signal.

The upper 6,000 Mc/s frequency band has been planned to have eight r.f. broadband channels spaced 40 Mc/s apart, for both go and return directions of transmission, and to be suitable for the transmission of 2,700 telephone channels on each r.f. broadband channel. An alternative arrangement will be to have double the number of r.f. channels, spaced 20 Mc/s apart, and each r.f. channel suitable for systems carrying up to 960 telephone conversations or a television signal. Radio equipment for the upper 6,000 Mc/s band is, however, not yet available.

The 1,700–1,900 Mc/s spur band is channelled in accordance with C.C.I.R.* recommendations to provide six r.f. broadband channels spaced 14 Mc/s apart in both the go and return directions; each broadband channel is capable of carrying up to 120 telephone channels. By increasing the broadband-channel spacing, however, the band may be used to carry television signals.

The future use of the 11,000 Mc/s band is at present

*C.C.I.R.—International Radio Consultative Committee.

being studied; it is likely to be used chiefly for short spur routes.

Link Planning

Line-of-sight microwave radio-relay links are planned to achieve substantially "free-space" propagation between adjacent stations for all but a very small percentage of the time. To meet this criterion there must be a certain minimum clearance between the direct transmission path of the microwave energy and the ground or obstructions on or near the transmission path, so as to avoid diffraction losses. To achieve this object, Post Office microwave paths are planned to clear the ground or any other potential obstructions by a minimum of about half the radius of the first Fresnel zone.* In practice this clearance ranges from a few feet at the ends of the path to 50 feet or more at mid-path.

The microwave energy does not, however, necessarily travel in a straight line. The lower atmosphere is not homogeneous, and there is a gradient in refractive index which varies with time and with height above ground. Although small, this gradient can produce significant bending in the wave path. Under what is known as "standard" refraction conditions the curvature of the path has the same sense as that of the earth's surface, but the radius of curvature of the wave path is four times that of the radius of the earth's curvature. When planning links and plotting path profiles, it is most convenient to consider that the propagation will take place over straight-line paths and to adjust the geometry by regarding the earth as having an effective radius four-thirds of its actual radius under normal conditions. Abnormal propagation conditions occasionally arise where the gradient of the refractive index is such as to cause the wave path to have a curvature opposite to that of the surface of the earth, thus subjecting it to diffraction losses at obstacles normally well clear of the path. To guard against these occasional adverse conditions it is assumed when planning microwave paths in the United Kingdom that the earth's radius is 0·7 of its actual value.

Fig. 9 shows a typical overland path profile drawn on a flat-earth basis; the dotted lines show the effective height of obstacles under subrefractive conditions when the earth's apparent radius is effectively 0·7 of its true radius. The heights of trees and possible building development are added to the dominant obstacles to obtain the final effective height above which a clearance of about one half of the first Fresnel zone is required to maintain free-space propagation.

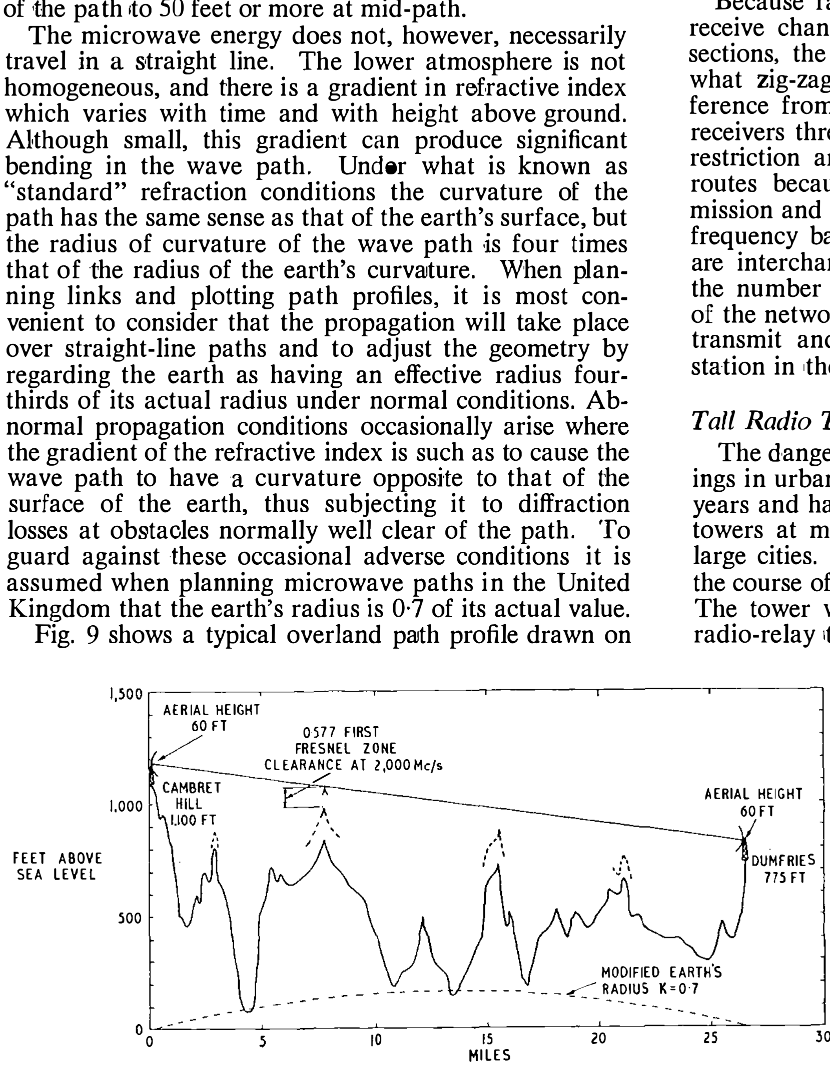
Where possible, stations on a link are sited so as to prevent signals that are reflected from the terrain below or on either side of the direct propagation path from reaching the receiving end. Where this cannot be achieved and the liability of reflections occurring is high, as on an oversea path, then diversity techniques are employed to minimize the effects of the reflected signals on the received signal.[10]

Because radio frequencies used for the transmit and receive channels of a link are repeated on alternative sections, the route must be planned to follow a somewhat zig-zag path in order to avoid over-reach interference from the transmitters at one station with the receivers three stations further along the route. Another restriction arises in planning a network of radio-relay routes because the radio frequencies used for transmission and reception are kept in separate halves of the frequency band, either high or low, at each station and are interchanged at adjacent stations. It follows that the number of radio-relay sections in any closed loop of the network must be even, otherwise a clash between transmit and receive frequencies must occur at some station in the loop.

Tall Radio Towers in Urban Areas

The danger of obstruction of radio paths by tall buildings in urban areas has become more apparent in recent years and has resulted in the provision of two tall radio towers at microwave-radio terminals at the centres of large cities. One example of this is the 620 ft tower in the course of erection at Museum Telephone Exchange.[11] The tower will be the London terminal of microwave radio-relay trunk routes to all parts of the country and the Continent. Fig. 10 shows a model of the 500 ft tower now being erected in the centre of Birmingham to replace the existing lattice-steel mast, which does not have sufficient aerial capacity to meet the expected traffic growth or sufficient height to avoid obstruction by high buildings planned in the Birmingham area. As with the Museum tower, the radio equipment will be mounted within the tower itself to keep the length of the feeders between the equipment and the aerials as short as possible and, hence, the feeder losses to an acceptably-small value. The aerial galleries of each tower have a height range of about 120 ft and will accommodate up to about 50 microwave aerials of various types.

Each tower will have a total capacity of about 220 broadband communication channels in both the go and return directions of transmission. The aggregate main-route traffic capacity of each tower could be 150,000 telephone circuits, if entirely used for telephony, or 100 television channels in both go and return directions if used entirely for television. The probable division of use will be 40 such television



Heights of principal hills modified (dotted lines) to allow for curved earth (k=0·7). Additional clearance of 0·577 first Fresnel zone at 2,000 Mc/s is also shown.

FIG. 9—OVERLAND PATH PROFILE DRAWN ON FLAT-EARTH BASIS

*Fresnel zones arise in the theoretical approach to the diffraction of light waves made by Huygens and Fresnel. A Fresnel zone may be defined as a zone, on a specified surface, such that the sum of the distances from the transmitting aerial and from the receiving point to any point in the zone, does not vary by more than half a wave-length throughout the zone.

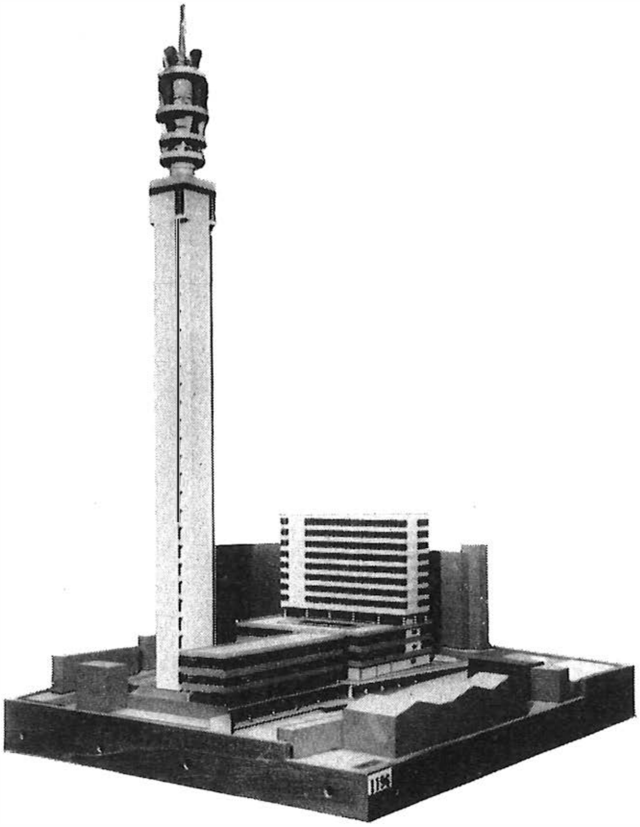


FIG. 10—MODEL OF BIRMINGHAM RADIO TOWER

FIG. 11—MODEL OF A MAIN-ROUTE MICROWAVE RADIO-RELAY REPEATER STATION WITH A CONCRETE TOWER

channels and 100,000 telephone circuits. In addition, the aggregate traffic capacity of the tower for "spur" routes will be 50,000 telephone circuits or 40 television channels in both go and return directions of transmission, but it is possible that part of this capacity will be diverted to main routes.

Radio Towers at Main-Route Intersections

The growth in the telephone trunk network, together with the need to provide new 625-line television networks, will considerably increase the number of channels to be carried by radio links in the next few years; Fig. 11 shows a model of a radio-relay station with a concrete tower, suitable for use at main-route intersections away from urban areas; six such towers are at present under construction. The towers have a maximum height of about 300 ft and are used solely as supports for microwave aerials, the radio equipment being housed in a single-storey building located near the foot of the tower.

(*To be continued*)

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Improvements to the Post Office Type 2 Uniselector

F. HAYTHORNTHWAITE and D. J. MANNING†

U.D.C. 621.395.658:621.395.342.21

The Post Office Type 2 uniselector has given satisfactory service for a number of years; experience has, however, shown the need for some minor modifications, and a mechanism with greater bank capacity has also become necessary. The improvements that have been developed and the way in which the bank capacity has been increased are described.

INTRODUCTION

THE Post Office Type 2 uniselector[1] has proved to be of a fundamentally sound and trouble-free design during the 10 years, approximately, since it was first brought into service. Nevertheless, certain improvements of detail have been found desirable, and these are described below. Also, a need has arisen for a third size of mechanism, having 10–12 levels or contact arcs, to supplement the original 3–5-level and 6–8-level mechanisms, and a uniselector of this capacity is being introduced.

BRUSH FEEDS

The most difficult maintenance operation during adjustment of the Type 2 uniselector is to replace the mechanism in its bank. This is because each brush feed consists of two splayed contact members that have to be compressed together by a comb tool of insulating material so that their tips enter the collector rings of the mechanism wiper assembly without fouling; the comb is subsequently removed. A new brush feed has been designed, dispensing with the need for a comb tool. It will be fitted initially to 12-level mechanisms and later to 3–5-level and 6–8-level mechanisms.

The new brush, called a "self-feed" brush because it feeds itself into position if the mechanism is correctly inserted into its bank, still has two splayed contact members (see Fig. 1). These are much shorter than in the present design of brush feed (so that the amount of deflexion for the same contact pressure is much less), and they come together at the "heel" of the brush just outside the associated collector ring of the inserted mechanism. At this heel they are spot-welded to a single member that extends to the top of the bank, where it is clamped, together with the other brush feeds serving the remaining collector rings, in a manner similar to that of the present design of brush assembly. Relative to the direction of rotation of the wiper assembly the contact tips "trail" the heel of the brush, and so extend further into the bank. Hence, when the mechanism is inserted in the bank, with the wipers set on contact 3 so that they pass between the upper ends of the brushes before the brushes enter the collector rings, the heel of each brush enters its associated collector ring in advance of the trailing tips. As the mechanism is inserted further into the bank the sides of the collector ring press the splayed tips together so that they automatically assume their correct position when the mechanism is finally home in the bank.

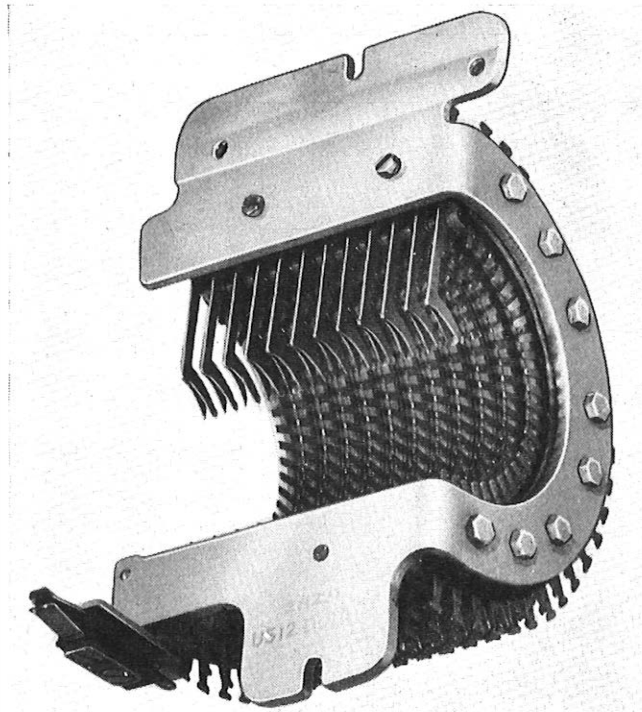

FIG. 1—TYPE 2 UNISELECTOR BANK WITH NEW-TYPE BRUSH FEED

BANK CONSTRUCTION

In the original form of bank construction, one or more sectors of bitumenized cloth were assembled between each arc of contacts and the insulating sectors on each side of the contacts. These cloth sectors were slightly tacky and compressible, and, with the high bank-clamping pressures used, helped to keep the contacts in place. In recent years, certain manufacturers have secured the contacts directly to the insulating sectors with adhesive, and other manufacturers are preparing to introduce a form of bank construction similar to that used in the Type 4 uniselector,[2] in which each arc of contacts (except any homing arc) is moulded into a sector of thermoplastic insulating material (Fig. 2), thus dispensing with the need for separate insulating sectors and

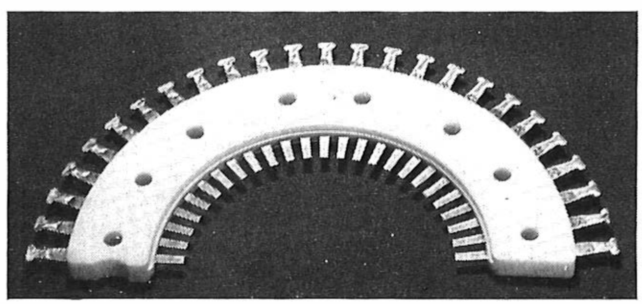

FIG. 2—MOULDED CONTACT-SECTOR

†Telephone Exchange Standards and Maintenance Branch, E.-in-C.'s Office.

[1] THOMPSON, J. O. The New Post Office Standard Uniselector. *P.O.E.E.J.*, Vol. 42, p. 17, Apr. 1949.

[2] MANNING, D. J. The Post Office Type 4 Uniselector. *P.O.E.E.J.*, Vol. 52, p. 215, Oct. 1959.

aluminium spacers. This method of construction reduces assembly costs and gives the maintenance facility of enabling single arcs to be replaced.

It has been found, with this moulded construction, that crosstalk between the arcs is not worsened by the absence of metal separators. The insulators in the original Type 2 uniselector bank were made proud of the aluminium spacers to prevent the metal dust, formed as a result of heavy use, causing tracking between contacts; the moulded sector is formed into a ridge along the line of the contacts for the same reason.

WIPER-ASSEMBLY CLAMP

A valuable feature of the Type 2 uniselector is that the drive mechanism can be adjusted independently of the position of the wipers on the bank contacts and with the mechanism withdrawn from the bank. When the mechanism is replaced in the bank the wipers can be rotated over the bank contacts, with the ratchet wheel held stationary by the pawl and detent, until the wipers are positioned correctly on the middle third of a contact. Once this adjustment is achieved the wiper assembly is secured firmly to the ratchet wheel by tightening a clamp that compresses a collar at the number-wheel end of the wiper hub on to the ratchet-wheel hub; the ratchet and wiper assemblies thereafter rotate as a whole on the fixed spindle when the pawl is operated. The wiper hub is of stainless steel, and the compressible collar is formed at its end by means of a T-shaped slot. When compressed by the clamp, the two "wings" of the collar wrap tightly round the ratchet hub, making a secure coupling. There have been occasional reports of failures of this coupling due to one wing of the wiper-hub collar breaking, and a new coupling has been designed in which the end of the wiper hub has six radial slots equally spaced around its circumference forming six equal leaves which the clamp compresses inwards upon the ratchet-wheel hub (see Fig. 3). With this type of coupling, brass, which is a much more easily-worked material than stainless steel, is a suitable metal for the wiper hub.

The new 12-level mechanism also uses the new type of ratchet-wiper coupling, but here the clamp is at the ratchet-wheel end of the wiper assembly (see Fig. 4). This makes possible an arrangement that considerably eases manufacturing problems, since the ratchet-wheel hub extends only to the depth of the wiper-hub collar. The wiper-hub collar has a considerably greater external diameter than that of the main length of the wiper-hub thereby allowing the wipers, etc., to be clamped against the shoulder thus formed.

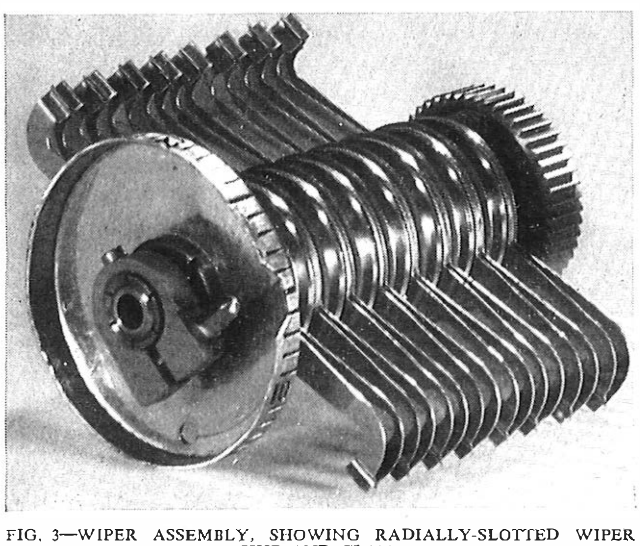

FIG. 3—WIPER ASSEMBLY, SHOWING RADIALLY-SLOTTED WIPER HUB AND CLAMP

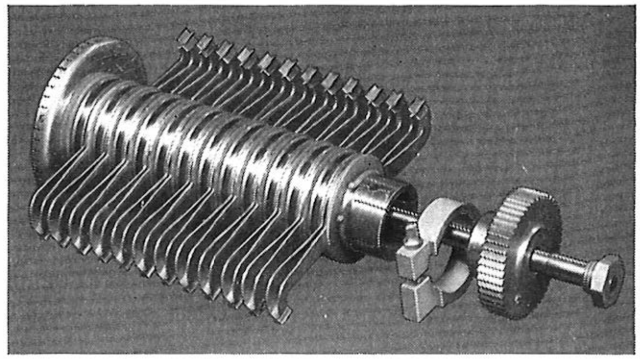

FIG. 4—TWELVE-LEVEL WIPER ASSEMBLY, SHOWING WIPER HUB, CLAMP AND RATCHET WHEEL

The end of the wiper-hub collar adjacent to the shoulder is of sufficient thickness for a 0·040 in. hole to be drilled radially from the outside of the collar through to the cavity between the hub and the spindle, thus providing a means of lubricating the spindle while the mechanism is in its bank. After lubrication, the outer end of the oil-hole is sealed by rotating the clip encircling the shoulder end of the wiper-hub collar. It is not practicable to provide this facility in the 3–5-level and 6–8-level mechanisms; with the new brush-feed assembly already mentioned, however, it will be comparatively simple to remove these mechanisms from their banks to lubricate the spindles, and afterwards to replace them.

INTERRUPTER CONTACTS

The Type 2 uniselector is primarily a heavy-duty switch and, therefore, the interrupter contacts were originally always of tungsten. Because an insulating film forms rapidly on the surface of this metal, the interrupter was designed so that the contacts closed with a pronounced rubbing action. Trouble has been experienced, however, where the uniselector is more lightly worked as the film is not ruptured so readily; failure to start may result except where initial energization is direct and not via the interrupter contacts.

Many of the Type 2 uniselectors used in lighter-duty applications are of the non-homing type, and it has been decided, in the interest of rationalization, that all non-homing Type 2 uniselectors will in future have platinum specified as the interrupter-contact material, thus eliminating the contact-resistance problem. This decision applies to all three sizes of mechanism.

CONCLUSIONS

The various improvements in the Type 2 uniselector mechanism-and-bank design that have been described are expected to reduce manufacturing and service costs, and make for easier maintenance.

Components and Materials for Submarine Repeaters

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U.D.C. 621.395.64—772:621.375.2:621.315.28

The design of components for submarine repeaters, their mounting and assembly provide problems that are almost unique to such equipment. The factors affecting component design for valve-type repeaters are discussed, and the types of component considered to be suitable for submarine repeaters are reviewed; two examples are described in more detail. A device, designed specially for submarine repeaters, that short-circuits the heaters of a faulty amplifier is also described.

INTRODUCTION

REPEATERED carrier-frequency cable links have been in use on land for 30 years; the ability to apply similar techniques economically to submarine cables was delayed, not by circuit considerations, but by the lack of suitable long-life components.

The first British submarine repeaters, other than experimental ones, were designed for insertion in existing shallow-water cables between Great Britain and the continent of Europe, and, for their economic operation, a repeater life averaging at least 5 years was required. The life of the type of valve then available, even excluding early failures, was not expected to exceed this figure, and it was therefore necessary to plan for the remaining components to have an estimated mean life well in excess of 5 years and the minimum possible early-failure rate.

The economics of present-day long-distance submarine-cable schemes require an average repeater life of more than 20 years, and valve designs are now available with estimated mean lives in excess of 30 years. Life tests and operational experience of the components designed for shallow-water repeaters indicated that they had a mean life well in excess of 20 years and that with minor modifications they would be satisfactory for inclusion in long-distance submarine-cable schemes. A large part of the recent component development has, therefore, been directed towards details of design, control of manufacture and inspection to reduce the early-failure rate. However, new components have been and are being developed to meet the steadily-changing requirements of the circuit designers and to enable existing requirements to be met more economically.

This article is concerned only with types of submarine repeater that have been manufactured in quantity, i.e. valve repeaters operating in the frequency band up to approximately 1 Mc/s. Submarine repeaters operating up to higher frequencies, using either valves or transistors, are now coming into service. These new designs will involve a few new requirements for components, and the types being considered are discussed later. The thermionic valves have already been described in detail* and are not considered here.

The electrical characteristics required for the majority of the components to be considered are those normally associated with amplifiers, filters and equalizers for the frequency range up to 1 Mc/s. Unusual requirements arise, however, because of the method of feeding power to submarine repeaters (Fig. 1). The repeaters are energized as a series load by a constant direct current in the centre conductor of the cable; the bulk of the electrical circuit is, therefore, above case potential by up to 5 kV, the exact value depending on the system concerned and the position of the repeater in the system. Consequently, there is a requirement for high-voltage capacitors in the power-separating filters and for rapid-acting protective devices across the transmission circuit to prevent damage if certain types of cable fault occur. Further, since the forward gain path of the amplifier is duplicated but the high-tension (h.t.) voltage for both paths is developed across all the valve heaters in series, it is necessary to provide a special component (short-circuiting fuse) to short-circuit the heaters of one forward gain path if an associated heater should fail.

A component is included to measure the relative humidity between the sealed inner capsule and the outer pressure case to check that the sealing operations on the outer case have been successful. This component is required to operate only during the late stages of manufacture of the repeater and not during its working life.

Reliability is closely related to circuit design and overall repeater design. The circuit engineer states what he wants, and the component and repeater engineers will state how nearly his requirements can be met. The final designs will be a compromise, produced by a process of successive approximation, between the performance the circuit engineer wants and the performance the component engineer can offer in the environment the overall design dictates. Factors affecting component performance are: temperature range, pressure range, a.c. and d.c. electrical stressing and loading, the surrounding atmosphere (including humidity and corrosion products), shock and vibration. Consideration must be given to the most adverse combination of these factors that will occur during operation, storage and transportation.

GENERAL

Certain features of construction and usage are common to all the components in a submarine repeater.

Operating Conditions

The components are housed in brass containers within the repeater pressure-case, and these containers are flushed with dry nitrogen for 24 hours and then sealed with a dry-nitrogen filling at atmospheric pressure and temperature. Measurements of early types of repeater indicate that the relative humidity slowly rises over a period of months, as occluded moisture leaves the components, and finally stabilizes at approximately 40 per cent at 10°C; this corresponds to the relative humidity in the repeater assembly shop.

To make provision for testing, laying and operating

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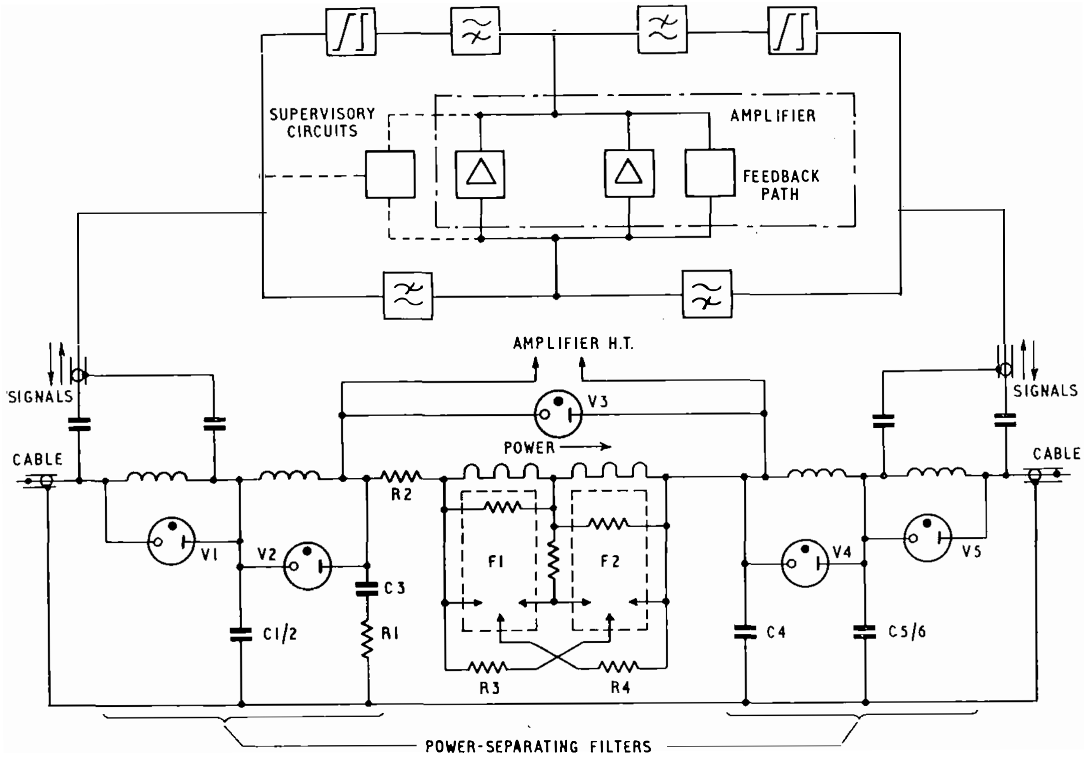
*HOLMES, M. F., and REYNOLDS, F. H. New Valves for Deep-Water Submerged Telephone-Repeaters. *P.O.E.E.J.*, Vol. 53, p. 98, July 1960.



V1–V5—Gas-filled cold-cathode diodes. C1–C6—High-voltage capacitors
F1, F2—Short-circuiting fuses. R1—Moisture detector

FIG. 1—SUBMARINE-REPEATER CIRCUIT

repeaters in any part of the world it is necessary to design for the following ambient temperature ranges:

Storage while unenergized	−20°C to +40°C
Testing single repeaters	−5°C to +25°C
Testing a chain of repeaters	0°C to +25°C
Operational repeater system	0°C to +25°C

The temperature rises within the British type of deep-sea repeater are:

Amplifier (at the centre of the repeater)	15°C to 29°C
Power-separating filters (at the ends of the repeater)	7°C

The components are not required to withstand large mechanical shocks during their manufacture or normal operation, but during repeater laying or recovery accelerations up to 10*g* can be experienced by the outer pressure-case.

Materials

The majority of units within the internal assembly are unsealed and any vapours evolved come into contact with most of the other components. Vapour concentrations build up, since there is no overall exchange of atmosphere as normally occurs in shore-based equipment. All materials must therefore be mutually compatible, not only within a component but also from component to component. In practice this means the exclusion of phenolic materials; polythene, perspex, vinyl-acetal enamel, silk and ceramic are used for the majority of insulating requirements as well as polypropylene, polyurethene and polytetrafluorethylene for a few special applications. Life tests have been conducted in air, nitrogen and simulated repeater atmospheres on repeater components using these insulants, and no mutual incompatibilities have been detected; further, there are no significant differences in the aging rates in the different atmospheres.

Certain metals grow whiskers when left undisturbed for long periods; tin and cadmium are particularly affected. These whiskers grow through surface layers such as lacquer or paint, but can be contained by insulating barriers spaced from the metal surface. This technique is complex and space-wasting, and metals liable to grow whiskers are excluded from submarine repeaters. Brass and copper, extensively used in submarine-repeater construction, do not grow whiskers, but if they are left unfinished they tend to become discoloured during the manufacturing processes and spoil the appearance of the finished article. The majority of such surfaces are therefore gold-plated; gold has a good appearance, does not grow whiskers, and solders well if suitable precautions are taken.

The normal approach is to exclude any part of a component not essential to its use in submarine repeaters. Extreme care in handling during manufacture enables protective screens and coatings to be eliminated, thus permitting more effective inspection of completed components.

Soldering

Unless destructive techniques are used in testing, the only competent judge of the quality of a soldered joint is the person who makes it. However, measures are taken to minimize the possibility of bad joints and of damaging components during soldering operations. Not more than two wires are permitted to be soldered to one arm of a tag; this facilitates the observation of the flow of solder when a joint is being made. Tag arms are chosen to have thermal capacities similar to those of the wires terminating on them, and it is usually possible to make the lead from the tag to the component sufficiently long to ensure that the component is not affected by heat conducted along the wire; if this is mechanically unreasonable, heat shunts are clamped on the wire during soldering.

Solder having a 60:40 tin-to-lead ratio is used for all tinning and soldering operations; this is on the excess-lead side of the eutectic alloy and does not leave free tin after soldering, thus preventing whisker growth. When gold-plated surfaces are being soldered the quantity of gold present must be carefully controlled since, if an alloy containing more than 0·5 per cent of gold is formed, the mechanical strength of the joint is seriously reduced. It is not permissible for a joint to be re-made; if a joint has to be replaced the piece-parts associated with it are also renewed.

Coding

Type, value and serial-number markings are not permitted on the body of a component if such markings introduce unnecessary additional materials or prevent an important part of the component from being inspected. Where necessary, markings are made on tally plates fixed to the leads, and the tallies are removed when the components are being fitted in their appropriate repeater assemblies.

FAILURE RATE OF COMPONENTS

The well-known failure-rate/time curve for electronic components is shown in Fig. 2; the curve is split into

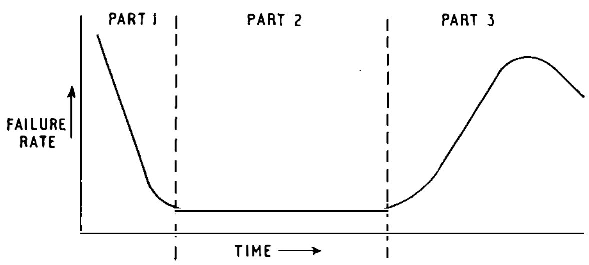


FIG. 2—FAILURE-RATE/TIME CHARACTERISTIC FOR ELECTRONIC COMPONENTS

three parts. Part 1 indicates the failure rate when "rogue" failures are occurring due to manufacturing faults not detected during inspection. Part 2 shows the failure rate during the useful operating life of components, when the failures are random and due to miscellaneous design weaknesses; failures in this part are at an approximately constant rate. Part 3 shows the rate during the natural wear-out of a component.

The period corresponding to part 1 must be completed before the components are brought into operational service, and this can be achieved by rigorous inspection and testing at all stages of manufacture and by generous pre-aging with careful observation of component parameters before, after and during the pre-aging period. Components that deviate from the normal performance during pre-aging are discarded even if the deviations suggest that the component is superior rather than inferior to average.

The period represented by part 3 can be established to be well beyond the required component life. This can be done by utilizing engineering experience and the results of life tests on different batches of components subjected to different degrees of acceleration for each significant operating parameter. The results of accelerated tests must, however, be interpreted with extreme caution since accelerating one mechanism of failure may inhibit another. Acceleration laws are difficult to establish, and the mechanism actually responsible for failure under normal operating conditions may be one that is inhibited by acceleration.

The period corresponding to part 2 is of great interest. By establishing the failure rate for each type of component during this period it is possible to calculate the failure rate of each part of the repeater, to establish the degree of component or unit duplication required, and to calculate the failure rate of complete repeaters or equalizers and hence complete systems. Unfortunately, however, part 2 is the part of the curve that cannot easily be determined for repeater components. With normal commercial components the failure rate per unit of time (about 0·10 per cent per 1,000 hours) can be determined with sufficient accuracy from the failure rate of reasonably small batches of components on life test for practicable periods. For long-distance submarine systems, by calculating backwards from the economically-permissible failure rate of the system it can be shown that failure rates at least two orders better than those obtained on commercial components are required, and, to obtain the failure-rate results in a reasonable time, hundreds of thousands of components would have to be placed on life test.

To obtain valid results it is necessary to test components made to precisely the same standards as those to be used ultimately, and this would involve quantities of components far in excess of normal production requirements and entail prohibitive costs. Of the 200,000 components at present in service in British deep-sea repeaters for periods of up to nearly 10 years there have not, as yet, been any failures. This gives some idea of the size of sample that would be required for useful life tests.

COMPONENT DESIGN

The following procedure, therefore, has been adopted as the basis of component design:

(*a*) Basic designs are chosen that are known, from engineering experience and available life-test data, to be of proven integrity.

(*b*) Designs are chosen for which the maximum information is known about the basic methods of deterioration and for which it is possible to ensure by inspection at every stage that the manufacture has been correctly executed.

(*c*) The design is examined in detail for obvious weaknesses, usually present as a result of commercial economies; the item is re-designed where necessary.

(*d*) The re-designed component is subjected to shock tests, vibration tests and temperature-cycling tests to a degree well in excess of that experienced in the component's normal environment. The components are also subjected to degrees of accelerated electrical stressing to destruction. Such tests reveal methods of failure, if not evaluating the order in which they would occur, and indicate safe electrical loadings.

(*e*) The design is then modified if the above tests suggest it to be necessary, and the component is again subjected to the same sequence of tests.

(*f*) The manufacturing, inspection and testing specifications for materials, piece-parts and every stage of manufacture are written so as to ensure that the design requirements are always carried out.

(*g*) Lastly, small batches of components are life tested at a range of accelerations to gain confidence that the design does not contain major mistakes.

COMPONENTS USED IN REPEATERS

The procedure described in the preceding paragraph suggested that the following types of component were capable of being developed for submarine-repeater use:

(*a*) Carbon-rod resistors for general low-wattage high-frequency applications in the amplifier. Their stability is poor, but this is a known characteristic and can be allowed for in the circuit design.

(*b*) Precision wire-wound resistors, on ceramic formers and using wax-impregnated vinyl-acetal-insulated wire, for use in the amplifier and equalizers.

(*c*) Vitreous-enamelled wire-wound resistors on ceramic formers for the d.c. power path.

(*d*) Epoxy-resin-encapsulated silvered-mica capacitors for high-stability requirements in filters and similar networks where the applied d.c. potential does not exceed 10 volts.

(*e*) Air-dielectric trimmer-capacitors for in-situ adjustment of critical resonant networks.

(*f*) Oil-impregnated paper capacitors with metal cans and ceramic-sealed terminals for the high-voltage units and all other miscellaneous capacitor requirements.

(*g*) Air-cored inductors manufactured by the same techniques as the precision resistors, together with dust-cored inductors and transformers for use in the amplifier, filters and equalizers.

(*h*) Quartz-crystal units and selected crystal-diodes for the supervisory units.

(*i*) Gas-filled cold-cathode diodes as surge suppressors in the d.c. path of the repeaters.

As will be seen from this list, the repeater circuit designer is confined to a narrow range of components, some of which are obsolescent for high-frequency techniques, but this is the price paid for reliability.

EXAMPLES OF DESIGN

The design approach already outlined is the same for all components, and since each individual design involves attention to a myriad of details it will be sufficient to describe the design of two fairly simple components to illustrate the technique.

Wire-Wound Vitreous-Enamelled Resistors

A simple, but good, example is the wire-wound vitreous-enamelled resistor, since such resistors are not always highly reliable when produced commercially.

Life tests, engineering experience, and the performance of such units in very early repeaters indicated that failures in commercial components were caused by:

(*a*) corrosion of the wire, particularly fine-gauge-wire, when resistors with crazed or pinholed enamel were run well below their maximum rating, thus permitting the ingress of moisture,

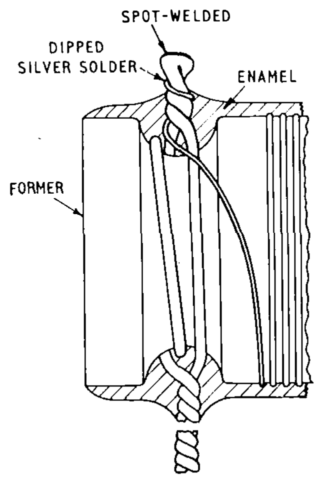
(*b*) poor insulation-resistance of certain ceramics used for formers when operating at high temperatures, leading to breakdown between the winding and the mounting posts,

(c) movement of the winding during firing of the enamel, and

(*d*) failures at the terminations due to straining the wire, nicking on sharp edges, and poor welds.

The last group of failures is the most common.

Units for submarine repeaters are produced with high-alumina ceramic formers that are subjected to detailed mechanical and visual inspection, and a new terminating technique for the winding has been developed, as shown in Fig. 3. One-piece terminating posts and lead-out



The enamel is shown in section
FIG. 3—TERMINATION OF WIRE-WOUND RESISTORS

wires without sharp edges are formed from nickel-chromium wire. The resistance winding is also of nickel-chromium, and the gauge of wire has been arbitrarily limited to not less than 41 s.w.g. This decision is based on considerations of handling and the risk of accidental damage during manufacture, coupled with the physical size of the components and the electrical performance required. Further, the space between turns is not permitted to be less than the diameter of the wire. The wire is terminated by winding into the thread of the terminal post, and is first secured by a specially-developed dip silver-soldering technique; it is further secured by spot welding to the top of the post. To prevent nicking the wire it is positioned with special rounded-contour tools only, and the posts are not disturbed after the terminations have been made, so that no strain is imparted to the wire.

Before enamelling, the winding and terminations are inspected with a $\times 35$ stereoscopic microscope. The most satisfactory craze-free and pinhole-free enamels developed to date are unfortunately not transparent, but satisfactory X-ray techniques, requiring three views, have been developed to inspect the winding after enamelling. The silver solder softens during firing, but is contained by the enamel, and the re-formed joint is completely satisfactory. The enamel has to be cracked-out of the lead-out wire after firing, and the crazing that occurs at this point is sealed with an epoxy-resin fillet. The finished design has been subjected to the testing techniques that have already been described and has been found to be completely satisfactory.

The operating temperatures for vitreous-enamelled resistors are relatively high, and, therefore, the mechanical strains between no load and full load are large compared with other types of repeater resistor; thus, the test procedure for each component includes noise measurements with and without percussion, both on and off load. A further check for short-circuited turns is made by checking the resistance before and after 1-hour load cycles.

Gas-Filled Cold-Cathode Diodes

A second example of component development is the surge-suppression diode used in the power path.

On submarine-cable systems operating with power-feeding voltages in excess of 2kV, the transient voltages generated by the discharge of the cable and repeaters into a shunt cable-fault can damage components in the transmission path of the repeaters. The voltages are generated across the power-filter inductors and, hence, across the passive sections of the transmission path and also across the amplifier h.t. supply, i.e. the heater chain (see Fig. 1). The rise time of transients across the inductors can be as short as 1 μs. The rise time across the h.t. supply is modified by the power inductors, but can be as short as 4 μs.

Various commercial designs of cold-cathode diode were investigated with the possibility of their meeting, or being modified to meet, the following requirements:

(*a*) Not under any circumstances to be a hazard to the repeater reliability.

(*b*) To be, if possible, reasonably small.

(*c*) To retain their characteristics after long storage periods in the dark.

(*d*) To retain their characteristics after repeated discharges with energy content of the order encountered in service.

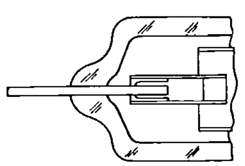
(*e*) To have low self-capacitance.

(*f*) To have a high RC product even after repeated discharges.

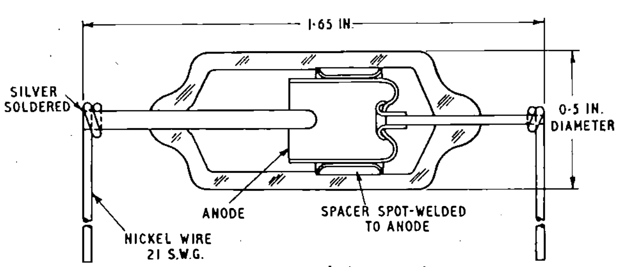
(*g*) To limit a 1 μs rise-time, 50 μs decay-time, 5 kV pulse to approximately 1 kV (Type A).

(*h*) To limit a 4 μs rise-time, 50 μs decay-time, 5 kV pulse to approximately 0·75 kV and also to extinguish in the face of an applied potential of 220 volts irrespective of the past electrical history This last requirement is to prevent the diode from continuing to conduct after a discharge, so preventing the short-circuiting fuse from operating in the event of a heater failure (Type B).

The most suitable standard commercial product is shown in Fig. 4(*a*). It is small and meets the broad



(*a*) Normal Production Component



(*b*) Submarine-Repeater Component

FIG. 4—GAS-FILLED COLD-CATHODE DIODE

electrical requirements for Type A. The tube is hydrogen-filled, has a nickel anode and a nickel-cathode sleeve, both of which are spot-welded to tungsten lead-out wires. It is kept ionized by a small quantity of radium bromide. A number of tubes of this type were tested to destruction by progressively increasing the energy content of applied surges. The first failures occurred when the nickel cathode became detached from the lead-out wire; at higher energies the envelope became fractured adjacent to the seals. The tube was re-engineered as shown in Fig. 4(*b*), with an integral tungsten cathode and lead-out wire and with the anode spacer welded to the anode. The metal-to-glass seals were improved by chromium plating the wire leads over the length in contact with the glass, the quantity of radium bromide was increased to ensure adequate ionization during the required long life, nickel-chrome connecting wires were silver-soldered to the tungsten leads, and the tube was mounted in an epoxy-resin box that retains the relative positions of the electrodes even if the glass envelope is fractured.

Extensive tests have indicated that the re-engineered tube has all the required properties. A similarly-engineered tube, argon filled, with a smaller electrode gap has been developed to meet the requirements of Type B.

The presence of radioactive material necessitates special precautions when handling the tube. The α and β radiation outside the glass envelope is negligible, and the γ radiation is only injurious if tubes are kept in close contact with the body for long periods. There is, however, a risk if the materials are ingested or inhaled when a tube is fractured, and special precautions have been taken to dispose of the waste if this should occur.

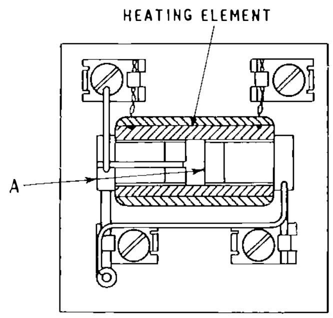
SHORT-CIRCUITING FUSE

The short-circuiting fuse was developed to meet a requirement that is peculiar to submarine repeaters.

With constant-current series power-feeding it is very desirable to maintain the continuity of the power circuit in the event of a valve-heater failure, to enable the remainder of the system to be energized for fault-location purposes. When parallel forward gain paths are employed in the amplifier it is necessary to restore the circuit across the group of heaters containing a failure, and with paralleled paths deriving their h.t. from within the heater chain it is further necessary to compensate for the change in total cathode current to maintain the correct heater current in the surviving half of the amplifier. The requirements might possibly be best met by an arrangement of non-linear resistors, but units with satisfactory long-term stability and reliability are not available.

Relays can be designed to meet these broad requirements, but the use of dry contacts in the main power loop was not favoured. A special component was therefore developed consisting of a wire-wound heating element surrounding separated contact-billets of fusible alloy. The heating element is connected across the valve heaters of each path (see Fig. 1) and normally passes only a small part of the direct line current; the temperature attained is then insufficient to melt the fusible alloy. When a valve heater fails, the total line current is diverted through the heating element across the relevant group of heaters, and the temperature rises to melt the alloy and fuse the contacts. The fused contacts connect resistors in circuit to restore the operating conditions of the surviving paths and re-divert the current away from the heating element; the fused contacts therefore cool and solidify.

There are many practicable geometrical configurations that will meet the above requirements, but the design indicated in Fig. 5 was chosen as it used the developed



A—Two fusible-alloy cups, each split and insulated to provide two contacts
FIG. 5—SHORT-CIRCUITING FUSE

and proved construction of vitreous-enamelled wire-wound resistors as a heating element. Numerous features must be satisfactorily combined to guarantee a good-quality fused joint in all possible positions of operation of the fuse, e.g. the geometry of the cups, treatment of the exposed alloy surface, the flow qualities of the alloys, surface qualities of the internal insulating materials and the temperature/time characteristics of the heating element after it has been switched off.

The fusible alloy used is a tin-lead-cadmium eutectic with a sharply-defined melting-point. The alloy does not require an active flux, and the exposed surfaces are protected by a thin coating of micro-crystalline wax. The composition of the alloy is carefully controlled to ensure the absence of blow holes and dross pockets when manufacturing the cups.

One in every 10 fuses manufactured is blown, and its failure to operate satisfactorily would be a cause for rejection for the whole batch. Fuses have been tested for several years with the normal current through the heating element. Some have then been opened, and detailed inspection has not revealed cold flow of the alloy or protecting wax or any signs of whisker growth. Others have been operated under conditions simulating a valve-heater failure, and the fused points have been found to be completely satisfactory.

MANUFACTURE

The construction of submarine-repeater components is carefully controlled by detailed manufacturing, testing and inspection specifications. At each major stage of manufacture 100 per cent inspection is required, and 100 per cent inspection of every finished item is followed by slightly-accelerated confidence tests.

Coupled with careful design, specification and inspection, however, there must be the desire and ability of the operators to make good components, if consistently satisfactory results are to be obtained. Different contractors have different methods of selecting and training personnel, but the result must be operators who are highly self-critical and completely trustworthy. They must be permitted to work without strain in an environment of highest-quality workmanship. It has not been found possible to combine two or more standards of quality in any particular manufacturing area without jeopardizing the highest. Thus all parts must be manufactured to the highest standard required irrespective of their function in the component or the function of the component in the repeater.

Every finished component is subjected to both contractor and customer inspection, both electrical and mechanical. The customer's inspectors have free access to inspect all materials and manufacturing processes in any of the contractors' works. At the repeater manufacturer's works the coils and capacitors are manufactured in special areas controlled to a temperature of 70 $\pm$ 1°F at a relative humidity of 20 per cent. Precautions are taken in the area to prevent the generation of dust, and a pressurized air-conditioning system prevents the entry of dust particles larger than 0·2 micron. Similar precautions are taken in the remainder of the repeater-manufacturing area to maintain the temperature at 68 $\pm$ 2°F and the relative humidity at 40 per cent and to exclude dust particles larger than 5 microns.

NEW TYPES OF COMPONENT

The types of component that have been discussed should be suitable, with minor modifications, for repeater design up to 3 Mc/s. Above this frequency, wire-wound resistors (except in the d.c. path) and oil-impregnated paper capacitors will have restricted use. It is hoped that metal-oxide resistors will satisfactorily replace the majority of wire-wound resistors and also be used to advantage in place of carbon-rod resistors. The most likely replacements for paper capacitors are ceramic and solid-tantalum electrolytic capacitors, but considerable work is required to prove they can be made to the required standards of reliability. Numerous new plastic materials are attractive, but few can show positive advantages over those already employed. The most promising are polycarbonates, polymethylene oxides and low-water-absorbtion nylons.

CONCLUSION

The high reliability of long-distance submarine-cable systems is obtained by meticulous attention to every detail that might be a cause of failure. After the production of the components every sub-assembly, functional unit and complete internal unit is rigorously tested and inspected. The completed repeater is subjected to a 6-week confidence trial with stringent requirements for all aspects of performance. New problems face the designers; whereas in the past submarine-repeater systems have had only to satisfy their own economics, now, with international competition between manufacturers, and with competition from communication satellites, it is desirable that the cost of submarine-cable systems be reduced and that failure rates should be determined to enable systems to be designed to the economic optimum as distinct from being only economically profitable. As more and more components are made and more cables are laid the necessary information will be steadily obtained.

A New Self-Contained Tree-Cutting Unit

E. W. CHARLTON, A.M.I.Mech.E.†

U.D.C. 629.114.7:634.0.31

An elevating platform, mounted on a Land-Rover and equipped with a 110-volt generator and electric tree-cutting tools, and a trailer-mounted brushwood chipper are described.

INTRODUCTION

TREE cutting has in the past usually been carried out by 3-man or 4-man parties equipped with ladders, pruning tools, saws and sashlines. The introduction of hydraulically-operated elevating platforms mounted on Land-Rovers and equipped with electrically-operated tools has enabled this work to be performed by 2-man parties.

The ease and safety with which the hydraulically-operated platform can be manoeuvred into positions that would have been difficult to reach, or even inaccessible, employing ladders has not only speeded up the process of tree cutting but has also enabled more effective cutting to be carried out, thereby reducing the periodicity of the work. This has, however, introduced a fresh problem—the disposal of a much greater quantity of timber in a given time. Disposal of this waste is not always easy, and in many instances it has to be carted away in a stores-carrying vehicle for a considerable distance to some convenient place where it can be burned. This means employing a third man and a vehicle to attend the tree-cutting party.

A trailer-mounted brushwood chipper has, therefore, been purchased for a trial, and it is hoped that the machine will solve the disposal problem by reducing the tree cuttings to small wood chips on the spot. The wood chips can either be bagged automatically or discharged directly into the hedgerow or woodland, where they will quickly rot down. The chips make excellent mulch and compost for orchards and market gardens, and can also be used for cattle bedding and poultry litter. There should, therefore, be no difficulty, when the chips are bagged, in disposing of them to advantage.

†External Plant and Protection Branch, E.-in-C.'s Office.

TREE-CUTTING UNIT

Carrying and Towing Vehicle

A general view of the complete tree-cutting unit is shown in Fig. 1. The chassis and cab of the carrying and towing vehicle are those of the standard 109 in. wheelbase Land-Rover converted for road use. Hydraulically-operated spring lock-out jacks, which lock the superstructure firmly to the rear axle, and two manually-operated telescopic tubular stabilizers have been added to maintain stability during operation of the platform.

Two full-length tool boxes have also been added, one on either side. Each tool box is 6 ft long, 10 in. wide and 18 in. deep, and has a lockable lid designed to give easy access from the roadway. The axle loadings of the vehicle permit 1 cwt of tools and stores to be carried in each toolbox. A mounting for a 110-volt generator has been provided on the floor of the vehicle immediately behind the cab, and a towing hitch has been provided for trailing the brushwood chipper. The spare wheel is carried on the bonnet. Accommodation has been provided on the cab roof for a sectional aluminium ladder. The ladder, which comprises five 4 ft sections, is carried in an open sheet-metal box. One end of the box is hinged to facilitate removal of the ladder, and two straps are provided to hold the sections firmly in position during transit. The ladder is provided for those few occasions when it may not be possible to manoeuvre the vehicle into a suitable position to enable tree cutting to be carried out from the platform.

Elevating Platform

The elevating platform is a commercially-produced item (Simon Engineering, Dudley, Ltd., Model L 25) consisting of a fibre-glass cage 2 ft 1 in. square and 3 ft 3 in. deep, mounted on two booms fitted to a turntable centre post. The platform is operated entirely by hydraulic means from a pump driven from the power take-off on the Land-Rover, with all movements of the booms controlled from the cage by hand-levers situated at the top of the upper boom. Fig. 2 shows the platform in use.

The maximum safe working load that can be carried in the cage is 250 lb. Maximum height from the ground to the floor of the cage is 21 ft and the maximum out-reach from the centre post to the front of the cage is 12 ft 3 in. round an arc of 300°. The cage has a roughened floor to reduce the possibility of slipping in wet weather, and an aluminium tool rack has been fitted to the inside of the cage to accommodate a chain saw and other pruning tools.

The platform is stable on hard level ground without the stabilizing jacks, but on soft or sloping ground they make a useful contribution to the stability of the unit. It is necessary for the vehicle brakes and the rear-spring lock-out jacks to be applied on all occasions before the platform is used, and metal

FIG. 1—COMPLETE TREE-CUTTING UNIT

FIG. 2—ELEVATING PLATFORM IN USE

wheel-chocks are also provided for use when the platform is being used with the vehicle on an incline.

Electric wiring has been run along the booms from the turntable to the cage. The 110-volt generator can be plugged into a weatherproof socketed plug at the turntable, and the socket-outlet at the cage permits the use of electric tools such as chain saws and pruners. The cage is insulated from the booms and affords protection to the operator from overhead power lines.

An extended cradle from the lower boom has been provided to carry the upper boom at a level high enough in the travelling position to clear the trailer chipper unit. The platform is prevented from slewing during transit by means of a turntable locking screw.

Chipper

The chipper, which is of American manufacture (Fitchburg Engineering Corporation, Mass., U.S.A.), will accept timber up to 4 in. in diameter and will reduce tree branches to small wood chips in a matter of seconds.

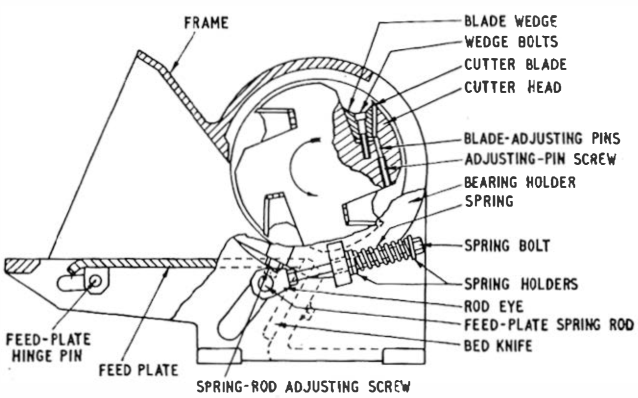


FIG. 3—CROSS-SECTIONAL DRAWING OF CHIPPER

It is possible for a 2-man party to convert 1 ton of timber to wood chips in 1 hour. Fig. 3 shows a cross-sectional drawing of the chipper.

The chipping unit consists of a $9\frac{1}{2}$ in. diameter cutter-head with four specially-tempered chrome-steel $6\frac{3}{8}$ in. wide cutter blades, equally spaced round the cutter head. The blades are securely locked in by steel wedges. A hardened tool-steel bed knife with four usable cutting edges is anchored to the chipper main frame. A special feature of the Fitchburg chipper is the spring-activated feed plate, which automatically adjusts itself to large or small material without the need for a large flywheel running at high speed.

The chipper is powered by a petrol-driven Ford 4-cylinder heavy-duty industrial engine developing 48 b.h.p. at 2,800 rev/min, and the cutter head, which is accurately machined and carefully balanced, is belt driven and runs at 2,300–2,400 rev/min. The power required for average working conditions is 30–35 h.p.

The chipper is fitted with a folding sheet-steel feed apron of sufficient size to permit a quantity of brushwood to be fed into the chipper easily with a minimum of trimming. The feed apron, as shown in Fig. 4, is

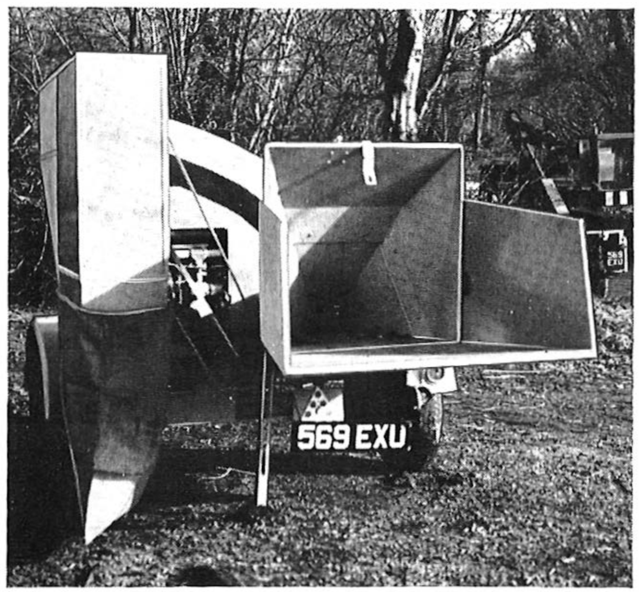


FIG. 4—FEED APRON AND BAGGING UNIT

large enough to prevent the operator from getting his hands into the cutter.

The overall dimensions of the chipper are as follows:

Length, from towing eye to feed apron (closed)	118 in.
(open)	149 in.
Width over mud wings	71 in.
Height to top of engine casing	55 in.
Weight	1 ton

A two-position engine-throttle control is conveniently positioned on the side of the chipper feed apron. For normal working the engine requires full throttle, but when the chipper is not in use the engine can be made to idle by pressing the throttle-control knob. An emergency stop button is provided at the top of the feed apron immediately in front of the operator, and when this is pressed the engine ignition is cut. The stop button has to be reset before the engine can be restarted.

The American machine was designed to feed the chips from the output side of the chipper, either sideways via a chute directly into woodland, or forward into a tipping lorry, but the British agents for the chipper (The Woodland Management Association, Ltd.) have, in conjunction with the Post Office Engineering Department, modified the equipment to include an automatic bagging unit for the chips. The unit is mounted on the near side of the trailer frame (Fig. 4) and consists of a sheet-metal rectangular box into which a curved square-section duct is led. The duct guides the chips as they are ejected from the chipper into the collecting box. At the bottom of the collecting box are two circular outlets, each with four hooks, on to which two standard 1 cwt sacks can be hooked. A hinged deflector plate, controlled from the outside of the collecting box, guides the chips into either one or other of the two bagging positions; when one bag is filled with chips the output is then diverted to the other bag by means of the deflector plate, the full sack is removed, and an empty sack is hooked on in readiness for the next change-over. Access to the interior of the collecting box is provided by means of hinged inspection covers should it become necessary to relieve choking of the outlets at any time.

If so desired, the curved chute may easily be detached from the collecting box, turned through 180° and connected to the chipper outlet again. The chips will then be discharged from the off side of the trailer directly into the hedgerow or woodland, where this is permissible. The chips are projected a distance of approximately 15 ft from the trailer. Fig. 5 shows this arrangement.

The trailer chassis is of all-welded steel-channel construction with two road wheels and front and rear steady legs. The front leg, with a steel castor wheel, is retractable and the rear leg is adjustable for height. Overrun brakes and a parking brake, which is lockable in the "on" position, are provided. A generous toolbox is provided and houses a spare set of cutter blades, honing stone, blade-setting gauges, and the necessary tools for day-to-day maintenance.

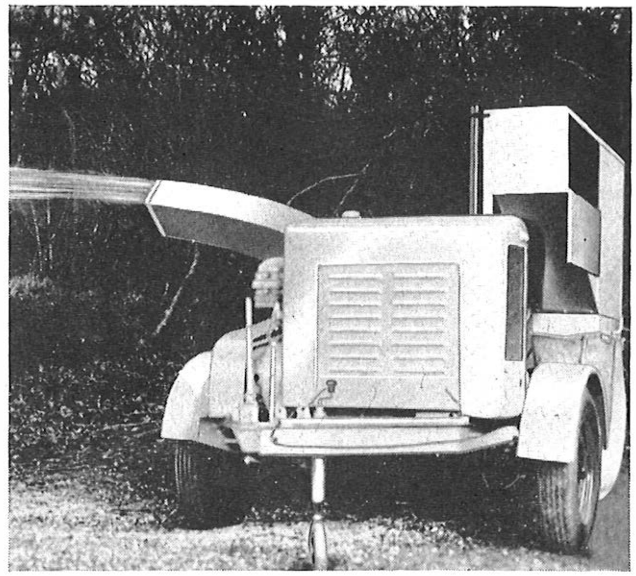


FIG. 5—CHIPS BEING PROJECTED FROM CHIPPER

Day-to-day maintenance of the chipper is small, and consists mainly of keeping the cutter blades sharp by honing once a day; access to the cutter blades for honing is achieved by removing the curved delivery chute and folding back the short chipper-outlet chute, which is hinged. The cutter-head bearings are totally enclosed ball-bearings and only require a shot of grease once a fortnight when the chipper is in continuous use.

ACKNOWLEDGEMENT

Fig. 3 is reproduced by the kind permission of Fitchburg Engineering Corporation, Mass., U.S.A.

Book Review

"Radio and Line Transmission (2 Volumes)" G. L. Danielson, M.Sc. (Tech.), B.Sc., A.M.I.E.E., and R. S. Walker, Grad.I.E.E., Grad. Brit.I.R.E. Iliffe Books, Ltd. Vol. 1: 252 pp. 200 ill. 21s. Vol. 2: 289 pp. 224 ill. 22s. 6d.

Students, and practising engineers, concerned with line transmission have always been very poorly served by the available textbooks compared with their radio engineering colleagues, and this has been a particular handicap for City and Guilds candidates for the past few years since the A and B grade examinations in these subjects were merged. The publication of textbooks claiming to satisfy the requirements of candidates for the Radio and Line Transmission A and B examinations is therefore an event of some interest.

Apart from the examination-preparation value of the books, the authors say that they have aimed to provide a background knowledge of the world of telecommunications. Inevitably within a small volume, they have only been able to touch a few facets of this world, but these, together with their lucid style should help to hold the interest of the student. The coverage of the City and Guilds syllabus is in most respects quite adequate, and in a few cases goes well beyond the depth required.

There are a number of corrections and alterations which should be made in the next edition of Vol. 2. On page 23 the sketch of a coaxial cable is most misleading as it would appear that the the outer conductor is formed from a single helical copper tape on which the edges of adjacent turns do not overlap. On page 29, question 1, the last sentence should read " . . . choice of insulating materials used. . . . " Perhaps the most unfortunate mistake occurs on page 116 where it is said that white noise voltage is proportional to bandwidth. The fact that in the expression immediately below it is correctly shown as proportional to $\sqrt{\Delta f}$ is probably insufficient to avoid many incorrect statements in future examination answer papers.

Throughout the books the diagrams show the excellent clarity well known to readers of the *Wireless World*, and the books can be strongly recommended to students and to City and Guilds candidates in particular.

Vol. 1, I.P.O.E.E. Library No. 2744.

J.S.W.

Reliability and Maintenance of Electronic Register-Translators

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U.D.C. 621.395.341.7

Two types of electronic register-translator equipment are in service at subscriber trunk dialling centres. Fault rates, overall performance and the cost of fault location and repair are given. The advantages and disadvantages of the two types of equipment from the maintenance point of view are discussed, and the effectiveness of the service-security arrangements are commented on.

INTRODUCTION

THE British Post Office has two types of electronic register-translator equipment in service for controlling the routing and call-charging of subscriber-dialled trunk traffic. This article gives information about fault rates, overall performance, the cost of fault location and repair, and comments on the service-security aspects and on the maintenance facilities as experienced during the operation of these equipments. One type of electronic register-translator uses cold-cathode discharge tubes[1] and the other uses magnetic-drum storage.[2]

The first installations of cold-cathode and magnetic-drum equipments were put into service in December, 1958, and May, 1961, respectively. A special fault docket for electronic equipments was introduced in February, 1962, and most of the statistical data given here refer to the somewhat limited period of 12 months from February, 1962, to January, 1963.

EQUIPMENT UNDER REVIEW

Cold-Cathode Register-Translators

The cold-cathode register-translator equipment provides the subscriber trunk dialling (S.T.D.) routing requirements for certain non-director area provincial cities. It employs cold-cathode tubes as storage devices, using voltage-transfer principles and miniature selenium-rectifier type logic circuits; the storage elements are used on a "space-division" basis.

The maximum capacity of a complete unit is 80 registers arranged in two groups of 40, 20 registers (including boundary relay-sets) and associated power supplies being accommodated on one rack. Each group has access to a translator via an electronic allotter, which associates a register with its translator for approximately 10 ms every 666 ms. A third translator and allotter is available for automatically replacing either working pair in the event of a fault being detected. Each translator has its own power supplies. Two pulse generators and their associated power supplies are provided, only one of which is required to serve the equipment at any time; the stand-by pulse generator is ready to be brought into use immediately if the working pulse generator or its power supply fails.

A complete unit, including the electromechanical-to-electronic connecting relay-sets, is accommodated on five racks, 4 ft 6 in. wide and 10 ft 6 in. high, and two small cabinets that house the pulse-generator pulse supplies. All power supplies operate from the public mains and provide regulated high-tension (h.t.) supplies for the operation of the cold-cathode tubes. The electronic components are mounted on plug-in units 24 in. × 7 in. × 15 in. accommodating up to 20 hinged boards each 1 in. × 7 in. × 12 in. The wire-ended cold-cathode tubes and associated circuits, together with the logic gates, are soldered to connexion strips mounted on those boards.

The equipment is in continuous service, and its correct functioning is checked at each stage of the progress of every call by means of built-in check circuits, which confirm, for example, that the right number of cold-cathode tubes in the stores concerned is struck every time a register is connected to its translator. Other built-in check circuits monitor the operation of the allotters, the pulse generators and the power supplies.

Faulty common equipment is automatically changed over to stand-by equipment. If a register fault is detected the register is automatically taken out of service and, as an aid to fault location, the stores of the faulty register are retained in the condition that existed at the instant of failure.

Periodical functional checks are made, under load conditions, of the power supplies to the pulse generators and translators. These checks are considered necessary because voltage regulation and on-off switching is being performed by fairly heavily-used valves. Otherwise no component or limit testing is done. All faults are revealed either by the built-in check circuits or by an overall functional test applied by means of an external automatic routiner.

Magnetic-Drum Register-Translators

The magnetic-drum register-translator equipment provides the S.T.D. routing requirements for director areas. Each rack of this equipment, 4 ft 6 in. wide and 10 ft 6 in. high, has accommodation for 47 registers, a translator and a 9 in. magnetic drum that provides temporary storage (register) and permanent storage (translator) functions. A second rack is required to accommodate 47 boundary relay-sets.

For service security, racks are provided in excess of traffic requirements at each centre, the smallest centres having a minimum of three register-translator racks. At the small centres, the full rack complement of registers is not provided.

The main equipment is mounted on about 40 plug-in functional units (about 24 in. × 12 in × $1\frac{3}{4}$ in.) each comprising up to 10 wired-in sub-units. In general, a sub-unit contains one amplifier or one toggle. All components including the wire-ended hot-cathode valves are soldered to connexion strips. The diode logic gates are mounted on connexion strips on the plug-in units. The circuit functions are performed by toggles and germanium-diode logic; cold-cathode tubes form the connecting link between the electronic and electromechanical parts of the system. The equipment is designed to operate from the public mains supply and will tolerate input-voltage variations of ± 6 per cent.

There are nine built-in check circuits per rack, monitoring the operation of each register-translator. When a failure is detected the rack is automatically switched out of service and an alarm given. In most instances any

†Formerly in Telephone Exchange Standards and Maintenance Branch, E.-in-C.'s Office, now retired.

calls in progress are allowed to proceed normally, but follow-on calls are inhibited.

Component or limit testing is not done; all faults are revealed by functional testing, mainly by the built-in check circuits. The component replacement rate is, therefore, largely a function of component reliability and tolerance of the circuit elements to component drift.

A routiner is also provided:

(*a*) to test parts of the equipment that are outside the scope of the check circuits, i.e. the register-connecting relay-sets, the incoming and outgoing scanners, and the cold-cathode repeaters on the signalling leads from each register, and

(*b*) to cover the possibility of faults on the main equipment that are not detected by the check circuits remaining undetected.

Early laboratory tests indicated that a rack internal temperature rise of about 15°C could be expected. In practice, possibly because of the effects of nearby parallel racks of equipment, internal temperature rises of 40°C were observed. A pair of $4\frac{1}{2}$ in. air extractors were then fitted at the top of each rack, notably because of probable adverse effects on diodes. From a survey of all installations during 1962–63, the greatest observed rack internal temperature was 34°C—a temperature rise of about 15°C.

EQUIPMENT AND COMPONENT QUANTITIES

Cold-Cathode Register-Translators

There are four register-translator centres with the cold-cathode type of register-translator; the four centres are served by a total of 240 registers. Table 1 shows the types of component and the average number used per register for this type of equipment.

TABLE 1
Component Quantities for Cold-Cathode Register-Translators

Type of Component	Average No. per Register
Valves	2
Diodes (selenium rectifiers)	1,270
Cold-cathode tubes	183
Resistors	1,140
Capacitors	183
Plugs and sockets	203 pairs
Wiring connexions	11,900
Miscellaneous	8

TABLE 2
Component Quantities for Magnetic-Drum Register-Translators

Type of Component	Average No. per		
	Rack	Register Installed	Register Required for Traffic
Hot-cathode valves	513	15	21
Diodes	5,660	166	234
Cold-cathode tubes	150	4	6
Resistors	4,790	140	197
Capacitors	1,410	41	58
Plugs and sockets	1,790 pairs	52 pairs	75 pairs
Wiring connexions	38,000	1,120	1,579
Miscellaneous (lamps, keys, transformers, chokes, etc.)	5,000	15	21

Magnetic-Drum Register-Translators

There are eight register-translator centres using the magnetic-drum type of register-translator. The eight centres are served by 36 register-translator racks with 1,227 registers installed; 862 registers are required for the traffic carried. Table 2 shows the types of component used and their quantities for this type of equipment.

RECORDING AND ANALYSIS OF FAULTS

Fault Docket

A docket was specially designed for the recording and subsequent analysis of faults in electronic equipments; it is in two, detachable, parts. One part, which is used for making various analyses, enables essential information about each fault to be briefly recorded. This information includes the type of equipment involved, the faulty circuit element and component, the nature of the failure and the time during which the equipment was out of service. The other part, the rear of which is a fault-clearance log, is for use at the exchange. The maintenance officer prepares a docket for each equipment irregularity, and classifies each fault by entering the appropriate number in each of the boxes relevant to the particular defect. The docket is "backed" by an appropriate fault-recording procedure.

Detection of System Faults

Fault rates are influenced by the method of detecting faults; they are not necessarily an indication of the comparative service given by an equipment, since this is dependent on the effect of each fault on the calls being handled by the equipment. For example, a comprehensive arrangement of self-checking, with the equipment being removed from service on the first failure of a check circuit, could produce a large number of recorded faults, although their effect on service would probably be insignificant and many would be classed as "fault not found" (F.N.F.). On the other hand, less critical checking, or delay in detection and action until two or more failures occurred within a given period, would reduce the recorded fault rate but result in a worse level of service.

Faults on the cold-cathode register-translators are detected by:

(*a*) an automatic routiner that passes test calls into each register (each register is tested three times a week),

(*b*) check circuits, built into the electronic equipment, that detect incorrect conditions during the progress of live traffic, and

(*c*) check circuits monitoring the common equipment and power supplies.

Failures under (*b*) and (*c*) give an immediate alarm and, where appropriate, automatic change-over or busying is effected. All failures, including faults indicated by the automatic routiner, are recorded on fault dockets and included in the analyses made.

Faults on the magnetic-drum register-translators are indicated by:

(*a*) an automatic routiner that passes test calls into each register (each register is tested three times a week), and

(*b*) a number of check circuits which apply a test sequence to each section of the electronic equipment.

The check circuits operate independently of live traffic and run continuously. A memory is provided in each check circuit, and an alarm is given on second failure and the rack of equipment is busied. The memory circuits are manually reset every 24 hours: only second failures within the resetting period are recorded on fault dockets, togther with all faults indicated by the automatic routiner.

Comparison of Systems

Valid and precise comparisons of the performance of different designs of register-translators are not easy. Comparisons must necessarily take into account fault liability and the effects of faults on the service given, as well as the cost of fault location and repair.

As regards fault liabilities, an overall fault rate in terms of, for example, faults/1,000 components/year alone, is not a valid comparator because the nett fault liability is a compound of the total components used and the component fault rates, the latter being affected by, for example, the extent to which the circuit designer has permitted components to be worked within their capabilities.

A reasonable basis for comparing the performance of register-translators would appear to be the total system faults per register function. However, comparisons made in that way between the magnetic-drum system, which for service security incorporates an excess of registers and relay-sets, and the cold-cathode system, in which service security is obtained by a form of common-equipment switching, are still misleading. It is considered, therefore, that it is fairest to compare system faults per register required for traffic.

Calculations show that the 1,227 registers required at the magnetic-drum register-translator installations could be replaced by 862 registers if the system did not need an over-provision of registers for security purposes. Thus, the faults/register required for traffic/year figures for making a fairer comparison between the magnetic-drum and cold-cathode register-translator systems may be obtained by multiplying the faults/register installed/year figures for the magnetic-drum register-translators by 1·42.

Faults/Register/Year

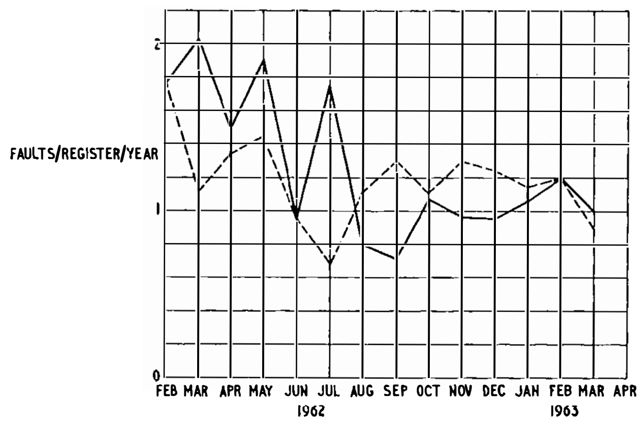
The faults/register/year are shown in Table 3; the overall rate for electromechanical register-translators is also shown for interest and comparison.

TABLE 3
Faults/Register/Year

Location and Type of Fault	Cold-Cathode Register-Translators	Magnetic-Drum Register-Translators		Electro-mechanical Register-Translators
		Per Register Installed	Per Register Required for Traffic	
Faults due to components in the electronic equipment, including those due to mains variations and magnetic drums	1·12	0·55	0·78	—
F.N.F.s	0·18	0·36	0·51	—
Total faults on electronic equipment	1·30	0·91	1·29	—
Faults due to boundary relay-sets	0·08	0·49	0·70	—
Total	1·38	1·40	1·99	5·1

Table 3 also gives the fault rate/register for the relay-sets forming the boundary between the electronic and mechanical equipments. Faults due to relay-sets were more numerous in the magnetic-drum installation: this may be in part due to the increased complexity of those relay-sets compared with their counterparts in the cold-cathode equipment. Both types of relay-set have double-contact high-speed relays for pulsing out, but the relay-set for the magnetic-drum register-translator has an additional high-speed relay for repeating incoming pulses.

Comparison of results for the purely electronic parts of the equipment on a per register required for traffic basis indicates approximate parity for the year of observation. It should be borne in mind, however, that a fault recorded as F.N.F. may eventually recur as a fault for which the cause is detected, and so in effect the fault may be brought to account twice in the fault total; this event is more frequent for the magnetic-drum equipment. It will be seen later that in terms of the component replacement rate, the performance of the cold-cathode equipment is significantly the better.



—— Magnetic-drum register-translators
- - - Cold-cathode register-translators

FIG. 1—VARIATION OF FAULT RATE WITH TIME

Fig. 1 shows how the electronic-equipment fault rate/register required for traffic varied with time. It should be remembered that the first of the four cold-cathode type register-translator installations had been working for 3 years before February 1962, whereas the first of the magnetic-drum installations was working only 9 months before that date. For either type of register-translator the monthly results for the second half of the year show greater stability than do the results for the first 6 months, notably so for the magnetic-drum equipment.

Interval Between Faults

The average interval between faults, expressed in various terms, is shown in Table 4. On a per-1,000-component basis the large differences in the average interval for the two types of register-translator will be noticed.

TABLE 4
Average Interval Between Faults

Type of Register-Translator	Average Interval Between Faults (Including F.N.F.s)			
	Per Rack	Per Installation	Per Register Required for Traffic	Per 1,000 Components
Cold-cathode	—	4·7 days	0·77 years	2·15 years
Magnetic-drum	11·7 days	—	0·77 years	0·42 years

In 10 per cent of the instances, the interval between successive faults was more than 12 days for cold-cathode installations and more than 30 days for magnetic-drum racks. For either cold-cathode installations or magnetic-drum racks, with 30–40 per cent of faults, including F.N.F.s, a fault or F.N.F. occurred within one day of the preceding one.

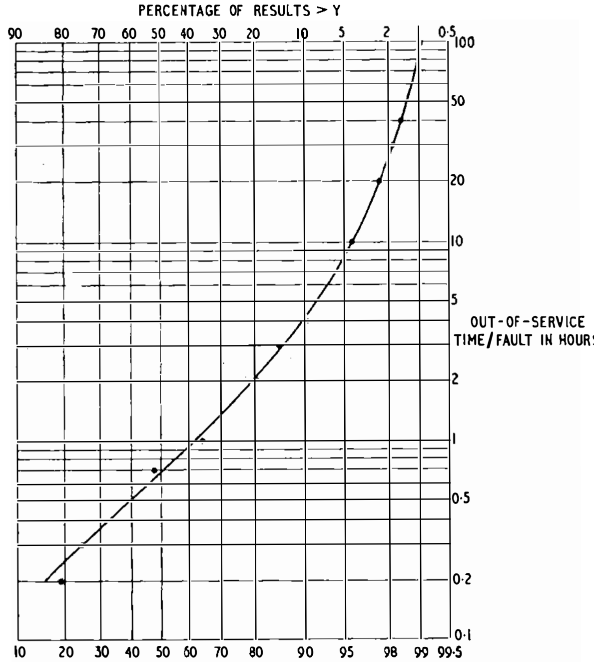
REGISTER-TRANSLATOR UNSERVICEABLE TIME

For the data presented in this article, unserviceable time or out-of-service time is defined as the time expressed in hours and decimal parts thereof from the detection of the fault until the equipment could have been restored to service, if desired, by the substitution of spare equipment. Periods of 6 minutes and less are recorded as 0·1 hour.

In comparing the two types of register-translator, account should be taken of the two methods incorporated in them of providing service security. In general, security is achieved in the magnetic-drum register-translator by having additional drum racks in normal service over and above those required to handle the busy-hour traffic. An electronic fault, except on a relatively few components individual to one register, causes a complete rack of electronic equipment to be removed from service together with those registers (up to 47) connected to it. The cold-cathode register-translator, however, has reserve functional units built into the design. Thus, for example, if either a pulse generator or its associated power unit serving the whole of the installation develops a fault, a stand-by circuit is automatically switched into use and all registers in the installation continue to provide service.

Register-Translator Out-of-Service Time/Fault

The distributions of the register-translator out-of-service-times/fault for the two types of equipments are substantially the same; the combined distribution is shown in Fig. 2.

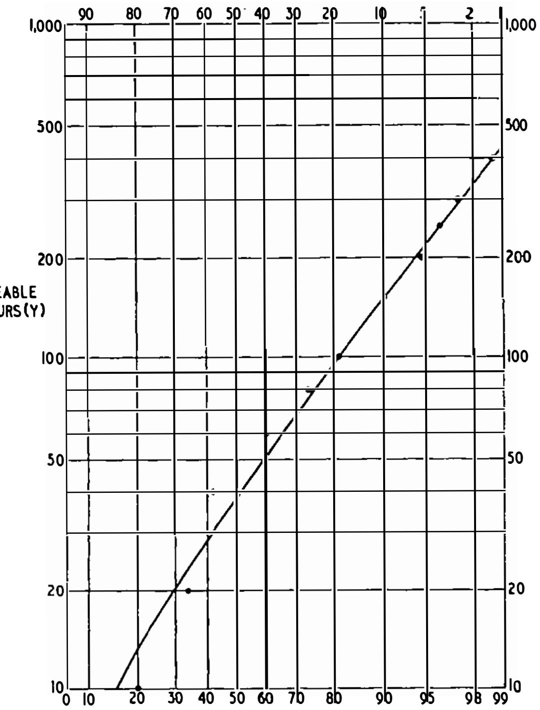


For magnetic-drum register-translators, the number of faults reported = 773, and the mean out-of-service time/fault = 3·92 hours.

For cold-cathode register-translators, the number of faults reported = 140, and the mean out-of-service time/fault = 3·78 hours.

FIG. 2—DISTRIBUTION OF OUT-OF-SERVICE TIME/FAULT

It will be noted that the mean out-of-service-time/fault is in the order of 4 hours, and that 10 per cent of the results exceed this value; 2 per cent may be as long



The number of faults reported = 773 and the average unserviceable time/rack/year = 84·4 hours.

FIG. 3—DISTRIBUTION OF RACK-UNSERVICEABLE TIME

as 30 hours. For the magnetic-drum register-translator installations, where a complete rack may become unserviceable, the annual out-of-service time is assessable on a rack basis. Fig. 3 shows the distribution of rack-unserviceable times; the average time is about 84 hours, representing a rack performance of 99 per cent serviceable time/year. On average, the number of occasions per year that a rack is out-of-service is 21·5.

MAINTENANCE MAN-HOURS

Distributions of fault-locating and repair man-hours/fault are shown in Fig. 4.

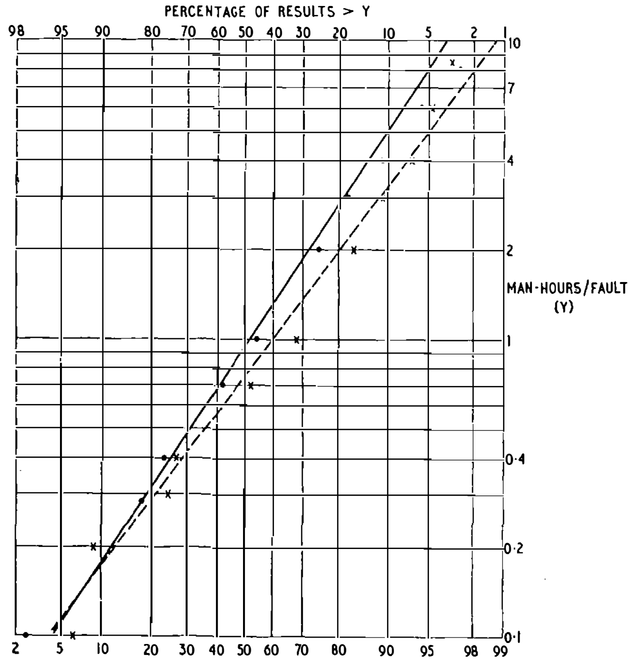
The average fault-repair time was 0·7 hours less for the cold-cathode than for the magnetic-drum installations, and 1·2 per cent of the faults took 20 per cent of the total repair time.

Table 5 shows the average man-hours spent in repairing faults arising from certain components and in dealing with F.N.F.s.

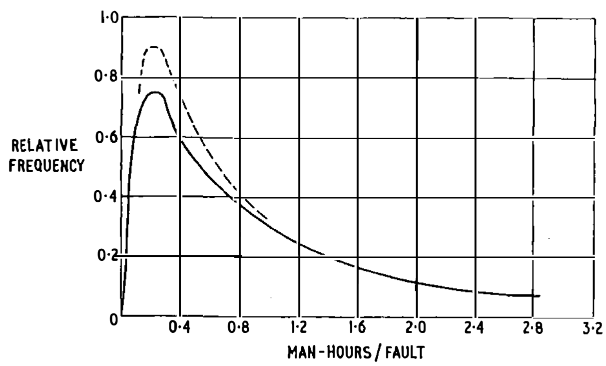
Overall Maintenance Man-Hours/Register/Year

The maintenance effort, expressed in man-hours/register/year, is shown in Table 6.

As for register fault rates (Table 3) the man-hours/register/year figures for the magnetic-drum register-translators which should be used for comparison with the cold-cathode and electromechanical register-translators are in column 4 of Table 6. On this basis of comparison, the maintenance costs for the cold-cathode register-translators are the most favourable, but main-



(*a*) Man-hours/Fault



(*b*) Relative Frequency

—— Magnetic-drum register-translators
- - - - Cold-cathode register-translators

	Magnetic-Drum Register-Translator	Cold-Cathode Register-Translator
Number of faults reported	1,011	269
Mean	2·16 ± 0·20	1·46 ± 0·20
Median	0·92 ± 0·08	0·75 ± 0·10
Mode	0·17 ± 0·02	0·20 ± 0·03

(95 per cent confidence limits)

FIG. 4—DISTRIBUTIONS OF FAULT-LOCATING AND FAULT-REPAIR MAN-HOURS/FAULT

tenance costs for the electromechanical register-translators are three to four times those for their electronic equivalents.

COMPONENT REPLACEMENT RATES

It has been suggested that for operational equipments the "component replacement rate" is a more appropriate term than "component fault rate." There seems to be some justification for this since, for example, a component rejected because a parameter has drifted so as to cause operational failure in one design of equip-

TABLE 5
Fault-Locating and Repair Man-Hours

Faults Arising From:	No. of Faults Repaired	Average Man-Hours Spent in Repairing Each Fault
Valves	351	3·2
Cold-cathode tubes	184	1·1
Diodes	38	3·0
Wiring	47	3·2
F.N.F.s	457	0·9
Overall Average Man-Hours/Fault	Cold-Cathode Register-Translators = 1·46 ± 0·20; Magnetic-Drum Register-Translators = 2·16 ± 0·20	

TABLE 6
Maintenance Man-Hours/Register/Year

Action Required	Cold-Cathode Register-Translators	Magnetic-Drum Register-Translators		Electro-mechanical Register-Translators
		Per Register Installed	Per Register Required for Traffic	
Locating and clearing faults on electronic equipment	2·40	2·01	2·84	—
Locating and clearing faults on boundary relay-sets	0·04	0·25	0·35	—
Other maintenance (estimated)	0·40	0·30*	0·42*	—
Total	2·84	2·56	3·61	12·2

* Excludes the maintenance of the drums themselves.

ment might still give prolonged service in another design. On the other hand, some components, although actually within specification limits, may have been changed because they were thought, rightly or wrongly, to be the cause of incorrect operation of the equipments. Again, occasionally a component may suffer damage whilst a defective component, directly the cause of a fault, is being changed.

The replacement rate reflects the actual number of components changed during fault repair. Sometimes more than one component had necessarily to be changed to cure a single irregularity in the equipment. On other occasions components which were not the cause of the original fault were inadvertently damaged during fault repair: for the magnetic-drum equipment this happened in 8 per cent of the proven faults compared with only 1·5 per cent for the cold-cathode equipment. With regard to this difference and to the lower average fault-repair time for the cold-cathode register-translator, and when comparing the component replacement rates for the two types of register-translator, attention is directed to the following points.

(*a*) The components used in the cold-cathode equipment are generally more robust: resistors and capacitors are of higher rating and, hence, are physically stronger; the electrode structure of the cold-cathode tube (CCT 6) is larger and less complex than the miniature pentode (CV 466) used in the magnetic-drum system; diodes of the selenium type, used largely in the gate circuits in the cold-cathode register-translator, are considerably larger and more easily handled than are the diodes (CV 448) used in the magnetic-drum register-translator. The diodes CV 448 are of the germanium point-contact type and, in the magnetic-drum equipment, are used not only as gate diodes but also for clamping the inputs and outputs of toggles; when used as a clamp, the forward resistance of the diode must be low, and diodes with unacceptably-high forward-resistances account for the majority of diode faults in the magnetic-drum register-translators

(*b*) The removal of a cold-cathode tube CCT 6 in the cold-cathode equipment is achieved by disconnecting three leads and unclipping the tube, but to remove a miniature pentode CV 466 in the magnetic-drum equipment the sub-unit concerned must be taken from the panel and the front plate removed before the eight valve leads can be unsoldered.

(*c*) The basic "memory" of the cold-cathode register-translator requires one CCT 6, whereas the magnetic-drum register-translator uses two complementary CV 466s.

(*d*) A number of hot-cathode valves used in the cold-cathode equipment are used to switch the h.t. supply to the storage tubes. The failure rate of valves under these conditions is higher than that of most of the valves used in toggles and amplifiers in the magnetic-drum equipment.

(*e*) Signalling power levels are higher in the cold-cathode equipment.

Table 7 gives the component replacement rates for the two types of register-translator, and this shows there is a general superiority in the replacements/1,000 components for the cold-cathode equipment. However, when the overall component replacements per register required for traffic per year figures are compared for the two equipments, the magnetic-drum register-translator appears superior: the figures are 0·87 and 1·35 for the magnetic-drum and cold-cathode equipments, respectively.

TABLE 7
Component Replacement Rates

Component Type	Cold-Cathode Register-Translators			Magnetic-Drum Register-Translators		
	Component Quantity	Replacements		Component Quantity	Replacements	
		Per 1,000 Per Year	Per Cent Per 1,000 Hours		Per 1,000 Per Year	Per Cent Per 1,000 Hours
Hot-cathode valves	480	85·400	0·97500	18,400	25·700	0·29300
Diodes	304,000	0·062	0·00071	204,800	0·280	0·00319
Cold-cathode tubes	44,000	5·160	0·05880	5,400	8·100	0·09200
Resistors	275,000	0·040	0·00045	172,300	0·075	0·00080
Capacitors	44,000	0·140	0·00160	50,900	0·280	0·00319
Miscellaneous	2,000	1·500	0·01700	18,100	2·660	0·03000
Total	669,480	0·459	0·00520	469,900	1·380	0·01580
Plugs and sockets (pairs)	48,800	0·041	0·00047	64,700	0·060	0·00068
Wiring	2,865,000	0·0024	0·000027	1,353,800	0·040	0·00046

FAULTS AND ADJUSTMENTS OF MAGNETIC DRUMS

During the period February 1962 to January 1963, there were two magnetic-drum mechanical failures, each of which was indicative of mishandling of the drum at some time: one of the drum units had to be replaced and the other was repaired on site by the manufacturer.

Following periodic inspections 80 heads were adjusted, most being rephased and a few being re-gapped. These adjustments were made to secure uniformity of output so that any subsequent deviation might the more readily be detected and not because there would necessarily have been any equipment failures.

There were 51 reports of faults associated with the lubrication system, 35 of which were detected during the manufacturer's service visits. The total faults were divided about equally between "oil leak" and "oil-alarm equipment" categories, with a few in the "oil-circulation" category.

SERVICE SECURITY OF MAGNETIC-DRUM REGISTER-TRANSLATOR INSTALLATIONS

As mentioned earlier for service security, racks are provided in excess of traffic requirements. In the smallest centres there is a minimum of three racks, and the standard grade of service is provided with one of the three racks out-of-service. Should a second one fail whilst the first is still under repair the availability of a register-hunter group drops from 16 to 8, resulting in a substantial reduction in the grade of service. How far this may be tolerated depends on the probability of the event, especially during the busy hour or busy period.

Probabilities of Failure

The probability of any one rack remaining operational during a time of T hours is

$$p_o = e^{-rT},$$

where r = average failures/rack/hour,
and T = average out-of-service time in hours/failure.

Therefore, the probability that any one rack will fail during a period T hours is:

$$p = 1 - e^{-rT}.$$

The average number of occasions a rack is out-of-service/year is 21·5.

Therefore $r = 21{\cdot}5/8{,}760$.

Thus $p_f = 1 - e^{-21{\cdot}5T/8{,}760}$

In Table 8, p_f is tabulated for various values of T.

TABLE 8

Probability of Failure of a Magnetic-Drum Rack

Time (T Hours)	Probability, p_f, of Failure of Any One Rack During a Period of T Hours
1	$0{\cdot}245 \times 10^{-2}$
2	$0{\cdot}490 \times 10^{-2}$
3	$0{\cdot}735 \times 10^{-2}$
4	$0{\cdot}980 \times 10^{-2}$
5	$1{\cdot}225 \times 10^{-2}$
8	$1{\cdot}960 \times 10^{-2}$
10	$2{\cdot}450 \times 10^{-2}$
15	$3{\cdot}650 \times 10^{-2}$
20	$4{\cdot}850 \times 10^{-2}$

The average out-of-service time/rack-fault is, from Fig. 2, say, 4 hours.

For $T = 4$, $p_f = 0{\cdot}0098$,

The probability of any two out of three racks failing during a time of 4 hours is

$$p_{f(2/3)} = 0{\cdot}0098^2 \times 3 = 2{\cdot}88 \times 10^{-4},$$

and the interval between failures will be

$$\frac{10^4 \times 4}{2{\cdot}88 \times 8{,}760} = 1{\cdot}6 \text{ years.}$$

Thus, based on data obtained for the year 1962–63, and assuming a constant rack-failure rate, it is estimated that on average every 1·5 to 2 years whilst a drum rack is out-of-service for fault repair another one of the three racks will also become non-operational. The probability of two out of three racks failing during various assumed rack out-of-service times and the interval in years between such failures are shown in Table 9.

TABLE 9

Probability of Failure of Two out of Three Magnetic-Drum Racks

Rack Out-of-Service Time (T Hours)	Probability of Failure (p_f)	Years Between Failures
1	$0{\cdot}180 \times 10^{-4}$	6·4
2	$0{\cdot}720 \times 10^{-4}$	3·2
3	$1{\cdot}62 \times 10^{-4}$	2·1
4	$2{\cdot}88 \times 10^{-4}$	1·6
5	$4{\cdot}50 \times 10^{-4}$	1·3
8	$11{\cdot}50 \times 10^{-4}$	0·80
10	$18{\cdot}0 \times 10^{-4}$	0·64
15	$40{\cdot}0 \times 10^{-4}$	0·43
20	$70{\cdot}6 \times 10^{-4}$	0·32

The probability of all three racks failing during the average rack out-of-service time of 4 hours is $0{\cdot}941 \times 10^{-6}$ and the event is likely once in about 500 years.

Since the effect on service of the failure of the racks is most significant if it extends over a busy hour, it is of interest to estimate the probability of a busy hour being affected.

If a rack failure occurs during the 8 hours between 7.0 a.m. and 3.0 p.m. it is likely to affect either the morning or afternoon busy period.

If a second rack fails during the 4 hours preceding the busy period over which the first is still faulty, this is likely to result in the two racks being out of service together over the busy period.

The probability of a failure occurring on any one rack during the 8-hour period is

$$p_{f8} = 1{\cdot}960 \times 10^{-2}$$

The probability of a second rack failure during the 4-hour period up to the busy period during which the first rack is out of service is

$$p_{f4} = 0{\cdot}980 \times 10^{-2}$$

Thus, the probability of the two racks being out of service together is:

$$p_{f8} \times p_{f4} = 1{\cdot}960 \times 0{\cdot}98 \times 10^{-4}$$
$$= 1{\cdot}92 \times 10^{-4}$$

But as there are three equipments there are three combinations of any two being faulty together.

Thus, the probability of any two being faulty during the busy period of the day is

$$p_{f(2/3)} = 3 \times 1{\cdot}92 \times 10^{-4}$$
$$= 5{\cdot}75 \times 10^{-4},$$

and the interval between such failures will be

$$\frac{10^4}{5{\cdot}75 \times 365} = 4{\cdot}8 \text{ years.}$$

COMMENT AND CONCLUSIONS

Cold-Cathode Versus Magnetic-Drum Register-Translators

From a maintenance point of view, there appears little to choose between the two types of electronic register-translator. The cold-cathode equipment is perhaps easier to maintain, for the division of registers into separate physical units assists fault location. Where equipment is predominantly shared on a time-division basis, as in the magnetic-drum register-translator, fault location becomes more difficult—although to some extent this is compensated for by the considerably smaller number of components per register, which tends to reduce the register fault rate.

Maintainability is largely influenced by the ease with which a system may be broken down, both mentally and physically, into small functional units. Good documentation is essential, so that, for example, detailed information about the wiring and location of components is readily available, and the most desirable form of physical construction for maintenance is that using small interchangeable modules joined together via reliable plugs and sockets.

The circuit-diagram presentation of the cold-cathode register-translator is adequate, but information on the wiring and location of components is not in a sufficiently convenient form. The physical construction is such that faulty components have to be located in situ; a complete store, for example, cannot be removed and tested on the bench. The book-leaf construction provides reasonable testing access whilst the large plug-in units are still in the rack. The use of cold-cathode tubes enables some appreciation of the state of the equipment to be gained, since it can be seen which tube is struck. Furthermore, the system operation is such that a number of similar items work into a common item; this makes for easier processes of deduction and elimination before actual fault location commences.

The magnetic-drum register-translator has been provided with excellent wiring diagrams and with logic script which explains the circuit operation in time sequence. However, the equipment cannot be conveniently broken down into circuit elements; the removal of a toggle, for example, entails the unsoldering of some 16 connexions. Valves are also soldered in; this must increase fault-locating and repair times. Generally, faults on the magnetic-drum register-translator are fairly rapidly located to a functional unit and even to a circuit element; location of a faulty component in the circuit element accounts for most of the fault-locating time.

Check Circuits

The number of faults observed on each equipment is partly dependent on the method of checking the operation of the equipment. Where built-in check circuits are provided the number of faults brought to notice will tend to be higher than on equipment without check circuits. An efficient self-check circuit will detect a fault and protect the service being given by rapidly withdrawing the equipment from use. At the worst, the effect of the fault on the service will be to lose all the calls being established at the instant the fault is detected. However, transient faults will be detected, an alarm will be given and subsequently, when maintenance attention is given, the fault condition will not be reproduced. This disadvantage may be minimized in two ways:

(*i*) By the use of an alarm arrangement that operates only when a check circuit detects two faults within a preset period. This will reduce the number of alarms and, hence, tend to make fault locating more productive. The length of the preset period depends on a compromise between the protection of service and the reduction in the number of occasions when no fault is found after an alarm is given.

(*ii*) By designing the check circuits so that the maintenance officer can readily appreciate details of what is happening when a fault is detected. Ideally, the faulty replaceable package should be indicated rather than mere failure of a complete function.

Clear presentation of the facts causing a failure will result in the reduction of fault-locating and repair time, for the maintenance officer will then be able to reproduce the failure sequence precisely and thus increase the chance of finding an intermittent fault. Check circuits that do not provide this kind of information make it difficult, if not impossible, to locate intermittent faults which, although they may have no significant effect on the service, nevertheless may cause considerable disturbance to the exchange staff and waste of time.

The magnetic-drum register-translator equipment exhibits a higher F.N.F. rate than the cold-cathode register translator. The magnetic-drum equipment uses the facility mentioned in (*i*) but has short-comings so far as (*ii*) is concerned. On the other hand the cold-cathode equipment provides more of the type of information detailed in (*ii*) although an alarm is given on the first detection of a failure. However, the allotter check-circuit on this equipment provides little information about the conditions at the instant of failure, and, because of this, it has often proved very difficult to locate the cause of a failure.

Incidence of F.N.F.s

The design principles of an equipment influence the F.N.F. rate. With the magnetic-drum equipment the use of high-impedance logic and low-level signals renders the equipment susceptible to interference from external sources. A design based on low-impedance logic, e.g. one using transistors, might have reduced this susceptibility.

The cold-cathode register-translators are less affected by external influences, probably due to the use of higher-amplitude signals.

Power Supply Variations

The cold-cathode equipment uses regulated power supplies, which make it practically immune to public-mains fluctuations. On the other hand, the magnetic-drum equipment, which largely employs unregulated supplies, has experienced a number of faults clearly arising from variations in the public-mains supply. It is also likely, but unfortunately difficult to prove, that supply variations due to lack of mains regulation have been responsible for the replacement of some components, notably valves.

Security of Small Magnetic-Drum Register-Translator Installations

The decision to instal a minimum of three racks of magnetic-drum equipment is now seen to be justified. It has been shown that the probability of two out of three racks being non-operational during a busy period is about once every 5 years.

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[2]BENSON, D. L., and VOGAN, D. H. Controlling Register-Translators, Part 4—Magnetic-Drum Register-Translators. *P.O.E.E.J.*, Vol. 51, p. 291, Jan. 1959.

Book Review

"The Effect of Disturbances of Solar Origin on Communications." Edited by G. J. Grassman. Pergamon Press, Ltd. x + 349 pp. 100s.

This volume forms the report of a technical meeting on ionospheric research held in Naples in May 1961. It contains much practical information, concerning in particular h.f. and v.h.f. communications across high latitude regions of the earth. A number of papers discuss the observed effects on h.f. circuits of polar-cap absorption and distinguish these from auroral-absorption effects, which for many years have been known to interrupt or disturb h.f. radio circuits across the North Atlantic.

Despite the addition which these papers represent to the scientific literature and the application of the newly developed methods of oblique incidence sounding, the help they afford to the communications engineer is limited. This is a consequence, no doubt, of the tremendously complicated process of ionospheric propagation, studies of which only slowly yield new information of practical engineering use. Nevertheless those concerned with communications across polar regions will find this volume of considerable interest. In particular it provides helpful warnings of certain possible causes of circuit interruptions that hitherto have not been fully realized and understood. J.K.S.J.

A Push-Button Torn-Tape Relay System for Electra House, London

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U.D.C. 621.394.763.4

About 60,000 overseas telegrams are handled at the London overseas telegraphs centre, Electra House, every day. The messages are received and transmitted by telegraph instruments accommodated on four floors of the building, and the messages are circulated between the operators' positions by a conveyor-belt system. On such a large scale the mechanical handling and the manual processes of cross-office transmission are very costly, and a torn-tape relay system has been designed to give greater efficiency and speed of service.

INTRODUCTION

THE overseas telegraph centre at Electra House, London, deals with about 60,000 international telegrams every day, and approximately 120 overseas telegraph circuits are used for the transmission and reception of the messages. The telegraph instruments used are accommodated on four floors of the building, and a conveyor-belt system transports the telegrams between the operators' positions. The mechanical handling and manual processes involved in cross-office transmission on such a large scale are very costly, and a torn-tape relay-system has been installed to handle some of the traffic and give greater efficiency and speed of service.

Overseas telegrams are accepted from and delivered to telegraph offices and subscribers in the United Kingdom by means of the teleprinter automatic switching system, by telex, private circuits and phonograms; there is also some hand delivery in the City of London.

Now that the older forms of overseas telegraphy have been largely supplanted by teleprinter working over modern submarine-cable systems or error-correcting radio telegraph systems,[1] the direct relaying of messages from one overseas circuit to another, or from an inland office to an overseas circuit, has become feasible, and the push-button torn-tape system now described has been installed as a first step towards this objective. The purpose of this message-relay system is to effect transmission without the message having to be conveyed physically across the office, either as a printed message or as a perforated tape, and so eliminate manual transmission. At the same time it is necessary to fully exploit the traffic-carrying capacity of the overseas circuits, the number of which is still limited on the majority of routes, and the system has, therefore, to provide storage capacity to enable messages to be queued for each outgoing channel.

The push-button torn-tape relay system at Electra House has been designed to work with decentralized offices in London and the provinces as an interim stage in the modernization of traffic-handling of overseas messages. The installation consists of incoming positions at which messages are received as punched and printed tape, and transmit positions with push-button panels giving access to outgoing circuits. Normally, each message is handled by one operator only: the received tape is examined for the address, the route determined, the message inserted in a transmitter head, and the appropriate circuit button pressed. Incoming messages are numbered at the office of origin or at the preceding stage of transmission, and outgoing messages are automatically renumbered and a monitor copy recorded on a teleprinter.

The operating and message-checking sections are located on one floor of the building, and under normal conditions messages are received and transmitted within one minute.

OUTLINE OF THE TAPE-RELAY SYSTEM

Each operating position consists of a transmit console flanked by two receive consoles, as shown in Fig. 1. Two triple-headed automatic transmitters are mounted on the transmit console, together with a push-button control and route-selection panel. Each receive console contains two printing reperforators with a tape run-out key and supervisory lamps; an incoming line is connected to

†Telegraph Branch, E.-in-C.'s Office.

[1]CROISDALE, A. C. Teleprinting over Long-Distance Radio Links. *P.O.E.E.J.*, Vol. 51, pp. 88 and 219, July and Oct. 1958.

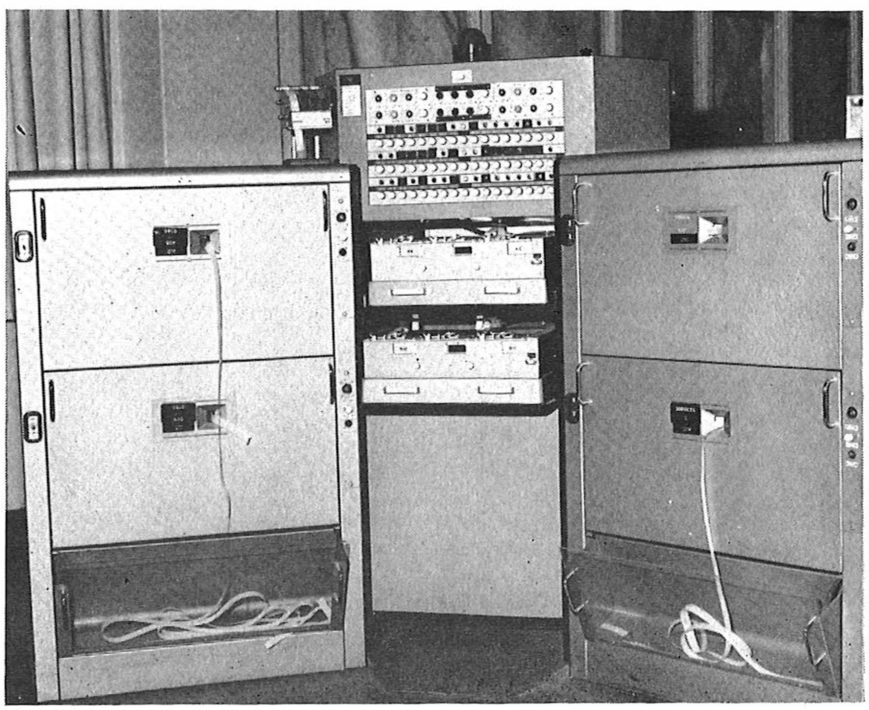
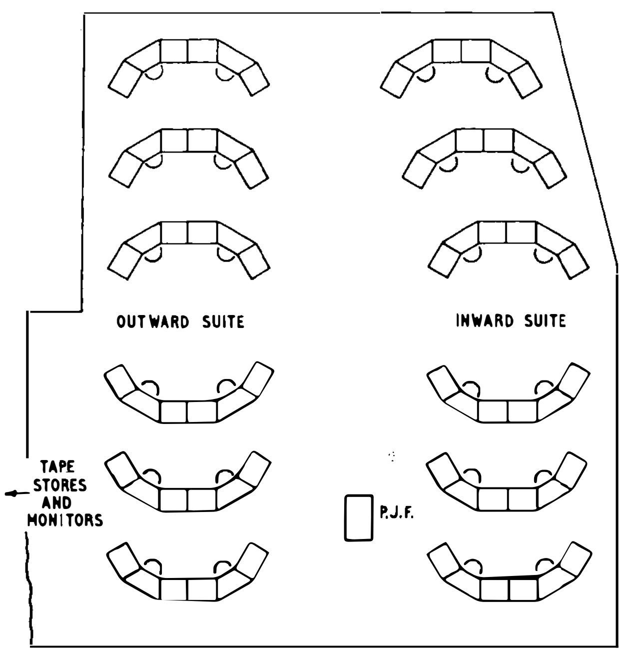


FIG. 1—OPERATOR'S POSITION

each reperforator, and messages are received as punched and printed tape. The operator tears off each message, reads the address, inserts the message in a free transmitter head and presses the appropriate routing button. No further action is taken by the operator, and when the line is free the message is transmitted. By operating a common priority button before pressing the route-selection button any message can be given precedence over other messages waiting for the same circuit. Facilities are given for adjusting the tape in the transmitter head without releasing the selected circuit. An alarm is given if the delay before transmission exceeds a predetermined period.

Each incoming message bears a serial number from the originating station, but when the message is transmitted a further serial number peculiar to the outgoing circuit is added. A monitor page teleprinter with reperforating attachment is provided on each outgoing line, and the page copies, which are subsequently also used for accounting purposes, are checked and filed in incoming numerical order to ensure that each message has passed through the relay centre. In the event of failure of the outgoing channel, a request from the distant terminal for a message to be repeated can be met with minimum delay by using the monitor tape and a trolley-mounted automatic transmitter connected to access points on the monitor position. Tape stores are provided to accumulate traffic in case of route breakdown or congestion, and a comprehensive patching jack-field is provided to give ready access for cross-connecting and testing circuits.

Separate inward and outward suites of positions are provided: the inward suite deals with messages entering the United Kingdom, and the outward suite deals with messages in the reverse direction. Fig. 2 shows the layout of the traffic hall.



P.J.F.—Patching jack-field
FIG. 2—LAYOUT OF TRAFFIC HALL

OPERATION OF SYSTEM

Circuit Outline

Fig. 3 is a block schematic diagram of the system. A message received in tape form is loaded into a message transmitter by operating and releasing the feed-wheel key. The operation of the feed-wheel key engages the transmitter-head relay-set, and the operation of a routing button causes the circuit-marker uniselector, CM, associated with that message head to rotate to a contact corresponding to the marked circuit. When the uniselector reaches the marked outlet, a lamp on the control panel, associated with the message head, lights to indicate that the message routing has been registered and that the operator may release the push-button and attend to further messages. Circuit-marker uniselector CM connects a start potential to the line relay-set, and if the line is free the associated position-finder uniselector, PF, rotates and makes connexion with the calling position. If the line is engaged and messages are already waiting on other positions, uniselector PF rotates as soon as the line becomes free, and connects the first calling position in the direction of rotation, except that positions with priority messages are given precedence over positions with non-priority traffic.

When the line is seized, a circuit-identification code and serial number are sent to line by a serial-numbering transmitter[2] associated with the line. At the conclusion of the numbering sequence the numbering transmitter is disengaged, the message transmitter energized, and the message sent.

Messages for destinations connected by physical lines or voice-frequency telegraph circuits are transmitted directly from the transmit positions and each outgoing circuit is monitored by a teleprinter-reperforator to provide a page copy of every message. For outgoing lines connected to error-correcting radio circuits a different arrangement is necessary, as the rate of transmission is controlled by the radio-terminal equipment. Messages for transmission over error-correcting radio circuits are therefore routed from the transmit position to a buffer store, where they are received on a teleprinter-reperforator providing a page copy and a tape. This tape is fed continuously into an automatic transmitter, and each character is transmitted under the control of character-release pulses from the error-correcting equipment. The buffer store also ensures that any delay caused by the radio circuit does not result in messages accumulating at the transmit consoles but provides for their storage in a large-capacity tape-box.

Outgoing-Line Selection

The method of outgoing-line selection using the access uniselectors CM and PF is shown in Fig. 4. When a tape is loaded into the transmitter head, relay TL in the transmitter-head relay-set operates, and contact TL1 prepares a circuit to cause the associated uniselector CM to rotate. When the required route-selection key, KA, is pressed, relay DR operates and completes the circuit to energize uniselector CM, while earth potential from contact KA2 marks the appropriate contact on arc CM7. When uniselector CM reaches this contact, relay TR operates, cutting the drive circuit of uniselector CM and operating relay CD. Contact CD2 connects earth potential to the start lead of the line relay-set, and contact CD1 marks the bank of uniselector PF associated with the required line. When the line becomes free the start relay, ST, in the line equipment operates, and contact

[2]MARSH, H. An Electronic Serial-Numbering Transmitter. *P.O.E.E.J.*, Vol. 55, p. 195, Oct. 1962.

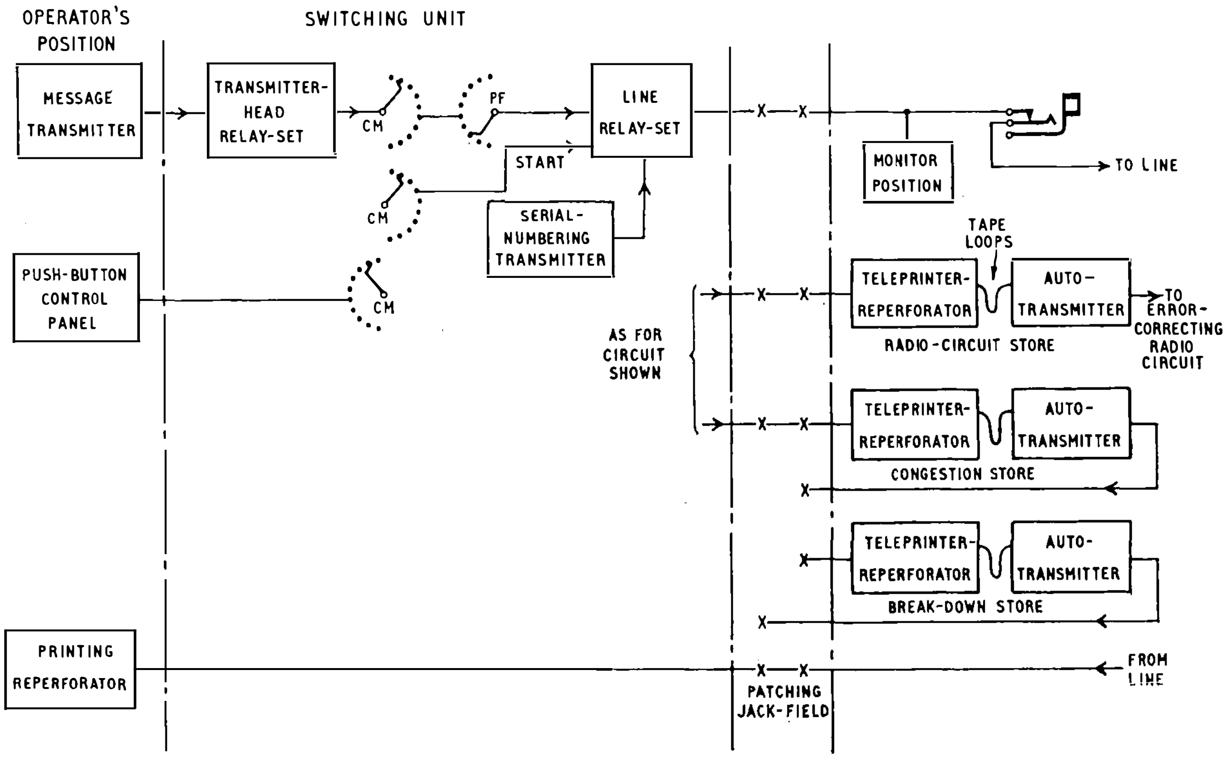


FIG. 3—BLOCK SCHEMATIC DIAGRAM OF TAPE-RELAY SYSTEM

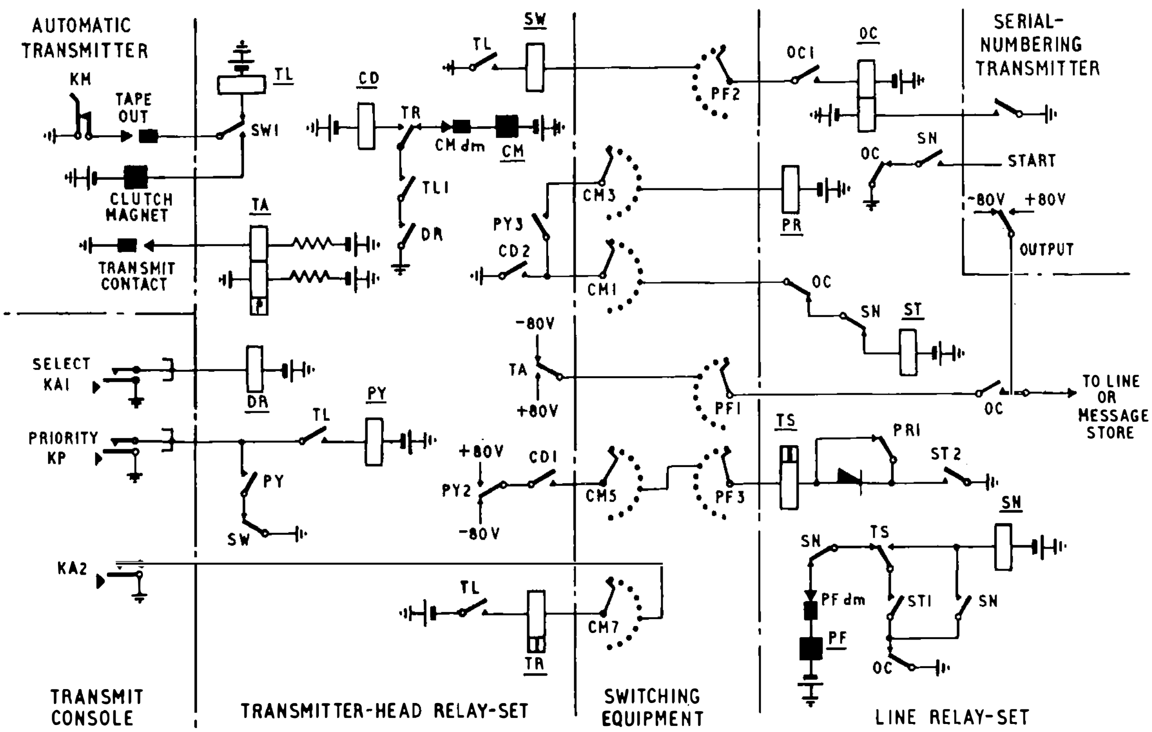


FIG. 4—OUTGOING-LINE SELECTION CIRCUIT

ST1 causes uniselector PF to rotate until the required position is selected. The operation of the switching relay, TS, in the line equipment operates relay SN, which starts the serial-numbering transmitter, sending the numbering preamble to line. At the conclusion of the preamble the serial-numbering transmitter operates relay OC, and contact OC1 operates switching relay SW in the transmitter-head relay-set. Contact SW1 energizes the clutch magnet of the automatic transmitter and the message is sent to line.

Priority Selection

Fig. 4 also shows the circuit for giving precedence to any required message. The priority key, KP, operates relay PY in the switching equipment, and, when uniselector CM has stopped at the selected line, contact PY3 connects earth potential to relay PR in the outgoing-line relay-set. Contact PY2 changes the marking potential on arc CM5, and hence on arc PF3, from negative to positive, and the opening of contact PR1 arranges the circuit of switching relay TS so that it will only operate to a positive potential on arc PF3. Thus, if a number of positions are awaiting connexion to a particular line and one has priority, when the line becomes free uniselector PF will rotate and select the position accorded precedence. When this position is connected to line, relays PY and PR release and switching relay SW connects the message transmitter to the outgoing-line circuit.

Error-Correcting Radio Circuits

As already mentioned, it is necessary to provide a buffer store between the switching unit and the error-correcting equipment used on radio telegraph circuits.

Messages from the switching unit are received on a teleprinter-reperforator; the page copy is used for message checking as on the monitor machines. The punched tape is fed to an automatic transmitter, and the loop of tape is accommodated in the tape box. Fig. 5 illustrates the position equipment and the circuit elements are shown in Fig. 6. Incoming signals are received by the teleprinter electromagnet and are monitored by relay MM, the message being received as a page copy and fully-punched tape. Contact MM1 changes over at the

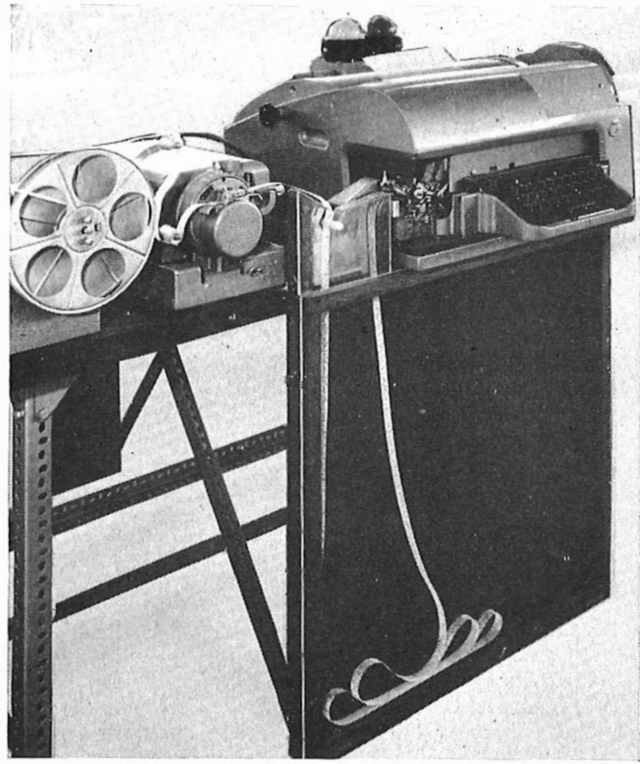


FIG. 5—TAPE STORE FOR ERROR-CORRECTING RADIO CIRCUIT

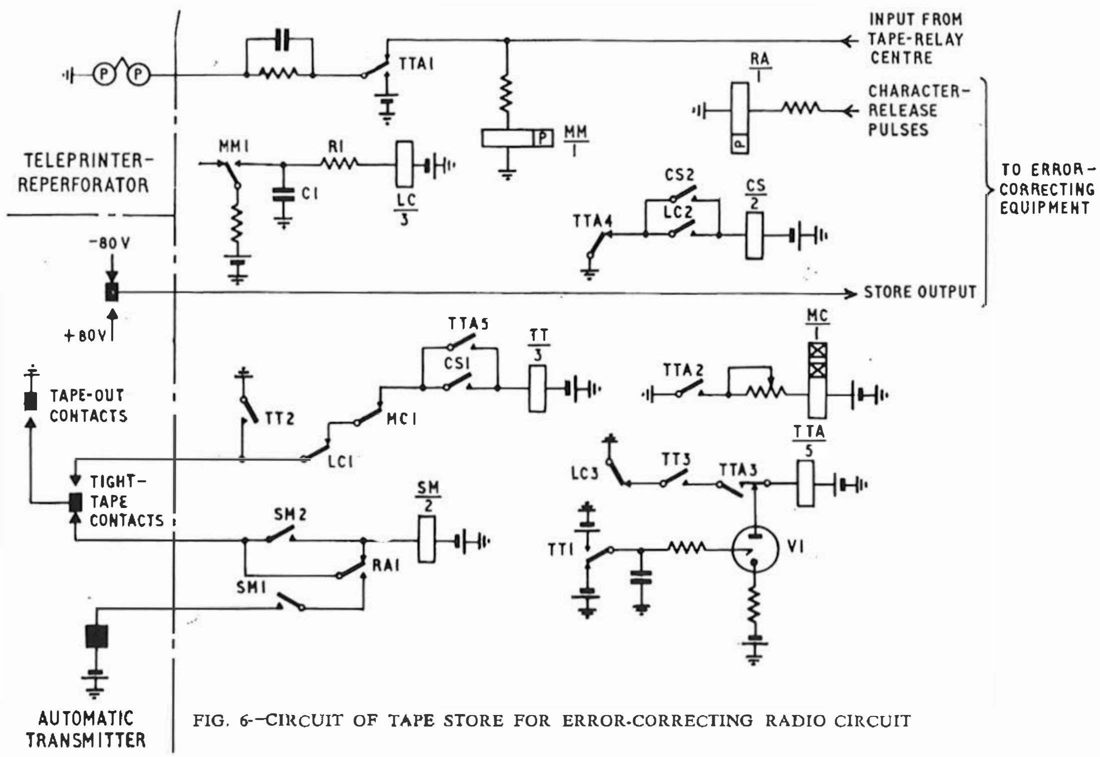


FIG. 6—CIRCUIT OF TAPE STORE FOR ERROR-CORRECTING RADIO CIRCUIT

first positive element, charges capacitor C1 and operates relay LC. The time-constant of resistor R1 and capacitor C1 ensures that relay LC remains operated for the whole of the message, successive positive elements in each character recharging the capacitor. A contact of relay LC operates relay CS, which prepares the tight-tape relay TT. As the punched tape is produced by the teleprinter, the tight-tape contacts of the automatic transmitter release, and earth potential from the transmitting tape-out contacts operates relay SM. Contacts of relay SM prepare a circuit to energize the transmitter clutch magnet. Character-release pulses from the error-correcting equipment are received by polarized relay RA, and the relay contact energizes the transmitter clutch magnet so that one character is transmitted for each pulse. Contacts RA1 and SM1 are arranged to prevent the operation of the clutch magnet to the short pulse that occurs if relay RA operates just before the tight-tape contacts release.

Under normal radio conditions transmission is at a slightly higher speed than reception from the transmit positions, and the tight-tape contacts will occasionally operate, releasing relay SM and disconnecting the clutch magnet. As further characters are received the tape loop again forms, the tight-tape contacts release, and further characters are transmitted. When the incoming message ends, relay MM ceases to respond to signals and relay LC releases, contact LC1 preparing a circuit to operate relay TT. When the tight-tape contacts close, relay TT operates and contact TT1 applies positive potential to the cold-cathode tube V1, which conducts after 2 to 3 seconds and operates relay TTA. This delay is to allow time for the switching equipment in the tape-relay centre to connect a waiting message and commence transmission before the operation of relay TTA. Contact TTA1 applies positive potential to the teleprinter electromagnet, causing blank tape to be produced to release the tight-tape contacts and ensure that the remainder of the message stored on the tape between the teleprinter and the transmitter is released to the error-correcting equipment. Thermal relay MC operates after 20–30 seconds and disconnects relays TT and TTA.

Provision is made on the position for tape-exhaust alarms and for busying the incoming circuit when the tape spool is being reloaded. This tape is collected by a tape winder, and any message repetition necessary can be effected by unwinding the tape and inserting the required portion in the transmitter in the normal way.

Patching, Monitoring and Testing

A large patching jack-field gives full flexibility for cross-connecting machines or lines to positions and equipment, as necessary. Monitoring facilities are provided so that each circuit may be supervised to assist in the location of faulty machines or numbering transmitters, and, as already described, a separate teleprinter-reperforator is connected to each outgoing cable or land-line circuit. A monitor position is illustrated in Fig. 7.

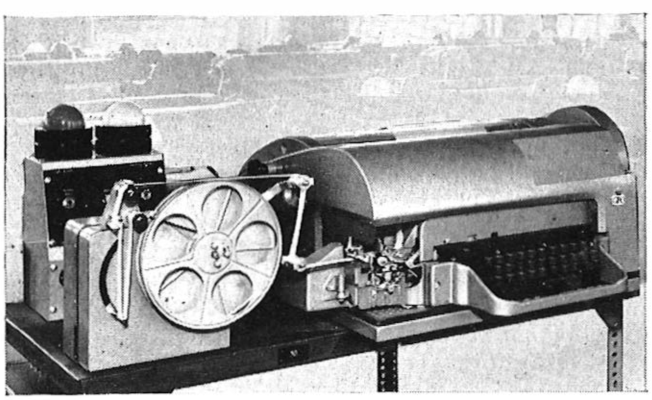


FIG. 7—MONITOR POSITION

A mobile automatic transmitter is provided with plugs and cords for connexion to any control panel. The machine is connected to the appropriate monitor position, and the required message withdrawn from the tape winder and loaded into the transmitter. The BUSY key on the control panel is operated to prevent any further messages being received from the tape consoles; if the line is engaged, the busy condition is applied as soon as the line becomes free. When the message has been transmitted the machine is withdrawn, the BUSY key restored, and transmission from the tape consoles continues.

A separate patching jack-field is provided for connecting reserve serial-numbering transmitters. These are equipped with code-setting keys so that they may be used for any circuit, and the number setting and resetting keys ensure that the numbering sequence can be maintained. A small U-link panel is also provided to accommodate reserve pulse-generators.

Congestion and Break-Down

Congestion may occur on circuits, making it necessary to separate priority, normal and "letter-rate" traffic. The first two categories of traffic may be dealt with by use of the priority push-button, but the letter-rate traffic is diverted to a congestion circuit. This consists of a normal outgoing line, without serial-numbering transmitter, connected to a teleprinter-reperforator with an automatic transmitter and tape store. The letter-rate traffic is separated from other traffic by the operator at each transmit position, loaded into a message head in the normal way, and the appropriate congestion circuit button pressed. The message is received in the congestion store as a page copy and as punched tape. The former is printed on coloured paper and stored in the incoming message file to be replaced by the normal white copy when the message is finally transmitted to its destination. The tape is held in the tape store until the congestion eases; it is then loaded into the automatic transmitter, cross-connected on the jack-field to a spare incoming printing reperforator in the tape centre, and reprocessed as described above.

Occasionally, due to unforeseen circumstances, a route may be closed to traffic. If no alternative route is available the traffic is diverted to a break-down store by cross-connecting the circuits on the patching jack-field. The outgoing messages are transmitted from the tape-relay message heads, using the normal access button. The traffic is automatically numbered, and is received on the teleprinter-reperforatoron the break-down store position. As with the congestion store, the message is received as a page copy on coloured paper and as punched tape. The tape is stored in the tape box; when the route is restored to service the tape is loaded in the break-down transmitter and the output of the store is connected directly to the line terminal. Messages from the tape centre continue to be received by the teleprinter, but, when the tape store has emptied, an alarm is given to indicate that normal connexions may be restored. The BUSY key permits normal traffic to be resumed.

A diagram of the circuit elements of the congestion or break-down store is shown in Fig. 8. Incoming signals to the storage unit are received by the teleprinter-reperforator, giving page printing and perforated tape. When congestion has eased, or the closed route has been reopened, earth potential from the sleeve of the cross-connexion plug energizes the clutch magnet and transmission begins. Further messages are received and stored in the tape loop, but transmission from the store is continuous, and in due course the store will empty and the tight-tape contacts will operate. Earth potential from the sleeve of the output jack operates relay TT. Contact TT1 connects earth potential to the line relay-

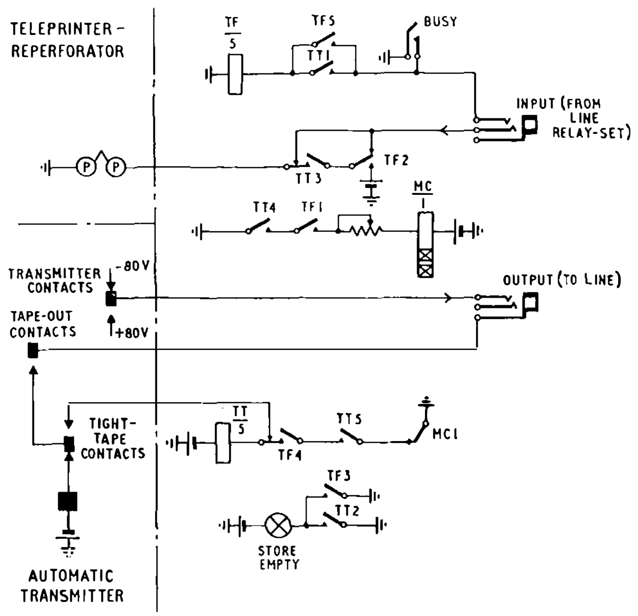


FIG. 8—CONGESTION OR BREAK-DOWN STORE

set to busy the incoming circuit, and contact TT2 lights the alarm lamp. A further contact of relay TT prepares a circuit for the operation of the thermal relay, MC. If a message is being transmitted through the line relay-set when the busy condition is applied, the relay-set waits until the message has been completed, refuses to accept any further messages, and responds to the busy signal by applying negative potential to the busy wire of the store, operating relay TF. Contact TF1 energizes the thermal relay MC, and contact TF2 disconnects the receive wire and applies positive potential to the teleprinter receive magnet to give blank tape; transmission proceeds when the tight-tape contacts restore to normal. After about 20 seconds, when sufficient blank tape has been produced for the end of the last message in the store to clear the transmitter head, relay MC operates and disconnects relay TT. Contact TT3 disconnects positive potential from the teleprinter and the store remains idle, with the line busied, until the reset key is operated and the patching cords removed.

CONCLUSIONS

The torn-tape relay system has reduced the time and the number of handling operations required for routing messages at the Electra House overseas telegraph centre and has improved operating conditions. It has demonstrated the use of message-relay operation at a large international telegraph centre, and knowledge gained from the working of this installation will be valuable in planning larger and more complex systems for the future.

A Duct-Rodding Machine

J. E. Deering†

U.D.C. 621.315.23

The rodding of a duct line prior to drawing in a cable is often a difficult operation to perform manually. The machine described enables one or two men to apply the necessary force to the rods in a more effective way than could the larger group of men that would be required without the machine.

INTRODUCTION

BEFORE drawing a cable into an underground duct it is necessary to "rod" the duct, i.e. to push some form of rod through it, and then to pull in a rope or wire by withdrawing the rod, subsequently using the wire or rope to draw in the cable.

The rodding of a duct line is usually a difficult operation because of the uncontrollable conditions experienced with salt-glazed ducts. Such conditions may include curves, non-alignment of bores, broken collars, variations of distance between jointing chambers, ducts entering jointing points, silted ducts, entry of vegetable growth into bores, and, of course, the probability of the presence of existing cables. The plant used for rodding must, therefore, be of a flexible nature to negotiate these hazards.

For the reasons mentioned, the rods, when pushed along a duct, invariably form a complicated spiral, and eventually the maximum physical effort that can be exerted on them by the operator is absorbed without effecting further forward movement of the rods. This applies when a number of cane rods are coupled together as well as when continuous rods are used.

A further hazard is the variation of the positions and levels of ducts entering jointing chambers. To ensure maximum utilization of effort, the ideal level for the duct mouth is waist height, but, as rodding cannot be performed by one operator, additional effort must be applied by a number of men positioned as near to the duct mouth as possible. In practice, however, a group of men can seldom be distributed evenly in front of a duct mouth and a great measure of wasted effort, therefore, occurs—a thrust as small as 100 lb has been measured in some circumstances. Furthermore, when operators cannot be evenly distributed, the spans of rod between them often bend, so reducing the forward movement.

During experiments using continuous rods it has often been demonstrated that, if a rod is given a sharp blow after the maximum forward distance had been reached, it will jump forward, and it will then be possible to manually thrust the rod even further forward. This demonstrates the energy that can be stored in the rod and thereby wasted.

RODDING MACHINE

Facilities

The inability to distribute operators evenly makes it impossible to apply a uniform thrust to the rods. From experimental work it has been found, however, that a

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series of thrusts, each of equal effort and applied regularly, move a rod farther than a series of spasmodic efforts. This led to the development of a machine embodying the following features.

(*i*) It is suitable for use with continuous rods.

(*ii*) The thrust developed by one operator is increased to 2,000 lb.

(*iii*) It is suitable for operation at ground level.

(*iv*) A flexible guide tube for insertion in the duct mouth is provided to prevent the rod bending.

(*v*) A meter is provided to indicate the distance rodded.

Description of Rodding Machine

The machine (Fig. 1) consists essentially of a manually-operated lever that extends upwards from a frame and is

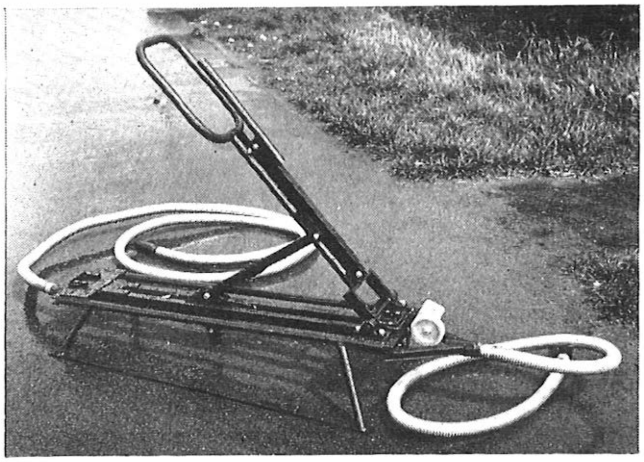

FIG. 1—DUCT-RODDING MACHINE

linked to a releasable mechanism that is free to slide along guides. The releasable mechanism is the principal feature of the machine, and it is so arranged that when the lever is operated in one direction it causes the mechanism to slide along the frame and grip the rod, thus feeding the rod forward. When the lever is operated in the reverse direction the grip is released from the rod and the mechanism is returned to its initial position in the frame. Alternatively, the mechanism can be made to release the rod on the forward stroke and grip it on the return stroke of the lever, thus enabling the rod to be withdrawn. Furthermore, the mechanism includes a means of locking the grip to the rod so that swinging the handle lever in either direction causes a corresponding forward and backward movement of the grip and of the rod with which it is engaged. Fig. 2 shows the mechanism.

Operation of Rodding Machine

When using the machine in the field, sufficient effort can be applied by one or two men to rod most unobstructed ducts. When difficulties are experienced additional men tend to damage the rod by buckling it, and if an obstruction is encountered it is preferable to withdraw the rod a few yards and make a renewed forward thrust. If the difficulty persists the mechanism can be

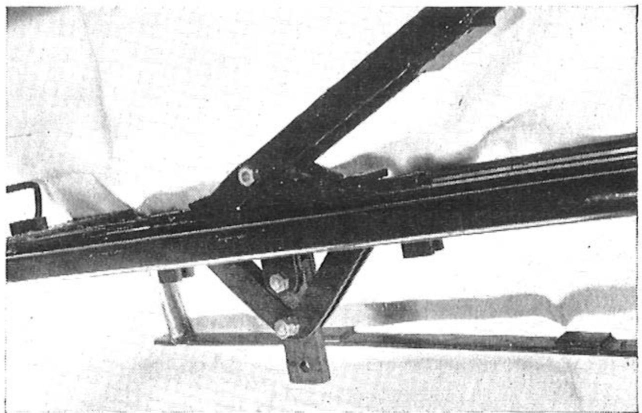

FIG. 2—MECHANISM OF DUCT-RODDING MACHINE

reset to enable the rod to be oscillated in the duct. The oscillatory thrust movement is limited by the stroke applied and cannot exceed the full stroke normally employed. The recommended practice is, therefore, to oscillate the rod backwards and forwards a number of times and then reset the mechanism to enable normal forward movement to take place. If several attempts to overcome the stoppage fail, the duct should be rodded from the other end, using thick cane rods, until "marrying" is attained. For this purpose the measuring device fitted to the machine is very useful as it indicates, to the nearest foot, the position of the coupling-up piece on the continuous rod. From this the number of canes

FIG. 3—MACHINE SET UP FOR RODDING A DUCT

required to marry up can be assessed. Fig. 3 shows the machine set up for rodding a duct.

Lasers and Communications

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U.D.C. 621.391.63:621.375.9

Lasers have been in existence for a mere 4 years, yet hardly an issue of a technical publication on electronics, physics or engineering now appears without some reference to them. This article explains what lasers are, how they work, and what they can do, with special reference to their potential application to communications. The main property of lasers that is of interest in this field is their ability to generate coherent electromagnetic waves, similar to radio waves, at wavelengths ranging from the shortest previously available down to the visible spectrum, where wavelengths are a thousand times shorter still.

INTRODUCTION

OPTICAL masers or lasers are quite a recent discovery. The first ruby laser was operated by Maiman in 1960, to be followed shortly by Javan's helium-neon gas laser. The semiconductor laser, closely related to the transistor, came along a year or so later. These three devices have in common the ability to generate coherent light; the term light being used loosely to include the ultra-violet and infra-red regions of the electromagnetic spectrum. Ordinary light from a hot body, such as a lamp filament, is a jumble of independent wave trains covering a wide band of frequencies, and can be compared with the output from a spark radio transmitter. Until recently this has been the only kind of light available, but laser light is a steady oscillation at a steady frequency, like the output from a crystal-controlled radio transmitter.

Radio services, using wavelengths from thousands of kilometres down to fractions of a millimetre, and with carrier waves modulated by speech or television signals, radiated from directional aerials, and selected by sharply-tuned receivers, could not have grown to their present level had only spark transmitters been available. In fact, the growth has been such that shorter and shorter wavelengths have been used to find sufficient space in the frequency spectrum. There is plenty more space between millimetre waves and visible light with wavelengths a thousand times shorter, and now that the laser offers something better than the equivalent of a spark transmitter for this region an important new field is opened up: there is room in the visible spectrum alone for a thousand times as many channels as in the whole of the present radio spectrum. However, it should be borne in mind that, because of propagation difficulties due to fog, rain, etc., light waves cannot directly replace the radio waves used for broadcasting, communications and radar.

Electromagnetic waves are radiated whenever electric charges are accelerated or retarded, and coherent radio waves are generated by forcing a current to oscillate steadily in a resonant system, using a valve or transistor to supply the energy lost in radiation. For the lower frequencies, coils and capacitors suffice, but resonant lines and cavities are used for the higher frequencies. Very delicate engineering is needed for the shortest radio waves so far generated—about a millimetre in wavelength—and to reach wavelengths a thousand times shorter the laser makes use of the internal structure of the atom itself. To understand how this is done it is necessary to look at some of the basic facts about the interaction of matter and radiation.

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ATOMS AND RADIATION

The simple picture of an atom as a miniature solar system will suffice for the purpose of this article. The central positively-charged nucleus is surrounded by a cloud of negatively-charged electrons moving in planetary orbits and sufficient in number to make the whole atom electrically neutral. Electrons in outer orbits have more energy than those in inner orbits. Only certain particular orbits are possible, so the energy of an electron can have only certain precisely-defined values. Fig. 1 shows

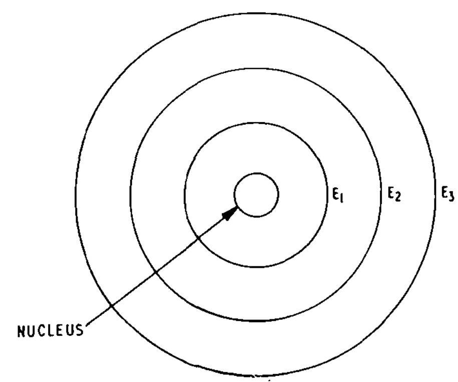


FIG. 1—ELECTRON ORBITS IN AN ATOM

three possible orbits, labelled with their energy values, E_1, E_2, E_3. The energy of the whole atom can alter only in discrete steps, for example by an electron jumping from orbit 1 to orbit 2. If an electron jumps outwards it must receive energy, and if it jumps inwards it gives out energy; in each instance the energy is in the form of a packet of electromagnetic radiation—a photon. One jump always involves one photon, but it is found that the frequency of the radiation in the packet is proportional to the energy difference between the initial and final orbits:

$$\Delta E = \mathrm{h}f \qquad (1)$$

where ΔE = energy change,
f = frequency of the radiation emitted or absorbed,
and h = Planck's constant.

The energy of a photon is thus proportional to its frequency. All electromagnetic radiation is in the form of photons, but at radio and lower frequencies the packets are so small that the stream of radiation appears to be continuous, just as the molecules in a jet of water cannot be appreciated individually. At optical frequencies the energies are high enough for separate photons to be counted, and this results in some differences between radio and optical receivers, and in theoretical calculations of noise levels.

Clearly an atom with a limited number of allowed orbits with energy levels of E_1, E_2, E_3, etc., can emit light only at frequencies corresponding to the possible energy jumps $E_1 - E_2$, $E_1 - E_3$, $E_2 - E_3$, etc. These permitted frequencies are characteristic of a particular type of atom and constitute the line spectrum exploited in spectrographic analysis. It should be noted also that an atom can be excited, i.e. can have some of its electrons shifted into higher energy orbits, only by radiation of the correct frequencies. Thus, a photon of frequency $f_{12} = (E_2 - E_1)/h$ can be absorbed if it encounters an electron in orbit 1. The electron will be lifted into orbit 2, and may in due course fall back spontaneously into orbit 1, emitting a photon of frequency f_{12}. These two processes, absorption and spontaneous emission, are supplemented by a third—stimulated emission—of particular importance to the laser. If a photon of frequency f_{12} encounters an electron already in the higher-energy orbit 2 it may stimulate the electron to fall back prematurely to orbit 1. When this occurs, a second f_{12} photon is created which is an exact copy of the stimulating photon: it has the same frequency, phase and polarization, and travels in the same direction. Two photons for one means amplification, and hence the name of the device: Light Amplification by Stimulated Emission or Radiation, or LASER for short.

Successful operation of a laser depends on making stimulated emission more likely than absorption, and this means having more atoms with electrons in E_2 orbits than in E_1 orbits. At very low temperatures all the atoms in a substance have their electrons packed into the lowest-energy orbits, but only one electron in each, by Pauli's exclusion principle. At higher temperatures some atoms are excited by thermal energy and have electrons in higher-energy orbits. For a material in thermal equilibrium the distribution of electron energies is given by the Boltzmann function, which may be written in the form:

$$N_2/N_1 = \exp\{-(E_2 - E_1)/kT\} \ldots\ldots (2)$$

where N_1, N_2 = numbers of atoms in energy states E_1, E_2, respectively,
T = absolute temperature,
and k = Boltzmann's constant.

For $E_2 > E_1$ this gives $N_1 > N_2$ so that, with materials in thermal equilibrium, absorption will always exceed stimulated emission and laser action is not possible. To achieve laser action it is necessary to "invert the population" of energy levels E_1 and E_2, i.e. to make $N_2 > N_1$ contrary to the natural order. The process by which this is done is called pumping.

PUMPING

It is usual to discuss these matters in terms of a level diagram, such as Fig. 2, which may be regarded as a slice through the electron orbit diagram of Fig. 1. If radiation of frequency $f_{13} = (E_3 - E_1)/h$ is directed at a material characterized by the energy-level scheme of Fig. 2, atoms will be excited from the lowest level E_1 (usually called the ground state) to level E_3. Some will fall back to level E_2 rather than level E_1, losing only part of their extra energy. With sufficiently intense pumping radiation at f_{13} the combined effects of the depletion of level E_1 and the supplementing of level E_2 can bring about the desired inversion, $N_2 > N_1$, and make amplification of frequencies $f_{12} = (E_2 - E_1)/h$ possible. The pumping radiation need not be coherent.

It is not to be expected that this process will be very efficient. The pumping radiation is higher in frequency and so has a higher energy per photon than the radiation

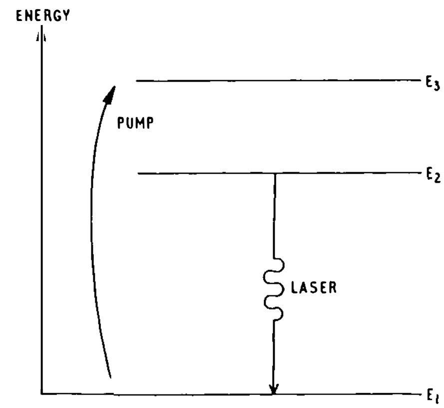


FIG. 2—THREE-LEVEL LASER

to be amplified. Much of it is likely to shoot right past or through the material without achieving its purpose, and many of the atoms will drop to lower levels in the wrong ways. Worst of all, practical light sources for pumping will have only a tiny fraction of their output at frequencies near enough to f_{13} to do any good. Developing a successful laser depends on finding or making materials with favourable properties, such as a group of levels close together instead of a single level for E_3, to facilitate pumping.

The scheme described above is a 3-level laser. A valuable advantage may be gained by using four energy levels, as illustrated in Fig 3. Pumping now takes place

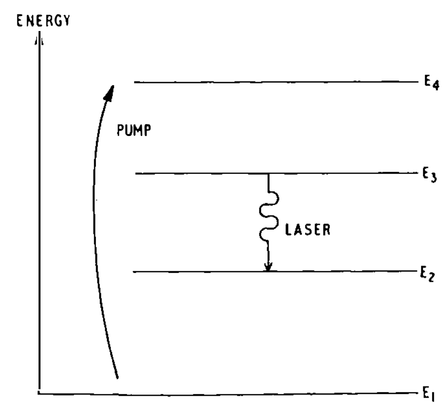


FIG. 3—FOUR-LEVEL LASER

between levels E_1 and E_4, and the population inversion is established between levels E_2 and E_3. The advantage comes from the fact that as level E_2 is higher than level E_1 it is more sparsely populated to start with, and less pumping suffices to make $N_3 > N_2$. Lowering the temperature, by immersing the laser in liquid nitrogen for example, can enhance the effect, as may be seen by studying the effect of T in equation (2).

The simple energy-level schemes described above apply to isolated atoms, and break down if the atoms are close enough to one another to interact. Either the atoms must be in the form of a gas at low pressure, or they must be dispersed at low concentration in the regular lattice structure of a host crystal. Thus, ruby consists of 0·05 per cent of active chromium atoms in a crystal of aluminium oxide. The rare-earth elements offer an exception to this requirement, however. Their atoms have relatively large numbers of electrons, and these achieve a stable configuration in which an outer shell screens the active electrons from external fields without itself taking part in optical transitions. Such atoms can be used at concentrations up to 6 per cent in an amorphous host material such as glass. It is easier and cheaper to make glass of good optical quality than to grow large perfect single crystals of a refractory substance like alumina. The most useful of these rare-earth materials is neodymium, which yields a 4-level system as in Fig. 3. Ruby, the original material to be used, is a 3-level system, but it still holds its own, especially for high-power devices, due to its superior thermal properties.

RESONATORS

To turn the laser amplifier into an oscillator a positive-feedback system is required, and the usual arrangement is a Fabry-Perot resonator consisting of a pair of mirrors parallel to and facing one another, as shown in Fig. 4.

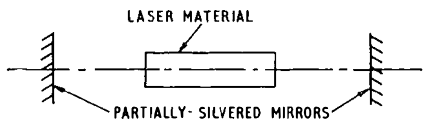


FIG. 4—FABRY-PEROT RESONATOR

The laser material is in the form of a rod or gas-filled tube on the resonator axis. Radiation emitted from the end of the rod is reflected backwards and forwards, gaining intensity at each passage until saturation occurs. It is easy to see that only rays near to the axis will build up strongly: others are soon reflected out of the system. The laser output when oscillating steadily is thus a narrow axial beam of small divergence.

For build-up to continue, successive round trips must return the waves in phase, and this means that the optical-path length between the mirrors must be an integral number of half wavelengths. Since a typical resonator may well be half a million wavelengths long a whole range of frequencies spaced apart by perhaps one part in a million can satisfy the resonance condition. Several of these frequencies or modes may be close enough to the atomic transition frequency to initiate stimulated emission, so the laser can adapt itself to any given mirror spacing. It may oscillate at the single frequency which fits best or at a number of frequencies simultaneously, depending on the gain and, hence, on the degree of pumping. In Fig. 5 the curve labelled

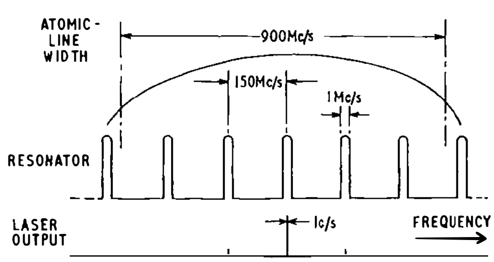


FIG. 5—FREQUENCY BANDWIDTHS IN A GAS LASER

atomic-line width indicates the response of the pumped atoms to frequencies slightly displaced from the nominal transition frequency. Below this is shown the multiple response characteristic of the resonator, and below this again the spectrum of the oscillating laser output. The laser oscillates only at the centre of each resonator response and the output lines are very narrow. In a typical gas laser the atomic-line width may be 900 Mc/s at a centre frequency of a hundred million megacycles per second, the resonator responses may each be a few megacycles per second wide, and the laser output lines less than one cycle per second wide.

From the foregoing discussion it will be seen that two of the most striking properties of the laser output—the very narrow beam of light and the very narrow bandwidth—are as much a property of the resonator as of the active material. Thus, the laser is not an atomic frequency standard, comparable with the caesium clock, for example: its frequency depends directly on the mechanical dimensions of the resonator. The radiation field within the resonator builds up to a very intense level, and a small fraction of the radiation is allowed to escape to form the output beam by only partially silvering the mirrors.

TYPES OF LASERS

Solid-State Lasers

Solid-state lasers, such as the ruby-crystal or neodymium-glass lasers, are usually pumped by discharging a bank of capacitors charged to a high voltage through a tube filled with xenon gas. The laser rod and flash tube are mounted parallel to one another along the focal lines of a reflector in the form of an elliptical cylinder (Fig. 6). The pumping flash lasts for a milli-

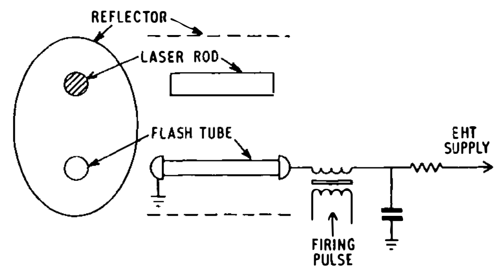


FIG. 6—SOLID-STATE LASER

second, and the laser output is in the form of pulses. Some solid-state lasers have been made to give a continuous output by cooling them to very low temperatures and pumping with heavily over-run mercury-arc lamps, but most are used in the pulsed condition. The ruby laser gives a deep-red output, and the neodymium laser output is in the near infra-red. Very many other materials are now available, mostly operating at infra-red wavelengths.

Each flash usually causes the laser to emit a train of pulses of light each of only a few microseconds duration. The peak power output in each pulse is measured in hundreds of kilowatts and the flash is far, far brighter than the sun. To get really high powers, however, a device known as "Q-spoiling" is adopted. One method of doing this is illustrated in Fig. 7, and uses a totally-

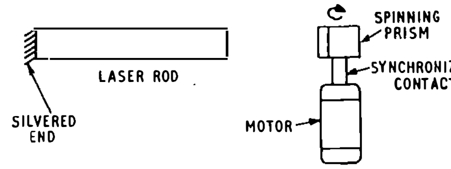


FIG. 7—Q-SPOILED LASER

reflecting prism spinning at high speed as one mirror of the resonator. A synchronizing contact on the prism shaft fires the flash tube, but the laser does not operate until the prism comes round to a position parallel to the fixed mirror. The energy stored up in the excited atoms is then released in one giant light pulse, which may have a duration of a few hundreds of a microsecond and a peak power of many hundreds of megawatts—as much as a fair-sized generating station. An ordinary laser pulse can drill holes in razor blades and diamonds, but the impact of a giant laser pulse causes a shock wave like a miniature explosive charge. The electric field intensity in the light wave may be high enough to ionize the air through which it passes.

Generally speaking, the solid-state lasers are high-power brute-force devices. They are likely to find applications for such things as machining refractory materials and welding small structures (especially in controlled atmospheres), and in devices such as range-finders operating on radar principles where the pulsed output is not a disadvantage. The short wavelength allows very narrow beams or very small illuminated spots to be produced; for example, a patch on the moon only a few miles across has been illuminated and observed from the earth. One particularly successful application has been the use of the laser in surgery to weld back detached retinas in the eye.

Gas Lasers

The range of wavelengths available from lasers operating with the active atoms in the form of a gas is much wider than that so far offered by solid-state lasers, and extends from half a micron,* in the visible green, to 330 microns, which overlaps the shortest radio wavelengths. Most gas lasers are pumped not with optical radiation but by a pulsed or continuous electrical discharge, and there is a variety of different mechanisms. The following description refers to the original helium-neon laser that, especially for communications, is still one of the most interesting as it can yield a very stable continuous-wave carrier of extreme purity, directed into a very narrow beam ideal for point-to-point services.

The pumping scheme for the helium-neon laser is shown in Fig. 8. Neon is the active material, and the

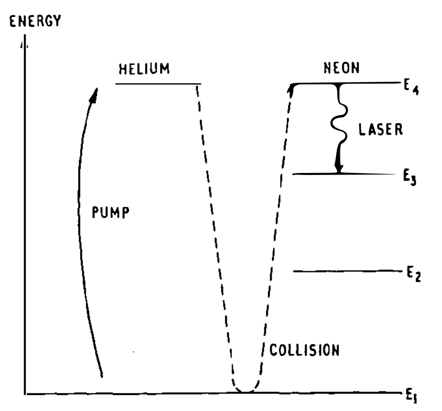


FIG. 8—ENERGY LEVELS FOR HELIUM AND NEON

laser transition takes place between levels E_4 and E_3. Pumping to level E_4 is achieved by collisions with helium atoms previously excited to a suitable energy level by an electrical discharge. It is a fortunate coincidence that the helium atom can assume just the right amount of energy to lift a neon atom from the ground state, level E_1, to level E_4, and that helium atoms in this particular excited state are metastable, i.e. they show little tendency to give up their excess energy except by colliding with other atoms.

*Micron—a millionth of a metre.

The arrangement of a typical helium-neon gas laser is shown in Fig. 9. The helium at a pressure of 1 mm

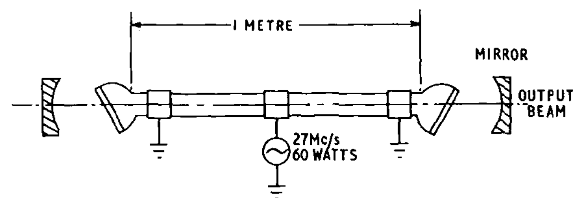


FIG. 9—HELIUM-NEON GAS LASER

of mercury and the neon at 0·1 mm, are contained in a quartz tube 1 metre long and 10 mm in diameter. Electrodes round the outside of the tube are connected to the output of a 27 Mc/s radio-frequency oscillator, which maintains a discharge to excite the helium. While a single pass through a ruby rod may give a gain of two, the gain for one pass through the gas is only a few per cent, and external losses must be kept to a minimum. For this reason the mirrors are usually spherical and spaced so that their common focus lies at the centre of the tube. Metallic reflectors absorb at least 5 per cent at each reflection, so special dielectric coatings are used, consisting of about a dozen films of high and low refractive-index materials deposited alternately on the mirror surface. Correct choice of the film thicknesses can yield a reflectivity of 99 per cent at the desired operating wavelength. The windows sealing the ends of the tube must be optically flat, and cannot be set square with the axis as they would then cause a loss of about 8 per cent each by surface reflection. Instead they are inclined, as shown in Fig. 9, at the Brewster angle. Light polarized in one direction then passes through them without reflection, and the laser operates only with light polarized in this manner.

The original helium-laser operated at a wavelength of 1·153 microns in the near infra-red. The level diagram shown in Fig. 8 is simplified, however, and not only are several different wavelengths available in this region, but the same system can be made to work in the visible red or orange, and also at the comparatively long infra-red wavelength of 3·39 microns. The desired range is chosen by altering the mirror coatings.

The output from such a laser is a few milliwatts when operating so that several resonator modes (Fig. 5) are excited, or a few tens of microwaves when operating in a single mode. In this latter condition the output is a very pure and stable oscillation. Though the total power is low, within the bandwidth which it occupies it is still millions of times more intense than the sun. The output is in phase over the whole cross-section of the beam so that the whole of the energy can be focused into a spot of the order of one wavelength in diameter, or can be collimated in a beam which might start off at a diameter of 1 cm and spread to only twice this diameter in a distance of 100 metres. For comparison, to obtain this degree of collimation at the short radio wavelength of 10 cm (3,000 Mc/s) would require an aerial a kilometre in diameter, which would be considerably larger than that at Jodrell Bank, and the energy would still be spread over a kilometre rather than two centimetres at the receiver.

Semiconductor Lasers

The third member of the trio is the semiconductor laser. This makes use of a rectifying junction between p-type and n-type semiconductors, similar to the collector or emitter junction in a transistor. A very heavy current is passed through the junction in the forward direction so that there is a very high density of electrons and holes in this region. These carriers can recombine with emission of radiation, and the recombination can be stimulated by radiation so that laser action is possible. The best material is the compound gallium-arsenide, and a typical laser consists of a 0·5 mm cube, as shown in Fig. 10, with a junction formed by diffusion half-way

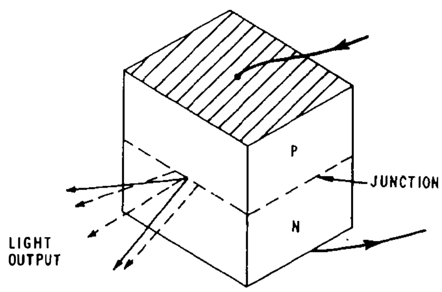


FIG. 10—SEMICONDUCTOR LASER

through it. The light is emitted in the plane of the junction and the gain is very high, so that the reflectivity of the cleaved crystal faces provides sufficient feedback for oscillation.

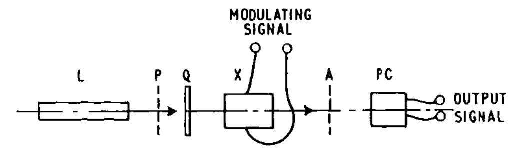
The gallium-arsenide laser can be very efficient, converting up to 70 per cent of the electrical power supplied into radiation just beyond the red end of the spectrum, and the mean output power may be more than a watt. Furthermore, the light output directly follows modulation of the electrical input up to at least 300 Mc/s. In these respects it appears that the semiconductor laser should be ideal for communications applications; there are, however, a number of difficulties. The high current density required before stimulated emission exceeds absorption can only be sustained in short pulses unless the laser is immersed in liquid helium at 4·2°K. The laser must be cooled at least to liquid nitrogen temperatures (77°K) if it is to give acceptable efficiency and power output. The radiation is emitted from an area only 0·5 mm by a few microns in size, so that the beam spreads over an angle of 1° by 10° due to diffraction. The wavelength of the radiation is unstable, partly due to the poor quality of the resonator system, partly due to heating during the pulse, and partly due to jumping between modes, which also makes the output noisy.

Though a number of simple demonstrations of the use of semiconductor lasers for carrying information such as a television signal have been given, it is doubtful whether in their present form they are serious competitors to gas lasers for high-quality trunk communication systems. For less-demanding applications, such as single-channel links, portable rangefinders, etc., their compactness, efficiency and ease of modulation offer many advantages. The range of wavelengths available by using different materials extends from the visible green, i.e. 0·5 microns, to 5 microns, and a useful feature is that the wavelength can be adjusted by mixing materials in different proportions.

LIGHT MODULATION

For any communications application it is necessary to modulate the light beam with the information to be carried. The semiconductor laser can be modulated directly up to at least 300 Mc/s, though it does have other drawbacks mentioned above. Solid-state lasers are capable of pulse operation at rates of not more than a few pulses a second, and gas lasers can be directly modulated only with bandwidths of less than 1 Mc/s. To make economic use of a laser link in the trunk network, wide modulation bandwidths are needed. External modulators using electro-optic effects are capable of modulating frequencies up to some 10 Gc/s, though at present the amount of modulating power needed, upwards of a watt, may be inconveniently high.

A typical communication link using a crystal of optically-active ammonium dihydrogen phosphate (ADP) as a modulator is shown in Fig. 11. The laser beam



L—Laser P—Polarizer Q—Quarter-wave plate A—Analyser PC—Photo-cell X—Crystal

FIG. 11—COMMUNICATION LINK USING ADP MODULATOR

is passed along the axis of the crystal X. Application of a potential difference between the electrodes makes the crystal birefringent, so that light polarized in two perpendicular directions travels at different speeds. The polarizer P and quarter-wave plate Q yield circularly-polarized light consisting of two components in space-and-time quadrature. Birefringence in the modulating crystal converts this into elliptical polarization to a greater or less extent and yields an amplitude-modulated wave at the output of the analyser A. The amplitude-modulated wave is detected by the photo-cell PC. Ordinary photo-multiplier tubes are limited to a few hundred megacycles per second, but new devices such as special semiconductor diodes and travelling-wave photo-tubes are capable of bandwidths greater than 20 Gc/s.

TRANSMISSION MEDIUM

The coherent short-wavelength radiation from a laser enables very narrow beams to be formed with tiny "aerials," and would be ideal for point-to-point communication services but for the fact that atmospheric attenuation in rain, haze or fog can virtually interrupt the path. For terrestrial links of acceptable serviceability it will be necessary to transmit the beams through pipes containing a controlled atmosphere. This unfortunately increases the cost very considerably, though light guides may prove to be less expensive than high-capacity waveguide. Two types of guide have been proposed: one consisting of a tube perhaps an inch in diameter with a reflecting inner surface will tolerate gentle bends and gives a loss of some 2 db/mile; the second type uses a series of long-focal-length lenses to relay the beam. In this type the pipe is merely an enclosure and may sag between relay points so long as it does not interrupt the beam. Automatic regulation of the lens positions by servomechanisms would probably be needed to compensate for earth movements, and the pipe would have to be buried to stabilize the temperature. The transmission loss of the lens system would be similar to that of the reflecting pipe.

CONCLUSIONS

The laser is a new device that extends the range of coherent electromagnetic radiation far beyond the present radio spectrum. The possibilities of generating high-energy concentrations and accurately collimated beams appear to open the door to a wide range of applications. For scientific purposes these are already being vigorously exploited, but many of the practical applications have remained in the potential stage, though some engineering development is under way. The communications field is one in which the potential advantages are perhaps as great as in any other, but it is also one in which a very high standard of performance and reliability is needed, especially for use in the trunk network, and economic competition with alternative systems is strong. The pace of new discovery and development in lasers and ancillary equipment is very rapid, however, and it is certainly too early to attempt any final assessment. A small group has been set up at the Post Office Research Station, Dollis Hill, to study possible applications in the Post Office and to keep in touch with new developments.

A New Range of Ringing Converters for Subscribers' Apparatus

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U.D.C. 621.314.263:621.395.631.4

Static converters for the provision of ringing supplies at subscribers' installations were first introduced in 1943; these converters produced a 16⅔ c/s output from a 50 c/s mains supply. A new series of static ringing converters, which produce a 25 c/s output from a 50 c/s mains supply, have now been developed, and this article describes their mode of operation.

INTRODUCTION

FOR many years the standard frequency of ringing supplies used by the British Post Office was 17 c/s, although a few machines having an output at 25 c/s were in use at some smaller telephone exchanges. In 1953 it was decided to standardize the frequency of the ringing supply at 25 c/s, this being the highest frequency to which the standard magneto telephone bell could usefully respond without special adjustment or selection. It also made possible a reduction in the size and, consequently, in the cost of a ringing device for the same given power output.

The usual ringing supply for automatic and large manual private branch exchanges is a rotary machine, and vibrators or static converters are used at other types of subscribers' installations.

The early static converters (Converters, Ringing, No. 1–3), first introduced in 1943, produced a 16⅔ c/s output from the 50 c/s mains by means of frequency division.[1] They have not been entirely satisfactory, however, and their performance depends on a critical relay adjustment which it is hard to maintain; the relay is required in the starting operation of the device to ensure that the input mains supply and the output are in phase.

A new approach has therefore been made to converting mains energy to supply ringing current, and the method developed is used in a new series of static converters described in this article. The new ringing devices, which produce a 25 c/s output and operate from the 50 c/s mains supply, have been coded Converters, Ringing, No.4, 5, 6 and 7. They are simple static devices and do not need a starting relay.

Basically, the circuit operation can be described as follows. The cores of each of two identical transformers are made to saturate on alternate positive half-cycles of the a.c. supply. Their secondary windings are connected so that when the cores are working linearly there is no output at the fundamental frequency, but, under saturation conditions, an oscillatory voltage at the subharmonic frequency appears in the output circuit.

†Subscribers' Apparatus and Miscellaneous Services Branch, E.-in-C.'s Office.

RINGING-CONVERTER PERFORMANCE

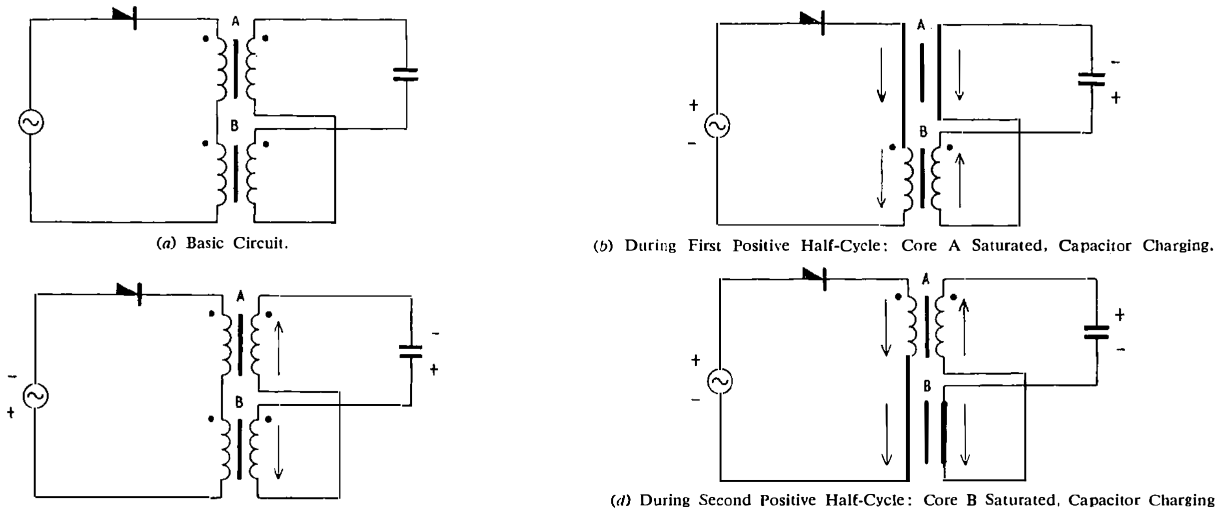
The output ratings of the earlier ringing devices have been expressed as a power in watts. It has been found, however, that the ratings of the 50/25 c/s converters are best expressed in terms of the number of parallel-connected telephone bells that they are capable of ringing satisfactorily. This is because their regulation characteristics depend upon whether the load is resistive or reactive.

The Converters, Ringing, No.7, 4, 5 and 6, respectively, are capable of ringing up to 1, 4, 20 and 60 magneto-bell circuits in parallel. Each such bell circuit may consist of up to four series-connected Bells No. 59A with a 2μF capacitor. Loading the converters with a number of parallel-connected bell circuits much in excess of the rated number results in complete cessation of oscillation, but oscillations recommence upon removal of the excess load. Under these overload conditions the input current tends to fall to its no-load value; the converters are, therefore, self-protecting.

The transformers in the converters are tapped so as to be suitable for operation on mains voltages in the range 200–250 volts $\pm$ 6 per cent. The output waveform is approximately sinusoidal, with a frequency of half that of the mains supply. The output voltage is restricted to a maximum of 70 volts, as higher voltages at 25 c/s are considered dangerous.

THEORY OF OPERATION

No precise theory explaining the mode of operation of magnetic frequency-dividers has yet been published, but a recent paper[2] has offered a qualitative explanation that appears to satisfy the observed effects. The basic circuit of the frequency divider is shown in Fig. 1(*a*). Two identical saturable transformers have their pri-



(*a*) Basic Circuit.

(*b*) During First Positive Half-Cycle: Core A Saturated, Capacitor Charging.

(*c*) During Following Negative Half-Cycle: Capacitor Discharging.

(*d*) During Second Positive Half-Cycle: Core B Saturated, Capacitor Charging in Reverse Direction.

⟶ Direction of current
The instantaneous polarity of the voltage is indicated

FIG. 1—PRINCIPLE OF OPERATION OF MAGNETIC FREQUENCY DIVIDER

mary windings connected in series and, via a rectifier, to the a.c. supply. The secondaries are connected in series opposing and to a capacitor; they may be tapped to provide an output at the required voltage. If this circuit were operated linearly there could be no transfer of energy from the primary to the secondary, since the voltages induced in the secondary circuit would be equal and opposite. Energy can, however, be transferred if one of the cores is saturated, and, consequently, is virtually short-circuited, while the other works linearly; and a second-order sub-harmonic current can be supported in the secondary circuit if alternate cores are saturated on consecutive positive half-cycles. To show that these conditions can exist in steady operation, assume that, during a particular positive half-cycle of the supply voltage, currents flow in the directions indicated in Fig. 1(*b*) and that the resultant ampere-turns in transformer A are sufficient to saturate core A. During this period, primary and secondary ampere-turns in transformer B are in opposition, so that this behaves normally; its secondary voltage supports a current in the direction assumed, charging the capacitor in the direction shown.

In the following negative half-cycle (Fig. 1(*c*)) neither transformer is saturated, as the primary current is reduced to a very low value by the reverse resistance of the rectifier, and the capacitor commences to discharge through the high inductance of the two secondary windings in series. During the next positive half-cycle of the supply voltage (Fig. 1(*d*)) the currents are in such directions that core B saturates and transformer A delivers a current to charge the capacitor in the reverse direction. It will be noticed that the charge on the capacitor changes sign during each positive half-cycle, indicating that a current having a frequency of half that of the supply is present in the secondary circuit. For the process to be self-maintaining, i.e. for the secondary current to cause saturation of the appropriate core at the correct time, the resonant frequency of the capacitor and unsaturated inductance of the secondary windings must be approximately equal to the sub-harmonic frequency.

This picture of the mode of operation is confirmed by study of the waveforms of current and voltage in a frequency divider working on load, as illustrated in Fig. 2.

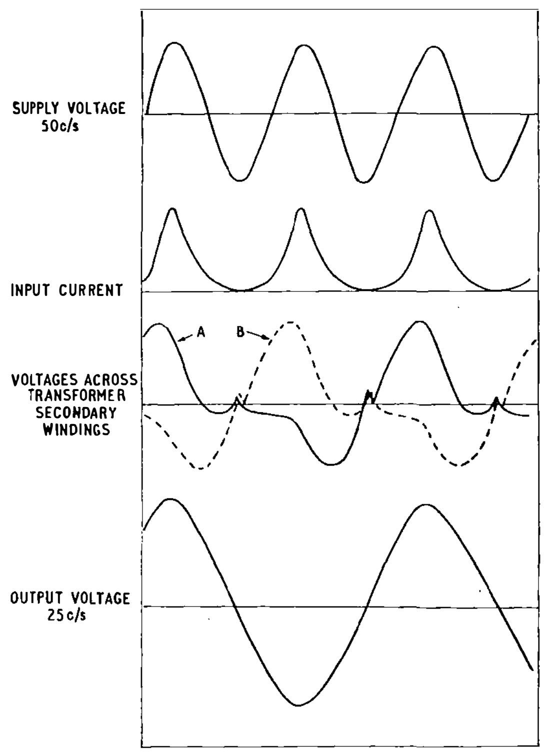


FIG. 2—VOLTAGE AND CURRENT WAVEFORMS OBTAINED WITH A MAGNETIC FREQUENCY DIVIDER WORKING ON FULL LOAD

The primary current is in phase with the supply voltage, flowing only during positive half-cycles, and it would appear that these current pulses maintain forced oscillations, at the second-order sub-harmonic frequency, in the output tuned circuit, and supply the power dissipated in the resistive part of the circuit and in the load.

It is of interest to note that if too low a value of capacitance is used, oscillations at the fundamental frequency occur. For this to happen, it is necessary for the same core to be saturated each positive half-cycle.

In the foregoing explanation of the basic circuit, the use of two separate transformers was assumed but, in fact, it is only necessary to provide two distinct magnetic circuits. This may be readily achieved by using a single shell-type transformer core as illustrated in Fig. 3. A single mains winding is placed around the centre-

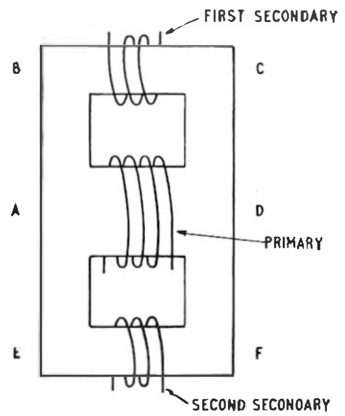


FIG. 3—SHELL-TYPE TRANSFORMER CORE FOR MAGNETIC FREQUENCY DIVIDER

limb (AD) and two identical separate secondary windings are wound on the outer limbs (BC and EF). Two separate magnetic circuits are thus formed, namely, ABCD and AEFD. This arrangement is more efficient and economical, and eases the manufacturing problems of matching two transformers.

CONSTRUCTION AND MOUNTING ARRANGEMENTS

The components of the static ringing converters are fixed to a steel chassis, which it is intended should be mounted on a wall, but the width of the Converter, Ringing, No.6 is such that it can also be mounted on a standard 19 in. rack. Converters, Ringing, No.4 and 5 (Fig.

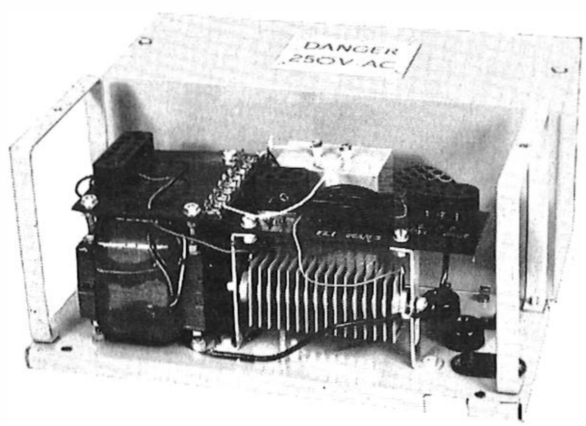


FIG. 4—CONVERTER, RINGING, No.4

4 and 5, respectively) can be adapted for mounting on a 19 in. rack by using two mountings D 91065.

The Converter, Ringing, No.7 can be accommodated under the covers of the standard range of 24-volt and

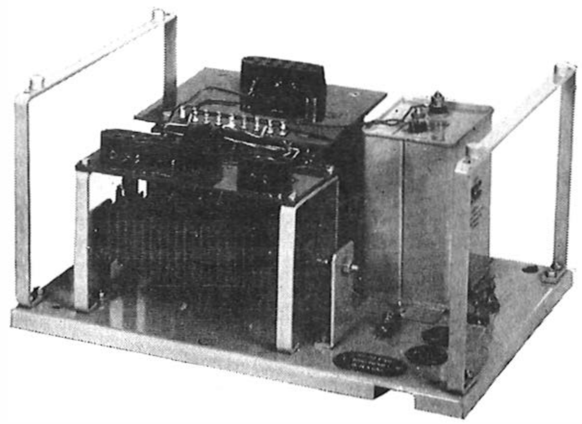
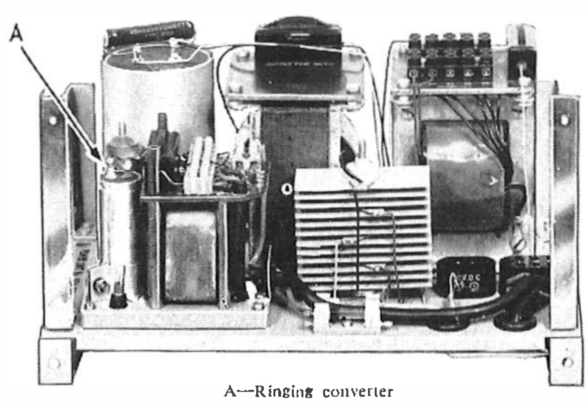


FIG. 5—CONVERTER, RINGING, No.5

50-volt power units, where space and fixing holes are provided for the purpose (Fig. 6).



A—Ringing converter

FIG. 6—CONVERTER, RINGING, No.7 MOUNTED IN POWER UNIT

FURTHER DEVELOPMENT

It is considered that the present range of mains-operated static ringing converters will meet conventional needs for the foreseeable future.

The development of any further converters is being limited to devices that are energized from a battery and which will be used where an a.c. mains supply either is not available or is considered insufficiently reliable; Converters, Ringing, No.10A, 11A and 12A, using transistor-type circuits, are in this category. Converter, Ringing, No.10A has already been introduced for use with the 50-volt lamp-signalling cordless switchboard.[3] The development of Converters, Ringing, No.11A and 12A is in an advanced stage, and the converters will be used with a projected 50-volt lamp-signalling floor-pattern cord-type switchboard; these converters are expected to come into service towards the end of 1965.

References

[1] DAVEY, F. R. A Mains Frequency Converter for Ringing Supplies. *P.O.E.E.J.*, Vol. 36, p. 110, Jan. 1944.

[2] GLOVER, B. W., and MAINE, A. E. Magnetic Frequency Dividers. *American Institute of Electrical Engineers*, Paper CP 58-520, 1958.

[3] HALLIDAY, C. M., and LIDBETTER, E. J. A New Small Cordless P.M.B.X. Switchboard. *P.O.E.E.J.*, Vol. 54, p. 22, Apr. 1961.

A New Pulsing Relay—Post Office Relay Type 19

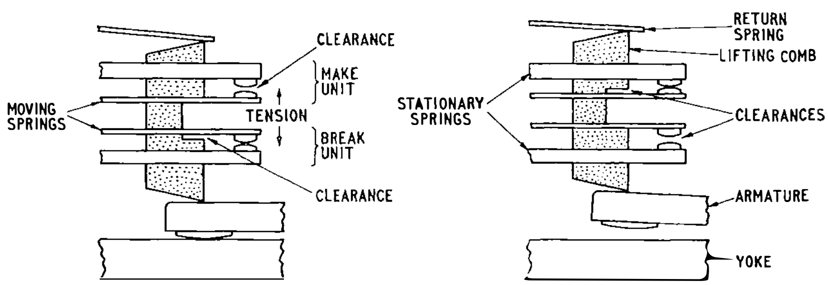
A. KNAGGS†

U.D.C. 621.318.562

A new heavy-duty pulsing relay basically similar to the 3,000-type relay but having a different spring-set action is described. The new design, which employs reverse-action comb-operated spring-sets, gives reduced contact bounce and should ensure a longer life and reduced maintenance attention.

RELAYS used for pulsing are amongst the most heavily worked in any exchange, both in terms of mechanical life and contact loadings. Under these conditions 3,000-type relays, with their pin-and-stud spring-set operation, need frequent re-adjustment and replacement of parts. A new relay has therefore been designed specially for pulsing operations. It will have a much longer life, and the time required for maintenance will be only one third, or less, of the present figure.

The new relay, which has been coded by the British Post Office as Relay Type 19, is basically of the 3,000-type relay design in that the same magnetic circuit is used, the springs have twin-contacts and standard relay-mounting arrangements apply. The essential difference lies in the spring-set design, that for the Type 19 relay being of the comb-operated "reverse-action" type. The distinguishing feature of reverse action is that the moving spring of a make unit is tensioned towards the stationary spring but is held away by the lifting comb (Fig. 1(*a*)). As the armature operates, the moving spring follows the comb as it is lifted but, when the contacts make, the moving spring and comb separate (Fig. 1(*b*)). For a break unit the comb is normally clear of the moving spring which, being tensioned towards the stationary spring, makes contact (Fig. 1(*a*)). As the armature operates, the moving spring is lifted away from the stationary spring by the comb (Fig. 1(*b*)). Restoration of the lifting comb when the armature releases is ensured by the return spring located above the contact springs. A return spring is required with this type of action, since make springs are tensioned upwards and it is necessary to ensure comb clearance at all break springs on completion of release of the armature.



(*a*) Armature Released (*b*) Armature Operated

FIG. 1—ACTUATION OF SPRING-SETS

The reverse-action type of spring-set operation gives a greatly reduced contact bounce compared with that resulting from the operation of a 3,000-type relay spring-set. A similar action is used on the Type 12 relay;[1] with the latter, however, the arrangement is slightly different in that the moving springs in a change-over action are the outer springs tensioned towards a single stationary centre spring.

Either one or two spring-set assemblies can be fitted to the Type 19 relay, each comprising one make-contact unit and one break-contact unit, the particular action required being obtained by adjustment or by the omission of unwanted springs, as explained later. This arrangement allows for several combinations, e.g. a make-contact unit and a break-contact unit on one side with a change-over (C) or make-before-break (K) contact unit on the other. C and K actions are obtained by connecting the two moving springs via a metal spacer and suitably adjusting the stationary springs. The latter are 40 mils thick with a longitudinal indent extending throughout the major part of their length; they are self-supporting and there is no buffer block.

An advantage of obtaining C and K actions from separate make units and break units is that the individual contact-unit material can be chosen in relation to the circuit in which it is used, e.g. a contact controlling the comparatively heavy current in a magnet circuit can be of a higher grade material than that controlling a B-relay element. In addition, adjustment of the spring-sets is easier than on the 3,000-type relay as, having set the make and break clearances and pressure, the required current performance is obtained by adjusting the tension of the return spring, leaving the previous settings unaltered.

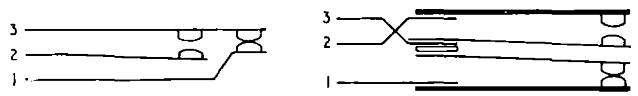
The new relay should have much improved contact life by virtue of its reduced contact-bounce characteristic. Adequate mechanical life is achieved by the use of the Type 10 relay armature[2] modified for pulsing, with the large-diameter back stop and residual screw, in conjunction with comb actuation of the springs. An undesirable feature of 3,000-type pulsing relays is the tendency for the armature to ride up the face of the knife edge during pulsing. On the Type 19 relay this is prevented by a special device restricting such movement away from the knife-edge.

In the Type 19 relay a contact spring is not formed in the usual manner with a tag at one end. Instead, each spring is laid up against an individual tag and held in contact with it by the clamping force on the spring pile. If a single make or break action only is required, the unwanted moving spring is replaced by a metal spacer but both stationary springs are retained, one for the required contact action and the other (without a contact and without an associated tag) to position the lifting comb. For C and K actions the two moving

†Telephone Exchange Standards and Maintenance Branch, E.-in-C.'s Office.

[1] ROGERS, B. H. E., and KNAGGS, A. The Post Office Type 12 Relay. *P.O.E.E.J.*, Vol. 57, p. 27, Apr. 1964.

[2] ROGERS, B. H. E. The Post Office Type 10 Relay. *P.O.E.E.J.*, Vol. 51, p. 14, Apr. 1958.



(a) 3,000-Type Spring-set (b) Type 19 Spring-set

The Type 19 relay springs are held in contact with their tags by the clamping force on the spring pile.

FIG. 2—MAKE-BEFORE-BREAK CONTACT-UNIT ACTION

springs are connected together as stated above and extend to the rear via a single tag. The K action has two of its three tags cranked as shown in Fig. 2. With these arrangements the spring numbering, when the relay is viewed from the rear, is identical with that of the equivalent actions on a 3,000-type relay, a condition which must be met to avoid changes to circuit and wiring diagrams when Type 19 relays are fitted.

Pulsing performance was assessed by laboratory testing of individual designs, using circuit conditions under which they will normally have to operate. This testing has been supplemented by field trials at Avenue (2,000-type selectors) and Wembley (4,000-type selectors) exchanges in London, using the new relays in A-digit selectors and directors and for pulse generation. These applications were chosen as typical examples of equipment containing heavily-worked relays, and the performance in all instances was very satisfactory.

The Post Office and Satellite Communications

U.D.C. 621.396.946

The international Agreements making interim arrangements for the establishment of the "space sector" of a single global commercial communications satellite system have recently been signed in Washington. The more important engineering aspects of these Agreements and their consequences are summarized in this note.

On 20 August, the Deputy Director General of the Post Office, Sir Robert Harvey, K.B.E., C.B., and the Chargé d'Affaires of the British Embassy signed in Washington, D.C., Agreements which make Great Britain a partner in interim arrangements for the establishment of the "space sector" of a single global commercial communications satellite system. Also joined in this enterprise are the United States of America, Australia, Canada, Ireland, Japan and most countries of Europe. This ceremony marked the end of a long and complicated series of international negotiations in which engineers, administrators and diplomats have been joined. It marks also the start of a new and exciting venture in international telecommunications. The details of these Agreements are contained in a White Paper* presented to Parliament by the Postmaster General. This note summarizes the more important engineering aspects of the Agreements and their consequences.

As to the negotiations that led to these Agreements, members of the Engineering Department have been joined with colleagues in the External Telecommunications Executive, as well as with colleagues in the Ministry of Aviation and the Foreign Office, as a United Kingdom team which, in retrospect, seems to have spent more time in aircraft and in foreign capitals during the past 12–18 months than at desks in London. For it must be recognized that the problems of satellite communications, though dependent absolutely upon competence in telecommunications and aerospace technologies, cannot be solved by that means alone, but, being international, inevitably touch upon matters of broad policy—domestic, Commonwealth and foreign. But during the negotiations two other factors also had to be borne in mind; first, the prime responsibility to ensure that the public are always provided with high-quality telecommunications services at a reasonable price. From this stems the concept of these new services as complementary to, and fully integrated with, submarine cable and h.f. radio systems and, of course, with national telecommunications networks. The second factor is the inescapably superior position of the U.S.A. (at least ad interim) in space technology and its policy not to charge the international venture for basic design and development on satellite launchers and launching facilities. This position of superiority had to be reconciled with the manifest international character of the venture and the understandable national requirement that joint participation and investment should carry with it the right of joint control.

The Agreements themselves (one dealing with general objectives—the second covering financial and technical matters) need not be considered in detail, save to note that

(*i*) they commit the Post Office to invest some £6M spread over the next 5 years in the venture,

(*ii*) the Post Office thereby secures a seat on the International Committee which is responsible for "the design, development, construction, establishment, maintenance and operation of the space segment," and

(*iii*) the United States Communications Satellite Corporation is appointed as Manager for the space segment "pursuant to general policies of the International Committee and in accordance with specific determinations" which may be made by the Committee.

For the immediate future, therefore, the Post Office will be taking an active part in the frequent meetings of the International Committee. This will necessarily require close and continuous technical collaboration between the Post Office Engineering Department and European, Commonwealth and American experts. The first objective is to ensure that all necessary steps are taken to make a telecommunications success of the experimental/operational synchronous satellite which it is proposed to launch and place in orbit over the Atlantic in March 1965. This first experimental/operational phase is designed to provide 100 or more telephone channels between North America and Europe—a much needed augmentation of the North Atlantic route. The second main objective is that of determining the shape and form of the immediately succeeding systems, which will be more global in character and designed to be in service in 1966–67. This work will require very close collaboration between engineers of all countries involved, will require brisk and efficient decisions at all levels,

*Satellite Communications Cmnd 2436, August 1964.

and will provoke considerable technical, administrative, and financial problems. In the negotiations that have concluded and in the joint venture that lies ahead close collaboration has been maintained with our Commonwealth partners and with the co-members of C.E.P.T.‡ The problems of future development are also to be discussed at the forthcoming Technical and Traffic meeting of the Commonwealth Telecommunications Board in London this month. Collaboration with our P. & T. neighbours in Europe is very close, and plans are being developed which will enable the three high-capacity ground stations in Europe (Goonhilly, Pleumeur Bodou and Raisting) to operate as an integrated unit linked by a high-capacity terrestrial network, to which network also the Italian low-capacity station at Fuicino can be attached.

‡C.E.P.T.—Conference of European Postal and Telecommunications Administrations.

Whilst international collaboration under the Agreement is directed towards the "space segment," complementary development is being undertaken at the United Kingdom earth station at Goonhilly. It is being overhauled and, in part, rebuilt in readiness to co-operate in a fully operational role with the synchronous satellite to be launched in March 1965. In preparation for the succeeding global phase, a second large aerial is being designed so that, in collaboration with our neighbours in Europe, we may be in a strong position to play our traditional role of importance in inter-continental telecommunications.

In a very real sense, therefore, these Agreements represent the logical development of the pioneer work of the "Goonhilly team" and carry forward the art of satellite telecommunications from the experimental phase into that of partnership in the world operational telecommunications network. J.H.H.M.

Book Reviews

"Tropicproofing Electrical Equipment." M. Rychtera and B. Bartakova. Leonard Hill, Ltd. xvi + 454 pp. 349 ill. £6 6s.

The authors say "the guiding idea of this book was to build the diverse parts of the subject matter into an integrated logical system," and "we have tried to summarize the results of our research work—together with practical experience from a variety of tropical industries and installations operating electrical equipment, and useful information drawn from the literature."

The treatment is technological rather than academic (a theoretical supplement is being published under the title "Atmospheric Degradation of Electrical Equipment") and the five parts into which the present work is divided are headed:

1. Climatic factors (detailed data regarding air temperature, humidity, air-pressure effects, solar radiation and biological factors, all over the world).

2. Climatic tests (principles, low-temperature tests, dry heat, damp heat, dust and sand tests, salt mist, biological tests, artificial sunlight, and tests at exposure stations).

3. Deterioration of electrotechnical materials (moisture pick-up by dielectrics, effect of moisture on electrical characteristics of dielectrics, micro-biological deterioration of insulating materials, a few words on the corrosion of metals and metal–insulant contact-corrosion).

4. Weathering of materials (weathering of—plastics, elasto-meric materials, varnishes, sealing and impregnating compounds, laminated and moulded insulants, fibrous materials, inorganic insulants, insulating oils, and some miscellaneous non-insulants).

5. Protection from weathering (basic principles, impregnation, fungicides, electroplating, paints, protection by design, and protection during transport, assembly, and erection).

On the whole this is an excellent book for the purpose specified, and contains a great deal of factual information, which should make it useful to those with limited library facilities. Some expansion of the section on corrosion of metals is called for even though the subject is "treated in numerous publications."

The following minor points might be corrected in a future edition: "condensers" for "capacitors" (p. 14, etc.); "insulating resistance" for "insulation resistance" (p. 295); "sporadical" (p. 54) is a little unusual; and surely the weights of urban dust given on p. 45 are high, corresponding to deposition per year rather than per day.

A.A.N.

"A Laboratory Manual for Principles of Electricity and Electronics." F. C. Halliday, B.Sc.(Eng.), and B. P. Morris, B.Sc., A.M.Brit.I.R.E. The English Universities Press, Ltd. xi + 100 pp. 35 ill. 9s. 6d.

Most students find early in their careers that their theoretical studies of elementary electricity must be supported by laboratory work if the subject is to become live and intelligible. Experimental work at schools and colleges is usually planned on the basis that every scholar is sceptical of what he has been taught in class and that he must therefore convince himself of its truth by practical work. With this in mind, electrical experiments are therefore undertaken to confirm known relationships between sets of physical quantities under specified conditions, in the hope that the student will be convinced and will remember the principles involved. A good teacher will, however, carry the matter further by using experiments to illustrate the relative importance of practical tolerances in measurement and the effects of ambient conditions, e.g. temperature changes or the voltage stability of a source of power.

Mr. Halliday and Mr. Morris, who teach at the Bristol Aeroplane Technical College, have clearly appreciated these points and well understand the difficulties some students have with experimental work. Their book largely consists of detailed descriptions of 35 electrical experiments as they should be written up in a laboratory notebook. The authors show in careful detail how the experiments should be carried out, how the equipment used should be noted and described, the importance of limits of accuracy attributable to measuring instruments and to observations, and how best to record readings, and calculate and present results.

The report of each experiment concludes with a few questions for discussion, bringing out the limitations of the method and of the equipment used.

The opening chapters discuss standard laboratory instruments in general terms and the units of measurements in the M.K.S. system; several useful reference tables are also included at the end of the book.

The standard is that of the O1 and O2 years of the Ordinary National Certificate in electrical engineering, which corresponds approximately to advanced level in physics in the General Certificate of Education and the Telecommunications Principles Grade A of the City and Guilds of London Institute. The book will be useful for reference to a student throughout his early years of study and would also be handy for revision before a practical examination. It is good value at 9s. 6d.

C.F.F.

Application of Program Evaluation and Review Techniques to P.A.B.X. Installation

Part 1—Introduction to Program Evaluation and Review Techniques

A. J. FORTY, B.A., A.M.I.E.E.†

U.D.C. 658.5: 621.395.24

In recent years new methods, known as program evaluation and review techniques, have been introduced for the effective planning and control of complex operations. Part 1 of this article describes one of these techniques and Part 2, to be published later, will give details of the way in which it has been applied to the problems of developing and installing a large, non-standard, private automatic branch exchange.

INTRODUCTION

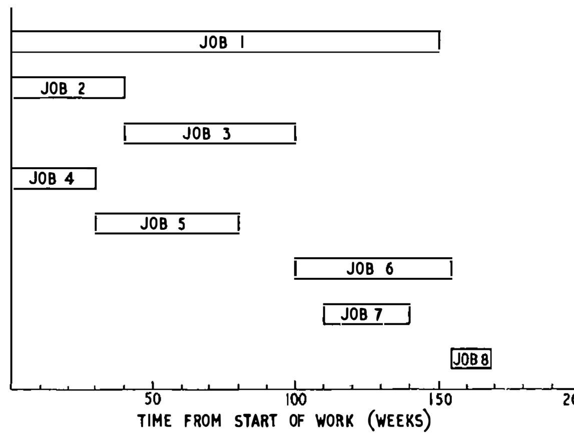
THE installation of a large private automatic branch exchange (P.A.B.X.) is a complex operation which must usually be completed by a predetermined date. It involves the customer, who provides the accommodation, the contractor, who supplies and instals the equipment, and the Post Office departments responsible for approval, provision of power supplies and provision of extension instruments. Normally the apparatus is of standard design, but for a new installation requested by the B.P. Trading Company novel principles are involved and an extensive development program must be added to the operations mentioned above.

It was clear from the outset of this task that special attention would have to be given to the co-ordination and progressing of the work in order that the ready-for-service (R.F.S.) date could be met; it was, therefore, decided to apply to the operation one of the methods of management control which have come to be known as program evaluation and review techniques, or PERT.

CONVENTIONAL METHODS OF CONTROL

Before describing the PERT methods it may be helpful to examine the shortcomings of the more usual approach to this type of control problem. Fig. 1 illustrates the type of chart which is often used to progress a project such as the installation of a P.A.B.X. The various operations involved are represented as bars on the diagram, commencing and finishing at allotted times, and by colouring or cross-hatching the bars the progress of each commitment can be watched as the job proceeds. Anyone who has used this method will know that it has serious drawbacks in practice. Firstly, it does not show the inter-relationship of the various stages of the work. In the example chosen, for instance, the installation of equipment cannot begin until the apparatus room has been made ready for occupation. Secondly, the chart is not usually sufficiently detailed. Again, in P.A.B.X. applications the overall period required for the erection of a new building is not significant: the dates which are relevant are those on which the storage space, battery room, apparatus room, staff accommodation, and so on, become available.

Thirdly, and perhaps most important, the onset of delay in completion of one of the operations is seldom foreseen, and when such delay occurs it is usually too late to apply effective remedial measures—the result is, all too frequently, a hold-up in the completion date of the project as a whole. To overcome these objections an elaboration of the technique is required which will ensure that all operations are recorded in adequate detail, that responsibilities are clearly defined, that forecasts are properly made and amended as necessary, and that potential causes of delay can be foreseen and re-



Job Number	Job
1	Erection of building.
2	Electronic equipment design.
3	Electronic equipment manufacture.
4	Mechanical equipment design.
5	Mechanical equipment manufacture.
6	Installation of equipment.
7	Installation of telephones.
8	Final testing.

FIG. 1—CONVENTIONAL CONTROL CHART

sources redeployed accordingly. Several methods, which by common usage have been called PERT techniques, have been devised in recent years to enable management to analyse and control complex problems of this nature. The Organization (Complements) Branch of the Post Office Engineering Department is responsible for advising on the use of these techniques and for stimulating their adoption generally.

THE PERT METHOD

The first step in the application of PERT is to break down the work of the project into a series of operations known as "activities," each of which is preceded and terminated by a milestone of progress called an "event." A typical activity might be "design of equipment," which would be preceded by the event "order placed for equipment" and ended by the event "design completed."

The various activities which go to make up a project each require time for their completion—they are "time-consuming." No activity can commence before the event preceding it has taken place, and no event can be accom-

†Subscribers' Apparatus and Miscellaneous Services Branch, E.-in-C.'s Office.

plished until all the necessary activities leading up to it have been completed. This state of interdependence can best be represented diagrammatically; a logic diagram is, therefore, drawn up for the whole project, with circles representing events and lines joining the circles as activities, and with a general progression in time from left to right of the pattern. The circles are numbered for requires three estimates of time to be made for each activity: an optimistic estimate assuming that all goes well, a normal estimate, and a pessimistic one. From these times an "expected duration" is derived and used in further computations. For the first application of these methods to P.A.B.X. work, however, the simpler approach of a single estimate per activity was adopted,

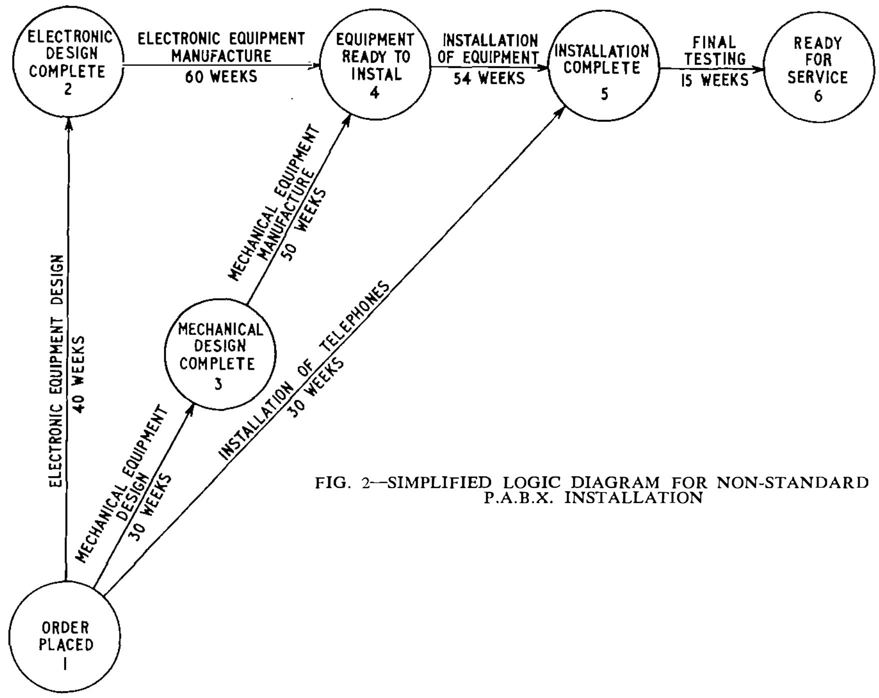


FIG. 2—SIMPLIFIED LOGIC DIAGRAM FOR NON-STANDARD P.A.B.X. INSTALLATION

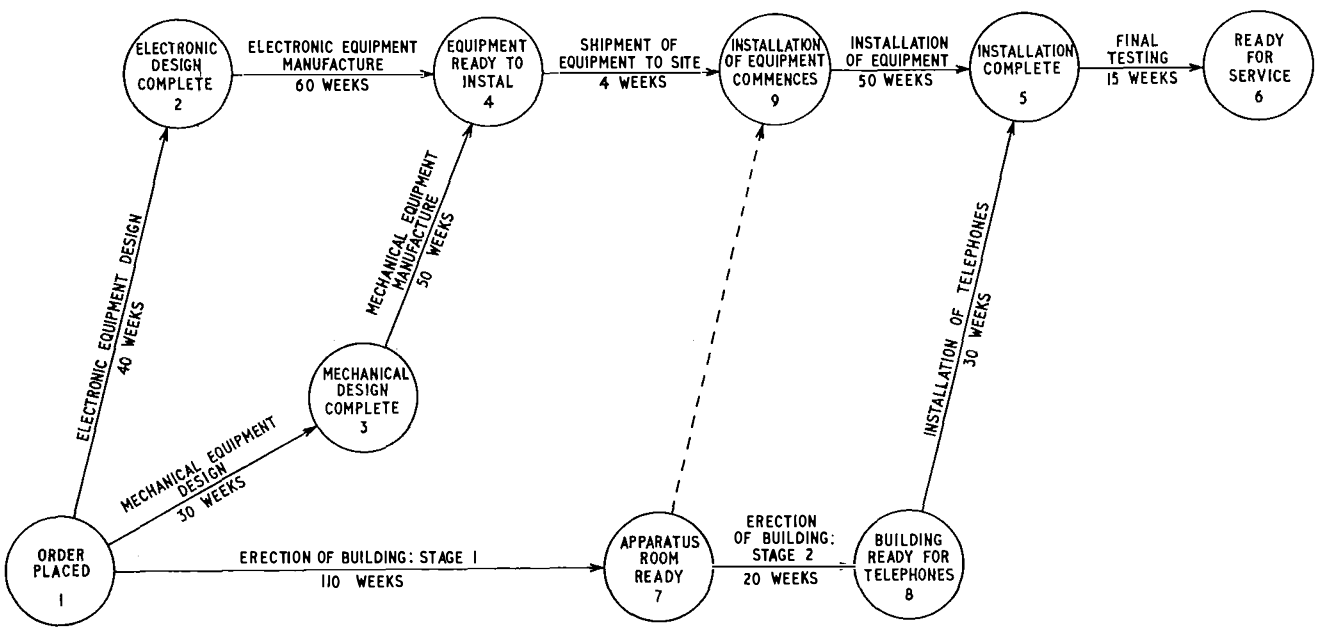


FIG. 3—INCORPORATION OF BUILDING OPERATION INTO LOGIC DIAGRAM

the purpose of identification. Estimates are sought for the duration of each activity (and it is important that each of these estimates is made by the person actually responsible for that section of the project), and these are written on the logic diagram adjacent to the relevant lines.

It should be noted here that the true PERT technique a variant of the technique which is known as the critical path method, or C.P.M.

A simplified logic diagram for a non-standard P.A.B.X. installation is shown in Fig. 2. Here there are three paths to the completion date: event sequence (1, 2, 4, 5, 6) requiring 169 weeks for execution, sequence (1, 3, 4, 5, 6) requiring 149 weeks, and sequence (1, 5, 6) requiring only 45 weeks. Path (1, 2, 4, 5, 6) is said to be "critical" since every activity on it must be completed on time if the R.F.S. date is to be met; the project manager will, therefore, watch this sequence of operations most carefully since, unless conditions alter, the ultimate timing of the whole project depends upon it.

Activities which are not on the critical path are not tied rigidly to a timetable: they have a certain amount of spare, or "slack," time available for their completion. Consider, for example, activity (3, 4). Event 3 cannot occur before week 30 after the order is placed, so that the earliest possible finish for activity (3, 4) is (30 + 50) weeks after event 1, i.e. week 80. Working backwards from the R.F.S. date it will be found that the latest permissible finish of activity (3, 4) is (169−69) weeks after event 1, i.e. week 100. Thus the path which includes activity (3, 4) has 20 weeks slack time. A detailed knowledge of the slack time relating to each of the paths

8, 5, 6), both of which have an estimated duration of 175 weeks.

In a practical case it is necessary to subdivide the main work headings still further; in fact, the work of breaking down and analysing the activities continues until a point is reached where further sub-division is no longer useful in aiding the supervision of the project. The stage when this occurs is a matter for the judgment of the PERT controller: there is little to be gained, for example, in analysing the manufacturing processes unless the controller is able to exercise authority over their execution. It is inevitable, however, that a project of the magnitude of a non-standard register-controlled P.A.B.X. will give rise to a complex logic diagram with many cross-connected paths. For example, the diagram for the B.P. Trading Company P.A.B.X., incorporates 139 distinct events and 212 activities (Fig. 4). Without aids the determination of the critical path

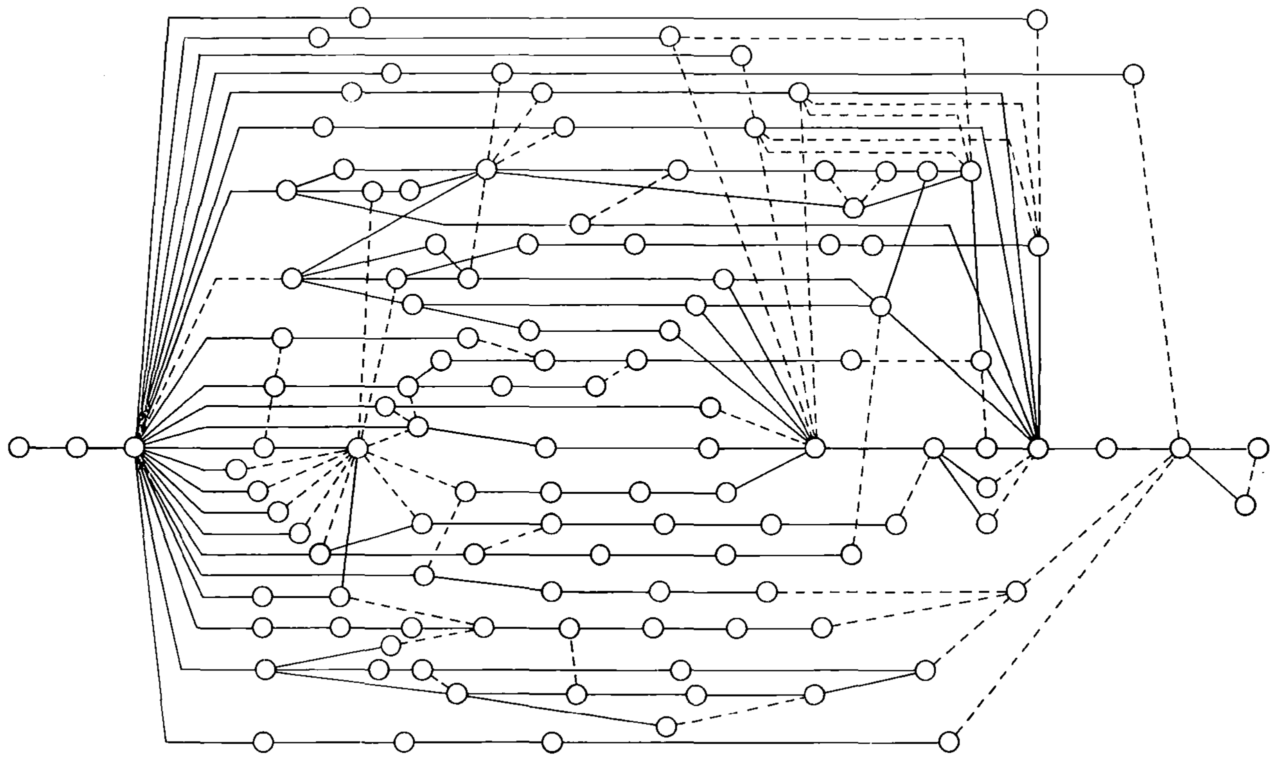


FIG. 4—LOGIC DIAGRAM FOR B.P. TRADING COMPANY P.A.B.X.

on the diagram is clearly of the greatest use in exercising overall control.

The simple logic diagram of Fig. 2 shows only the work of the contractor (activities (1, 2) (2, 4) (1, 3) (3, 4) and (4, 5)) and of the Post Office (activities (1, 5) and (5, 6)), and even these are presented in the most elementary way. If a new building is involved then the erection of this is the customer's responsibility, and the introduction of building requirements will necessitate a modification of the logic diagram as shown in Fig. 3 where, for the sake of comparison, the event numbering of Fig. 2 has been retained with additions as necessary. The commencement of installation of equipment must await the readiness of the apparatus room, and so the "dummy" activity (7, 9) has been inserted: it is shown as a broken line since it is not time-consuming. A comparison of the path lengths shows that there are now two paths which are critical, viz. (1, 7, 9, 5, 6) and (1, 7,

in such a diagram is a formidable task and resort must be made to the use of a computer. The detailed procedure for this part of the process will be described in Part 2 of this article: suffice it to say here that the end result is a printed list of activities against each of which is recorded the relevant slack time. All those activities which lie on the critical path, or paths, will have zero slack. The computer also records for each activity the latest possible finishing time (which is determined by the need to allow time for subsequent activities to be completed) and the earliest possible start time which is governed by the requirement that earlier activities on the same path must be completed before this one can commence).

Program Adjustment

The project controller now has full information concerning the timing of the job and can see, from examination of the data relating to the critical path, whether the initial estimates of activity times will allow the R.F.S. date to be met. If he is fortunate then this will be the case, but it is more likely that conservative estimating will have led to an overshoot: the first computer run on the B.P. Trading Company P.A.B.X. project indicated that the proposed R.F.S. date some three years ahead would be overshot by 70 weeks.

In these circumstances the logic diagram must be re-examined and adjustments made to bring the forecasts into line with the requirement. It may be that an alteration in the logic will produce the necessary result by changing the relationships in the activity pattern. On the other hand, all that may be required may be a more realistic approach to estimating, combined with additional effort in the areas where pressure is greatest. The point to be stressed is that the method has allowed this shortcoming to be detected even before work on the project has commenced, and has enabled steps to be taken to correct the fault at the outset instead of waiting until a crash relief program is required.

Progress Chart

Once the logic diagram has been settled there remains the major problem of progressing the project in accordance with the program. The information derived from the logic diagram is somewhat indigestible in the form provided by the computer and a further diagrammatic representation is required to enable the controller of the project to use it effectively.

A variation of the bar chart discussed earlier (Fig. 1) is therefore used, as illustrated in Fig. 5. Once more the activities are listed, but it is convenient now to divide them into groups according to the responsible authority, e.g. Post Office, customer, contractor, etc. The horizontal axis of the chart is divided into 4-weekly intervals, and the position of each activity on this time scale is shown by a line extending from the earliest possible starting date to the latest permissible finish. It is also useful to show the latest permissible starting time (derived by adding the slack time to the earliest possible start) for each activity.

By using this chart the controller is now able to keep an eye on the progress of every aspect of the project. He will pay particular attention to those items already in hand, and especially to activities on critical paths which are colour-coded for easy reference, but he will also look ahead to make sure that activities due to commence soon will in fact be ready to start in good time. To help in this, a system of periodic reminders sent to the responsible bodies can be used: for the B.P. Trading Company P.A.B.X. project they are issued at monthly intervals. If delays are likely then conscientious examination and reporting should reveal them in advance of their occurrence and, if necessary, staff or other resources can be redeployed to cope with the situation. Cases can arise, however, in which the early estimates of activity time prove to have been in error: this necessitates a reappraisal of the logic diagram, an adjustment of the timing of subsequent activities, and a fresh computer run. Detected in time, it does not necessarily result in overshooting the R.F.S. date.

Limitations of PERT

In this introductory article it is not appropriate to describe variations in the PERT technique which are required to deal, for example, with progressive approval of design running concurrently with manufacture. These and other modifications of the basic system can be introduced to deal with specific problems of production or installation. It is, however, important to realize that PERT cannot succeed unless means are available to implement necessary changes which become apparent and, above all, to carry them through expeditiously. While extra resources and allocation of funds may be obtained if the magnitude of the project warrants them, this is not always so where staff are concerned and where the quality as well as the quantity of the personnel is of importance. If PERT is to be used in projects controlled by the Post Office then more flexibility in the allocation of effort may be needed.

There is no doubt, however, that the PERT method is a most powerful weapon for ensuring that projects are completed efficiently and in due time. Perhaps its greatest advantage lies in the demand that it makes for logical thinking, both at the central control and at all levels of the management chain. The criticism which is sometimes met, that the effort spent on organization

Responsibility	Activity	Description of Activity	Earliest Start (see Note 1)	Latest Start △ (see Note 1)	Latest Finish (see Note 1)	Activity Time (see Note 2)	Total Slack (see Note 2)	Critical Path	Completed
Contractor	1-2	ELECTRONIC EQUIPMENT DESIGN	0	6	46	40	6		✓
	2-4	ELECTRONIC EQUIPMENT MANUFACTURE	40	46	106	60	6		
	1-3	MECHANICAL EQUIPMENT DESIGN	0	26	56	30	26		✓
	3-4	MECHANICAL EQUIPMENT MANUFACTURE	30	56	106	50	26		
	4-9	SHIPMENT OF EQUIPMENT TO SITE	100	106	110	4	6		
	9-5	INSTALLATION OF EQUIPMENT	110	110	160	50	0	*	
Customer	1-7	ERECTION OF BUILDING: STAGE 1	0	0	110	110	0	*	
	7-8	ERECTION OF BUILDING: STAGE 2	110	110	130	20	0	*	
P.O.	8-5	INSTALLATION OF TELEPHONES	130	130	160	30	0	*	
	5-6	FINAL TESTING	160	160	175	15	0	*	

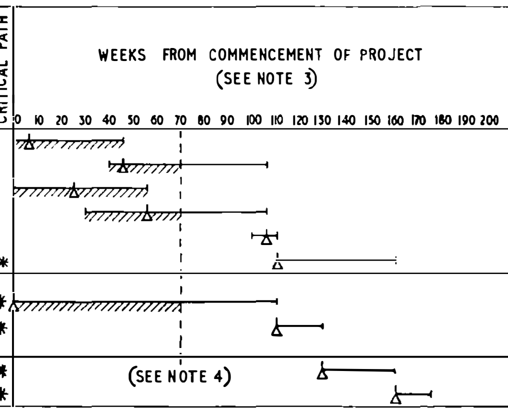


FIG. 5—DERIVED PROGRESS CHART

Notes:
1. The figures given for earliest start, latest start and latest finish refer to the number of weeks from the commencement of the project. They are shown pictorially in the right-hand section of the chart.
2. Activity time and total slack are given in weeks duration.
3. The time scale has been condensed in this illustration. In practice, each 4-week period is marked on the chart.
4. Cross-hatching shows the progress. At week 70 activities 1-2 and 1-3 have been completed.

could better be used on execution is, however, invalid, for detailed analysis of activity inter-relationships and the discussion which results helps everyone concerned to see the project as a whole and to have an interest in ensuring that his own particular section will proceed according to schedule. Once the plan has been produced the subsequent progressing absorbs little effort at the control point—much less, indeed, than the conventional approach in which planning, progressing and re-scheduling are inextricably mixed.

Future Applications

Experience gained in the first application of the PERT type of control to P.A.B.X. installation planning has shown that it is likely to be particularly useful in this field of work where successive projects follow the same general pattern yet differ in detail. Thus, the PERT framework which has now been established should be capable of variation to meet the needs of any particular case. Part 2 of this article will describe in detail the operation of the critical-path method, which has already proved its worth: subsequently, it is hoped to investigate the value of applying the full PERT technique of multiple-time estimation.

(*To be continued*)

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A Transportable Fault-Recorder for Automatic Exchange Routiners

U.D.C. 621.317.79:621.395.34.004.63

A transportable fault-recorder has been developed to enable the advantages given by fault recording with more modern routiners to be obtained, without extensive modification, from routiners of earlier design.

AUTOMATIC exchange routiners designed in recent years have invariably incorporated fault-recording facilities. This is achieved by providing a central recorder, a Fault Recorder No. 1B, usually mounted on the miscellaneous apparatus rack, to serve up to 12 routiners that may be operating simultaneously.[1,2] Each routiner is automatically started and stopped under clock control, and access to the recorder is obtained when it is required for printing the results of any test that has not been satisfactorily completed. Fault recording thus permits routine testing to be carried on while the exchange is unstaffed, a time when normal traffic is light, thereby avoiding the likelihood of mutual obstruction between testing and subscribers' traffic.

The advantages of fault recording on the newer routiners have led to a demand for similar facilities to be provided on the many existing routiners, some of which are of early design and not the subject of standard diagrams and drawings. Whilst it is technically feasible to provide identical facilities on equipments to all these early designs, with many it would entail complex modifications and difficulty in finding rack space for the additional apparatus. To overcome these obstacles a new arrangement has been devised: a standard Fault Recorder No. 1B is mounted on a trolley, permitting it to be wheeled around the exchange and connected by means of plugs and cords to one routiner at a time. This device (Fig. 1), entitled Equipment, Fault Recording, No. 1, does not provide the full range of facilities given by a central recorder, but it does, without entailing extensive modification, permit a routiner to be operated without staff in attendance.

In operation, this transportable fault-recorder com-

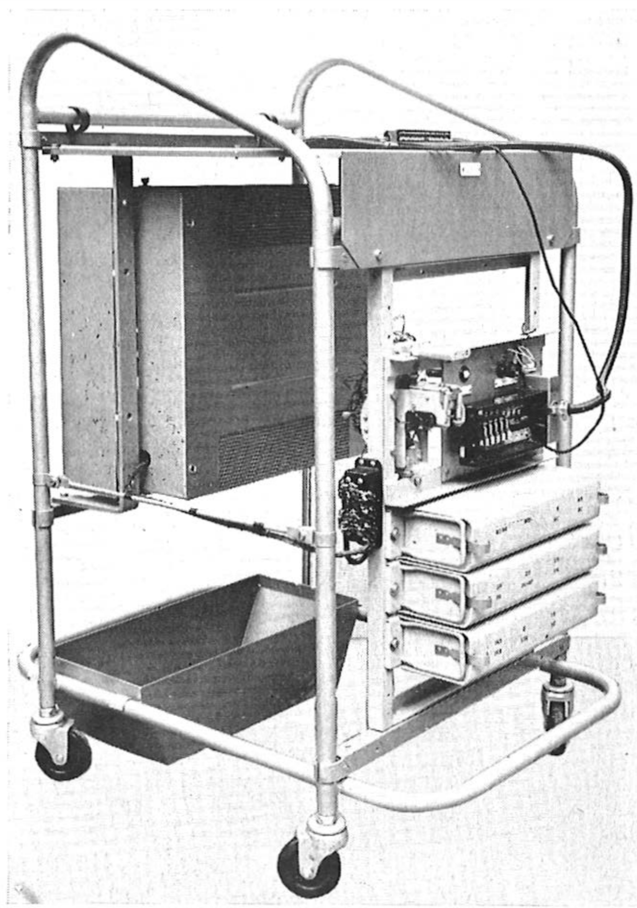


FIG. 1—TRANSPORTABLE FAULT-RECORDER

mences to function at the stage when the routiner with which it is associated would normally actuate an alarm, indicating that the test cycle has stopped because a test has not been successfully completed. This may be due

[1] URBEN, T. F. A. The Fault Recorder or Docket Printing Machine. *P.O.E.E.J.*, Vol. 45, p. 115, Oct. 1952.

[2] Fault Recorder No. 1B. *P.O.E.E.J.*, Vol. 55, p. 185, Oct. 1962.

to the item under test being engaged or failing to pass a test, or possibly due to necessary test equipment, such as a test line, being engaged. At this stage lamps on the routiner control panel will indicate the identity of the item under test (the access number) and the point reached in the test program (the fault indication). Without fault recording, the attention of the maintenance staff would then be required so that the cause of stoppage could be noted and the routiner stepped on to test the next item. Basically, this is the action taken over by the fault recorder, which produces a docket with the layout illustrated in Fig. 2.

The operation of an Equipment, Fault Recording,

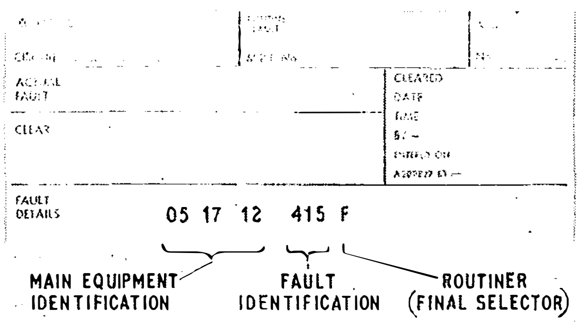


FIG. 2—DOCKET PRODUCED BY TRANSPORTABLE FAULT-RECORDER

No. 1, in association with the routiner modification, consists of examining each lamp lead on the routiner in an ordered sequence, pausing on each one found to have its lamp glowing, and printing numerical digits to indicate the physical positions of the glowing lamps. On completion of this operation a signal is sent from the recording equipment to step the routiner to its next access-equipment outlet, and testing of the next item commences. The numerical information on the docket is easily translated into access and fault information by reference to the lamp numbering on the routiner. One additional character is printed to indicate the identity of the routiner. This information is in slightly less convenient form than that given on dockets produced under standard fault-recording arrangements, but gives an acceptable alternative where it is necessary to minimize equipment modifications. The only modifications necessary if the portable recorder is used consist broadly of the provision, on each routiner, of one uniselector, a 33-point jack, and in some instances a small number of relays. Interference with existing wiring is slight.

It is expected that use of this fault-recording equipment, which can be installed quite quickly, will be of material assistance in completing routine testing programmes and will thus contribute to an improved quality of service.

K.S.L.

Book Review

"Electronic, Radio and Microwave Physics." D. E. Clark, B.Sc., Ph.D., A.Inst.P., and H. J. Mead, B.Sc., A.Inst.P. Heywood and Co., Ltd. viii + 521 pp. 436 ill. 130s.

Students seeking text books to cover the final year of a degree in engineering electronics usually find that they require access to a considerable number of books to give them the references they need. The syllabus for a degree or diploma of technology is large and constantly expanding, and a good student tries desperately to keep up with advancing techniques. An adequate personal library becomes out of the question for young people, who cannot afford the books, and a good omnibus volume can therefore be an economical purchase if it eliminates the need for several more specialized books.

This is such a work. "Electronic, Radio and Microwave Physics," by Dr. D. E. Clark and Mr. H. J. Mead, both members of the staff at the Northern Polytechnic, London, is a digest of material they have used in lecturing to degree and diploma classes for engineering and physics.

It is a thorough and "meaty" book with a strong bias towards fundamental principles rather than applications. In this respect it is typically the work of teachers rather than practising engineers, in that details irrelevant to the main principles are discarded. An engineer would have required twice the space to cover the same range of subjects because he would have felt bound to include practical illustrations and developments arising from the theoretical analyses in order to justify the need for, and prove the utility of, the theoretical arguments.

The first chapter is a survey of the mathematics needed—Fourier series, functions of a complex variable, the Laplace transform, Bessel functions, vector analysis, cylindrical and spherical co-ordinates. The principles of electromagnetic theory and the basic laws governing the behaviour of electromagnetic waves are dealt with in the second chapter. After these foundations have been laid, succeeding chapters are devoted to the theory of transmission lines, waveguides, properties of dielectrics and ferrites, and, for the physicists, spectroscopy at radio frequencies. The remaining nine chapters deal with theoretical aspects of radio fundamentals, radiation and aerials, transmission networks, thermionic valves, amplifiers, oscillators, klystrons, travelling-wave tubes and magnetrons, and, finally, a theoretical study of basic noise and its generation.

The treatment throughout is mathematical and rather academic. It is a book for the student rather than the professional engineer, whether he is engaged in research or design. It is not likely to be of much value in any other fields, except perhaps teaching, because complicated theoretical methods of finding well-known engineering results make an experienced man impatient. However, the authors have stated that they expect their readers to be still in the early, academic, stages of their careers, so this restriction was probably intentional. They are to be congratulated on having produced a work that should be most valuable to advanced students of electronics.

C.F.F.

The Use of Transistors in Conjunction with Relay Switching Circuits

C. D. VIGAR, A.M.I.E.E.†

U.D.C. 621.318.57:621.382.3

Transistors can be used in conjunction with electromechanical relay switching circuits to extend the range of performance of such circuits. The requirements of an ideal switch are described and a commentary on the important parameters of the transistors for use in these applications is given. The limitations imposed on the design of circuits by using the available supply potential and by switching inductive loads are also discussed.

INTRODUCTION

ELECTRONIC switching circuits using thermionic valves have been in use for the past 20 years, but the cost of valves, their power supplies and the problems of dissipating the waste heat have limited their use.

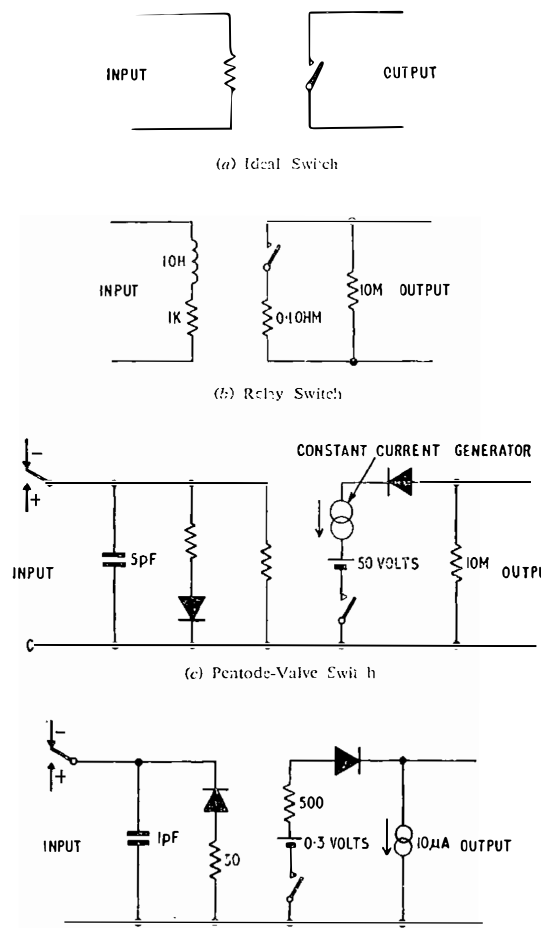
The transistor came into general use 10 years ago; in this period it has become cheaper and more reliable, and it now plays an important role as a switch for use in conjunction with relay switching circuits. It has the advantage over the valve that no special power supplies are required; manufacturers are now offering a range having working collector voltages from 2–60 volts, and transistors can be chosen which will work in circuits connected to the exchange battery.

Much of the study of transistors required for switching, e.g. computers and electronic common-control equipment, has been directed to reducing the time taken for the transistor to change from the switched-off condition to the switched-on condition. However, the general requirements of transistors used in conjunction with existing electromechanical telephone systems is that they shall be faster in operation than electromechanical relays. As the fastest relay takes at least 0·25 ms to operate, the ordinary audio transistor (which will change state in 10 μs) is fast enough to perform the switching functions required of it without any special study or design.

REQUIREMENTS OF A SWITCH

The equivalent circuit of an ideal switch is shown in Fig. 1(*a*). Such a switch would have a non-reactive input impedance and would operate on a very small input power. The output would be isolated from the input and would have an infinite impedance when in the switched-off, open or released condition, and zero impedance when in the switched-on, closed or operated condition. It would allow the output current to flow in either direction. Furthermore, the conditions in the output circuit would change at the instant the input condition was changed and would stay changed, with the output condition constant, until the input conditions changed again. All practical switches differ from the ideal switch, but different devices differ from the ideal in different ways.

Fig. 1(*b*) shows the equivalent circuit of a relay. The output impedances with the switch open or closed are very near to the ideal. The output circuit is isolated from the input circuit, and the output current may flow in either direction. Also, several such isolated output circuits can be provided on one relay and some of them may be inverted, i.e. receipt of an input condition can result in the output circuit being opened or closed. However, the minimum operate current is about 5 mA, and the contacts may bounce for several milliseconds when the switch is opened or closed.



(*a*) Ideal Switch

(*b*) Relay Switch

(*c*) Pentode-Valve Switch

(*d*) Transistor Switch

Note: Component values shown are typical

FIG. 1—EQUIVALENT CIRCUITS OF VARIOUS TYPES OF SWITCH

Fig. 1(*c*) shows the equivalent circuit of a valve. The input impedance is very high, and switching can take place when only a fraction of a microampere operating current is supplied. The switching time is less than 1 μs and the output circuit conditions remain constant after switching. However, the output impedance is high (typically 10K to 100K ohms) when the switch is closed. Only one output circuit can be provided and it has one terminal permanently connected to one of the input terminals. The output current can only flow in one direction. In addition, the valve circuit requires a heater

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current to be supplied continuously if the circuit is required for instant use.

Fig. 1(*d*) shows the equivalent circuit of a p–n–p transistor switch connected in the common-emitter configuration. For a n–p–n transistor all potentials would be reversed. The input impedance is low compared with the input of a valve but the switch can be designed to operate with an input current of 50 μA or so. The switch will change state in about 1 μs and the output circuit conditions remain constant after switching. However, a leakage current of up to 300 μA may flow in the output circuit when the switch is off, and when the switch is on a small potential (typically about 0·3 volts) remains across the output terminals. One terminal of the output is permanently connected to one terminal of the input circuit, and current can only flow in one direction in the output circuit, as in the valve circuit.

Furthermore, the relay switch will remain released with no input whereas the valve and transistor switches require an input voltage to ensure that they are held in the switched-off condition.

COMMON-EMITTER CONFIGURATION

A transistor may be connected to form a 4-terminal network in three different circuit configurations: these are known as common base, common collector, and common emitter. The connexions of the three configurations are shown in Fig. 2. The common-emitter

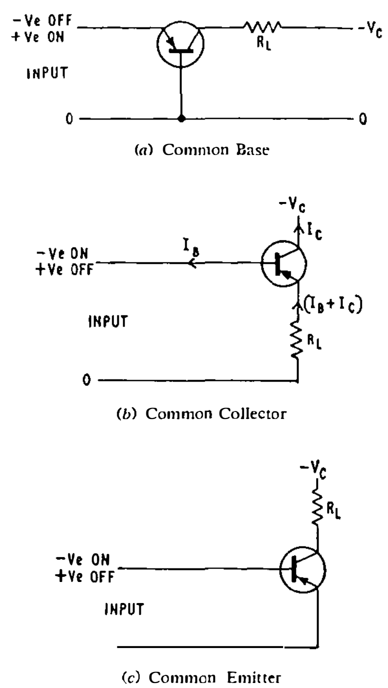

FIG. 2—CONFIGURATIONS OF TRANSISTOR CIRCUITS

configuration is the most useful as a switch, as this is the only configuration which gives a voltage and a current gain of the input power when the switch is closed. Also, very little power is required to control a transistor in this configuration. Only a small voltage change (less than a volt) is required to change the switch from one condition to the other, and only a small current flows in the input circuit in either the switched-on condition or the switched-off condition.

Input Currents for Satisfactory Operation

Fig. 3 shows the collector current, I_c, plotted against the collector voltage, V_c, for different values of base cur-

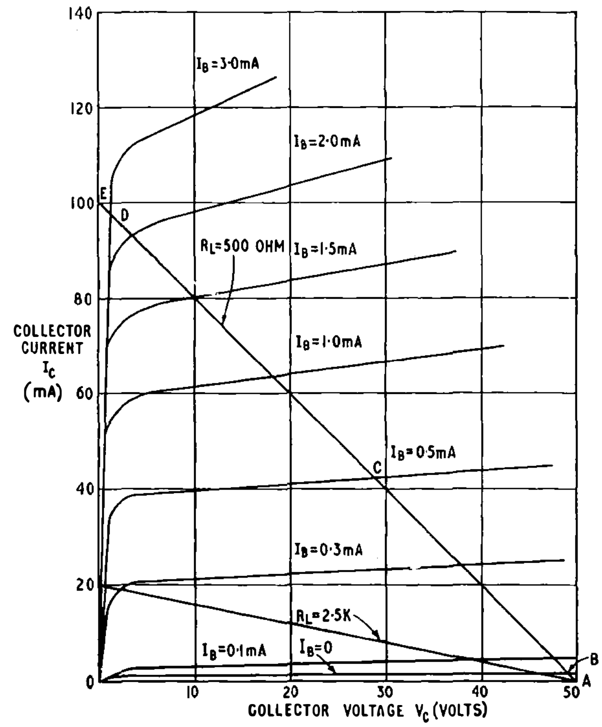

FIG. 3—TRANSISTOR OUTPUT CHARACTERISTICS

rent, I_b, when a transistor is connected in common-emitter configuration. These curves are known as output characteristics.

Load lines can be drawn across the characteristics for various values of load resistance (R_L) and two are shown on the figure, one for R_L = 500 ohms and the other for R_L = 2·5K ohms. An ideal switch with R_L of 500 ohms would work between points A and E. With the switch off (point A) there would be no current flowing in the output but there would be a potential of 50 volts across it; with the switch on (point E) a current of 100 mA would be flowing through it but the voltage drop across it would be zero. At both points no power would be dissipated in the switch as either the current or voltage would be zero.

Naturally, a practical transistor does not meet the conditions of the ideal switch, but works between points B and D. When the transistor is switched off the output circuit is not of infinite impedance due to the small collector leakage current that flows from the emitter to the base and which brings the operating point along the load line to point B. The power dissipated by the transistor in the switched-off condition is then $V_c I_{cbo}$, where V_c = 50 volts and I_{cbo}, the collector leakage current, may have a value from less than 1 μA to 300 μA, depending on the type of transistor and its temperature.

When the transistor is switched on the output is not short-circuit, as there is a small voltage drop between the collector and the emitter. The condition is represented by point D on the load line. The power dissipated is $V_c I_c$, where V_c may vary from 0·01 volts to 0·7 volts and I_c is approximately 100 mA.

However, the input current into the base must be sufficient to ensure that the transistor is fully switched on (or saturated); if in a circuit where $R_L = 500$ ohms the base current were only 0·5 mA the transistor would operate at point C. The collector voltage drop would be 28 volts and the collector current 42 mA; the power dissipation in the transistor would then be 120mW, which is high and may be more than the transistor's rated power capacity.

In practice the load resistor is chosen to have a value sufficiently high to prevent the transistor from being overloaded should the input current operate the transistor at a point such as C.

MERITS OF A TRANSISTOR FOR SWITCHING IN CONJUNCTION WITH RELAYS

Each type of transistor has limiting values for the various voltages and currents which may be applied to it with safety. These values, the manner in which they vary, and their relative importance and effect upon the design of transistor circuits are discussed below.

Collector Voltage

Each type of transistor has a limit to the maximum voltage which may be applied across the collector–base junction. Above this voltage the junction breaks down and conducts. For most transistors this value is 6–30 volts.

As the battery supply voltage at all but a few telephone exchanges is nominally 50 volts a transistor with a maximum permissible collector voltage higher than 50 volts offers advantages. Using a transistor of a lower permissible voltage requires special power supplies and also careful design to ensure that neither the input nor the output of the transistor is subjected to the full battery voltage of the exchange.

The breakdown of a transistor may occur by punch through, avalanche breakdown, or Zener breakdown.[1] As avalanche breakdown always occurs before either of the others take effect in the types of transistor used on high voltages, this is the only one that is considered.

Fig. 4 shows that the collector voltage at which the avalanche breakdown of a transistor occurs, known as the upper softening voltage, is higher when the base is reverse biased, and is reduced when the transistor is conducting, becoming smaller as the base current increases.

If a transistor is used to switch a resistive load R_L on a supply voltage V_s then the transistor will be switched off at the point A and on at the point B and will change state along the straight line AB. However, if the load is inductive, e.g. a relay, there will be a delay in the flow of collector current when the transistor is switched on and a delay in the reduction of the collector current when the transistor is switched off. The delays are caused by the back e.m.f. due to the inductance. The load line for an inductive load is shown by the dotted line. No adverse effects result during the switching-on period but in the switching-off period a point is reached when current is flowing from the collector and the back e.m.f. of the inductance has held the collector voltage high. Avalanche breakdown will then occur at a point such as C where the collector current is determined by the base current but the collector voltage is still very high. Current will continue to flow through the transistor, maintaining the breakdown until the energy from the inductance has been dissipated. The breakdown actually occurs at a voltage lower than the supply voltage V_s and

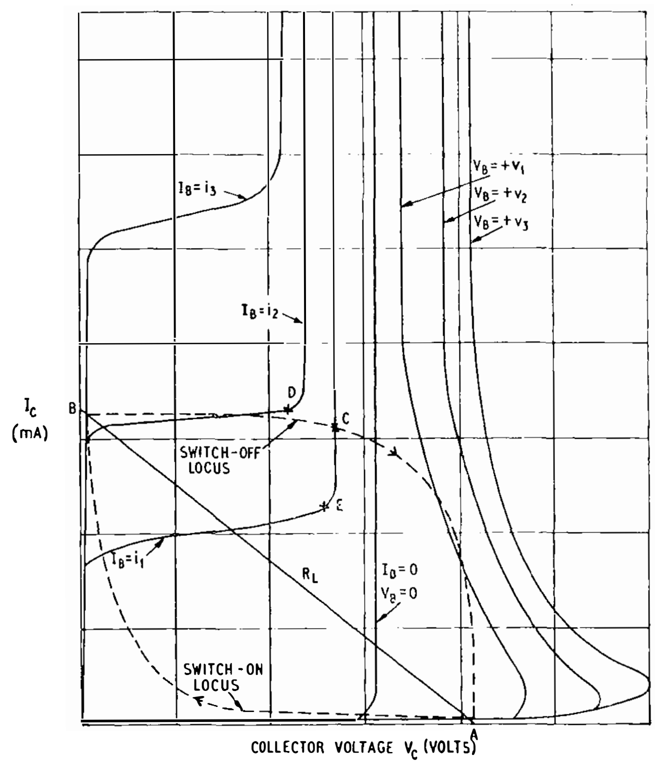

FIG. 4—LOAD LINES AND BREAKDOWN VOLTAGES OF A TRANSISTOR

cannot be prevented by a catching diode such as MR1 in Fig. 5. The effect of the inductance can be reduced by connecting a capacitor in parallel with it, so that the

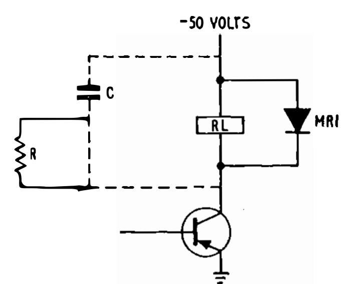

FIG. 5—RELAY-OPERATING CIRCUIT ELEMENT

path of the load line on switch-off passes below points such as D and E (Fig. 4), but very careful circuit design is required to be sure of avoiding breakdown as the capacitor and inductor tend to oscillate and cause breakdown at the voltage peaks of the oscillatory waveform.

As the usual supply voltage at telephone exchanges is 50 volts a more certain way of avoiding avalanche breakdown is to use a transistor with an upper softening voltage which is higher than 50 volts, and to restrict the collector current so that the switch-off locus does not pass above the knee points such as D and E.

Leakage Current

When a transistor is in the non-conducting state, i.e. with the base–collector junction reverse-biased and the emitter disconnected as shown in Fig. 6, a leakage current flows from the negative supply, through the load

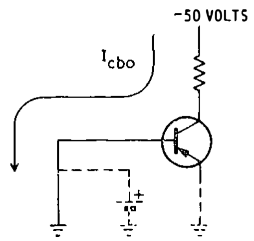

FIG. 6—COLLECTOR LEAKAGE-CURRENT PATH

and the base–collector junction, to earth. This current is the collector leakage current I_{cbo}. If, however, the emitter is earthed and the base is connected to a potential which, relative to the emitter, is positive (as shown dotted in Fig. 6) then the leakage current is reduced to about half the value of I_{cbo}. The reduced leakage current is called I_{cbx}. Circuits are usually designed so that the base–emitter junction is reverse-biased when the transistor is switched off in order to reduce the collector leakage current to the value of I_{cbx}.

The leakage current I_{cbo} is the only parameter for which a value is quoted by manufacturers. Its value is quoted at 25°C, and for germanium transistors varies from 1 μA to 30 μA with an average value of about 10 μA. For silcon transistors the values are lower, a typical value being 0·1 μA. Although the values at 25°C are low they double with every 7–8°C rise in temperature and at a junction temperature of 60°C they are about 30 times their values at 25°C. Thus, a leakage current of 30 μA at 25°C is nearly 1 mA at a junction temperature of 60°C.

A high leakage current gives rise to two effects:

(*i*) At collector voltages as high as 50 volts it can cause thermal runaway in the non-conducting condition because of the power dissipated in the transistor.

(*ii*) It restricts the design of the base circuit.

The manner in which thermal runaway can be caused can be seen by reference to Fig. 7. With the transistor in the switched-off position there is nearly 50 volts across the base–emitter junction and a leakage current of I_{cbo}. The power generated in the transistor is then equal to $V_c I_{cbo}$.

This power will be dissipated in the form of heat so that the power dissipated is $\theta \Delta t$, where θ is the cooling factor of the transistor and is usually 0·4°C per mW for a transistor without cooling fins, and Δt is the difference in temperature between the junction temperature and the ambient temperature.

Power generated = power dissipated per °C temperature rise × temperature rise,

i.e. $V_c I_{cbo} = \theta \Delta t$

From this equation and the relationship between I_{cbo} and temperature the curves in Fig. 7 can be obtained. These curves show junction temperature t_J plotted against ambient temperature t_A for a transistor connected across a 50-volt supply, as shown in Fig. 6, and having a heat dissipation of 0·4°C per mW.

These curves indicate that a transistor with a leakage current of 30 μA at 25°C will thermally runaway at about 25°C and one with a leakage current of 10 μA at 25°C will thermally runaway at about 36°C. When the junction temperature is above the runaway temperature it

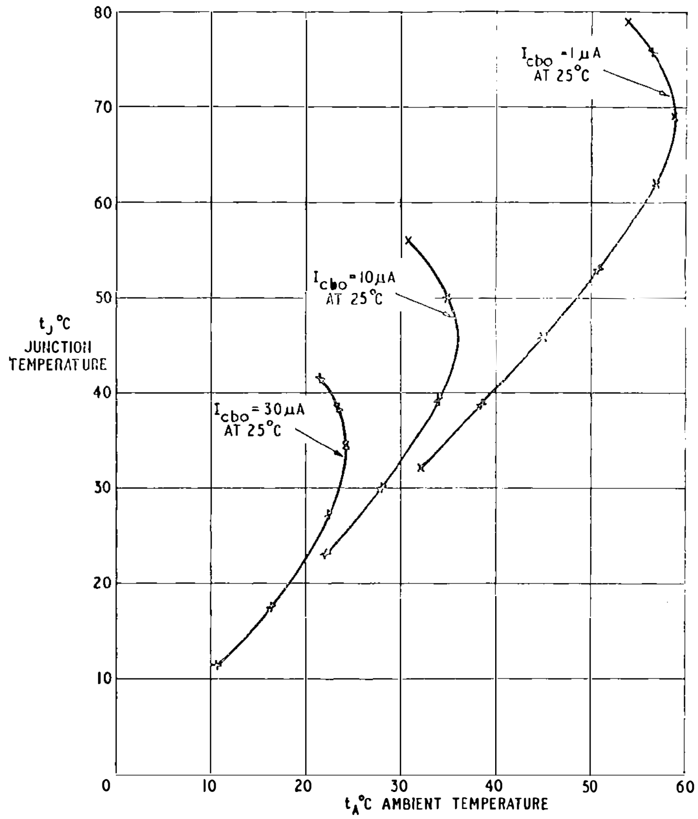

FIG. 7—RELATIONSHIP BETWEEN JUNCTION TEMPERATURE AND AMBIENT TEMPERATURE

will continue to increase even though the ambient temperature is decreased. Unfavourable temperature conditions in telephone apparatus could require a transistor to work in an ambient temperature of 45°C, which means that transistors which may have leakage currents up to 30 μA at 25°C cannot be used unless special measures are taken to keep them cool. Transistors which have a maximum leakage current of 1 μA at 25°C (mainly silicon type) will not thermally runaway until the ambient temperature reaches 59°C (see Fig. 7) and transistors with a leakage current of this order are more suitable as they may be mounted with other components without any need for special cooling.

Silicon transistors generally have a much lower leakage current (usually 1–5 μA at 25°C) and, although the rate at which the leakage current of silicon transistors increases with temperature is less predictable than with germanium transistors, this feature makes silicon transistors generally more suitable than germanium even though the silicon types are more expensive and have a lower value of β.

The leakage current also imposes restraints on the value of the base resistor. In order to restrict the value of the base current in the switched-on condition or to increase the impedance of the base circuit, a resistor is often connected in series with the base (Fig. 8). When the transistor is held in the switched-off condition (by earthing the point A or making it slightly positive) the leakage current flowing from the base will cause a voltage drop across resistor R_b which will tend to turn the transistor on. If then the transistor is to be securely switched off either there must be no resistor in the base circuit or the point A must be taken to a voltage more

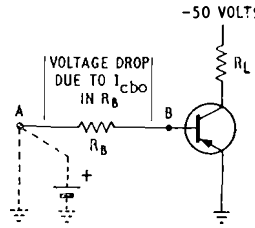

FIG. 8—USE OF BASE RESISTOR TO RESTRICT BASE CURRENT

positive than the emitter and the value of resistor R_b made small enough so that the voltage drop across it does not counter the positive voltage of point A.

Furthermore, if the base were left disconnected at the point B the collector leakage current would not be conducted away to a positive source along the base lead in the normal way and would therefore flow through the emitter–base junction. The collector leakage current I_{cbo} would then become a base–emitter current which would cause current βI_{cbo} to flow from the emitter to the collector. As β may be 30–50 the base should not be left disconnected on transistors which may have a collector current of accountable value.

Collector Current

Transistors which are used in conjunction with relay circuits will sometimes be required to operate a relay and the maximum permissible collector current should be large enough to operate ordinary 3,000-type relays, i.e. it should be greater than 50 mA. Where transistors are used to switch other transistor circuits the required collector current will usually be less than this. The base current required to saturate a transistor, i.e. the input current to a transistor switching stage is about 0·5 mA; thus, an output of 50 mA would switch 100 succeeding stages of ordinary transistor-type logic.

Reverse Base Voltage

The maximum reverse voltage that may be applied to the base–emitter junction is limited by the breakdown voltage of the junction. That is, there is a maximum positive voltage to which the point B (Fig. 8) may be taken in a p–n–p transistor. This voltage is usually about 6 volts and the application of a potential greater than this may damage the transistor. Protection of the base from higher reverse potentials often leads to elaboration of the base circuit. An example of this is illustrated in Fig. 9, which shows a circuit used for the detection of rever-

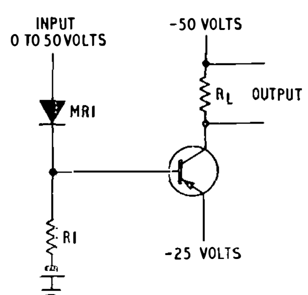

FIG. 9—USE OF SELENIUM RECTIFIER TO PROTECT BASE FROM HIGH REVERSE POTENTIAL

sals on a junction, and whose input may vary from 0–50 volts. The selenium rectifier MR1 has a reverse resistance of about 10M ohms and a forward resistance of 10K ohms. Resistor R1 can have a high value but must allow sufficient current to pass to saturate the transistor; it can be as high as 100K ohms.

When the input is more negative than −25 volts rectifier MR1 is biased to the non-conducting state and current flows through resistor R1 causing the transistor to conduct; the input impedance is then about 10M ohms When the input voltage is more positive than −25 volts rectifier MR1 conducts and has a resistance of about 10K ohms; this holds the transistor in the non-conducting state and presents an input impedance of about 100K ohms (the resistance of resistor R1); the base resistance (through which I_{cbo} will flow in the non-conducting condition) is 10K ohms. However, the base of the transistor is held at a potential equal to the input potential, and this may be more than 6 volts positive with respect to the emitter and thus damage the emitter–base junction.

Protection of the base–emitter junction can be provided by means of a crystal rectifier MR2 as shown in Fig. 10, ensuring that the base does not exceed a safe

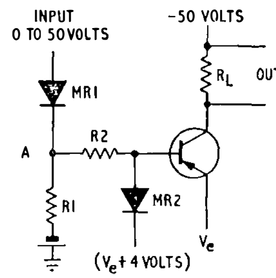

FIG. 10—USE OF RECTIFIER TO ENSURE THAT BASE POTENTIAL DOES NOT EXCEED A SAFE VALUE

potential and allowing the difference in potential between the input and the rectifier to drop across the resistor R2. As the collector leakage current I_{cbo} must pass through resistor R2 its resistance cannot be excessively high. Furthermore, the value of the resistance of R2 must be subtracted from that of resistor R1. The best that can be achieved is to make the sum of R_1 and R_2 about 50K ohms which offers an input impedance of about 25K ohms when the input is positive. However, as resistors R1 and R2 now act as a potential divider at the input, at which point A is clamped, the potential is not determined solely by the emitter potential as it is in the circuit shown in Fig. 9. If the transistor is to conduct when the input voltage exceeds a predetermined potential careful choice is required of the emitter potential V_e and of the values of resistors R1 and R2, and even then there will be a range of input voltages where the rectifier MR1 is conducting but insufficient current is flowing through resistor R2 to saturate the transistor.

A low permissible reverse base voltage can be a considerable disadvantage in a circuit where a high impedance input circuit has to be served from a source which may have a voltage swing as large as 50 volts.

THE OPERATION OF A RELAY

When a relay forms the collector load of a transistor (as shown in Fig. 5), protection is required to prevent the back e.m.f. due to the changing current in the coils of the relay from damaging the transistor. The back e.m.f. generated by a releasing relay can be as high as 300 volts and will cause breakdown of the transistor. The voltage must therefore be reduced by a quench and a most effective device is a crystal rectifier (such as MR1, Fig. 5) connected across the relay. This prevents the back e.m.f. rising above 50 volts but it considerably increases the release time of the relay. A resistor-capacitor quench can be used instead of a rectifier and this will not noticeably increase the release time of the relay; however, it will allow the back e.m.f. to rise 10–20 volts above the supply voltage. Thus, a transistor of higher breakdown voltage is required than if a rectifier is used. Also the value of the series resistor, R, must be individually chosen for each design of relay. Connecting a capacitor directly across the relay, as shown dotted, would also quench the high voltage, but it would also allow a large current to flow when the current is switched on and this would damage the transistor.

Relays with a very small inductance, e.g. high-speed relays, have been successfully operated in a pulsing test over a long period without any serious effect on the operating transistors. The conclusion has been reached that although the back e.m.f. of the relay is high enough to cause breakdown of the transistor, the energy content of the inductance is so small that insufficient heating occurs during breakdown to damage the transistor. If a transistor is to operate a high-speed relay without a quench, the time period of the breakdown must not last longer than the very short period of the back e.m.f., i.e. the switch-off locus must not pass through a point such as point C in Fig. 4 where breakdown will continue after the back e.m.f. has been reduced to a low value.

CONCLUSION

The introduction of transistor circuits into a system of electromechanical circuits requires careful design. The transistors must have particular parameters because of the 50-volt power supply of telephone exchanges and of the normal signalling voltages of the electromechanical system, which are high voltages compared with the voltages at which the majority of transistors are used. Precautions must also be taken to ensure that the high transient voltages generated by electromechanical devices do not damage the transistors. The transistor has an output equivalent to one "make" action spring-set of a relay with one side permanently connected to the input (Fig. 1(*d*)), whereas a relay may have a multiplicity of different isolated spring-set actions all isolated from the input.

However, the transistor is many times more sensitive than a relay, many times faster, and will provide an output which will change in one step to a new constant level. Transistors can be used with advantage in circuits, where very little operating current is avaiable, which can take advantage of alternating currents or which require a faster speed of operation than is possible with relays.

Circuits detecting a small operating current have found greatest use up to now. Coin-pulse detection in the coin and fee checking circuit[2] is achieved by detecting the current passing through a 5,000-ohm loop by means of a transistor. The detection of a potential on one plate of a capacitor by means of transistors is used in the regenerative circuit for the local register for director exchanges[3] and also in the finder circuit of the finder-type centralized service observation (C.S.O.) equipment.[4]

Alternating current principles are used in the line-signal monitoring unit[5] where a transistor blocking oscillator is set into oscillation by the potential which is to be detected; the output of the oscillator is rectified and used to switch a transistor which can then be used to operate a relay.

An example of the use of the comparative high speed of the transistor is the inhibit circuit of the finder-type C.S.O. equipment. The normal action of the circuit is to stop the rotation of a motor uniselector by a high-speed relay which operates in 0·25 ms (Fig. 11); the

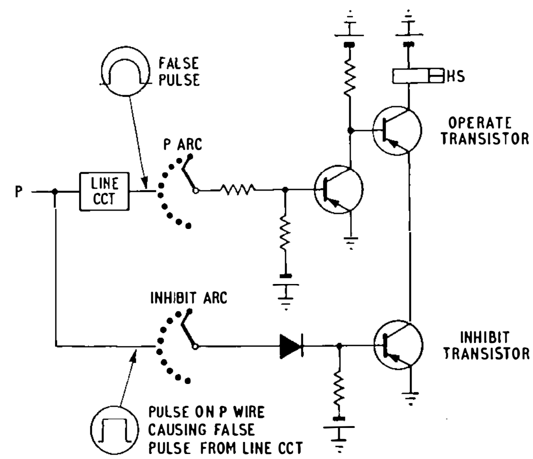

FIG. 11—TYPICAL APPLICATION OF TRANSISTORS IN A RELAY-OPERATING CIRCUIT

relay is operated by a transistor. Occasions arise when a false stop signal will cause the operate transistor to conduct; these false signals are always coincident with a voltage on another arc of the motor uniselector which switches off a second (or inhibit) transistor. The output of the second (inhibit) transistor is gated with the output of the operate transistor to prevent the operation of the relay to the false signal.

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[2]BASTOW, F. J., COLINWOOD, J. D., NEWELL, E., and PRICE, C. K. The Pay-on-Answer Coin-Box System. *P.O.E.E.J.*, Vol. 51, p. 343, Jan. 1959.

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[4]VIGAR, C. D. Central Service Observation Equipment Using a Transistor-Controlled Motor Uniselector. *P.O.E.E.J.*, Vol. 54, p.9, April 1961.

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The Fourth International Teletraffic Congress, London, 1964

U.D.C. 061.3:621.395.31

THE Fourth International Teletraffic Congress (4th I.T.C.) was held in London at the Institution of Electrical Engineers, Savoy Place, from Wednesday 15 July until Tuesday 21 July 1964, under the joint patronage of the Telecommunication Engineering and Manufacturing Association (T.E.M.A.) and of the British Post Office. Fig. 1 shows Sir Robert Harvey, K.B.E.,

FIG. 1—LEFT TO RIGHT: MR. E. P. G. WRIGHT, SIR ROBERT HARVEY, K.B.E., C.B., AND DR. ARNE JENSEN AT THE OPENING CEREMONY

C.B., the Deputy Director General of the British Post Office, opening the 4th I.T.C. on behalf of the Postmaster General, who was unable to be present.

The first congress was held in Copenhagen in 1955 at the initiative of Dr. Arne Jensen and other internationally-known persons concerned with the application of the theory of probability to telephone traffic engineering. The congresses have proved to be so successful and valuable in providing opportunities for criticism and discussion of this very important topic, and in stimulating new work, that since the first congress one has been held every third year: at The Hague in 1958; at Paris in 1961, and this year in London. The I.T.C. is governed by a Permanent International Advisory Council, the Chairman being Dr. Jensen, but the detailed arrangements for each congress are made by an I.T.C. Organizing Committee set up in the host country. That for the 4th I.T.C. was composed of the following members: *Chairman:* Mr. E. P. G. Wright (Member of the Permanent International Advisory Council); *Committee:* Mr. R. A. Moir, O.B.E., M.C. (T.E.M.A.), Mr. H. A. Longley and Mr. W. J. E. Tobin (British Post Office); *Secretary:* Mrs. M. L. Cannell (T.E.M.A.).

The 4th I.T.C. was the largest congress that has been held so far, with 177 participants attending from 21 different countries and representing national telephone administrations, telephone-equipment manufacturers, computer manufacturers, telephone-operating companies, and universities. Fig. 2 is a photograph of part of the assembly during the presentation of one of the

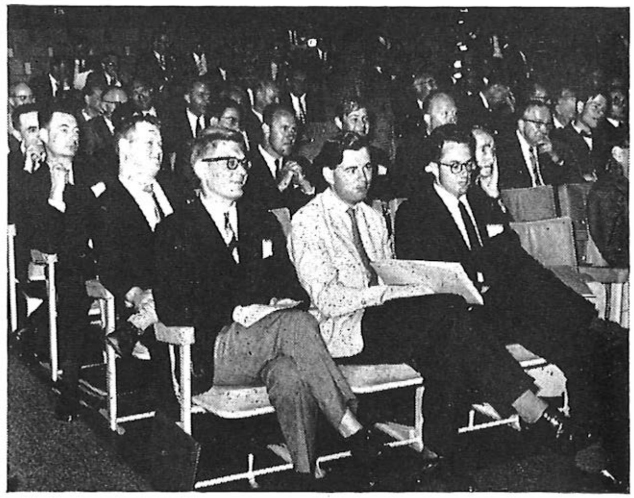


FIG. 2—SOME OF THE DELEGATES DURING ONE OF THE SESSIONS

papers. The British Post Office was represented by members of the Engineering Department, the Inland Telecommunications Department, the Chief Statistician's Office and the London Telecommunications Region. Sixty-one papers were presented during the 10 half-day sessions, and included a report from the Nomenclature Committee, which is engaged in constructing a comprehensive set of definitions of traffic engineering terms, and one from the Bibliography Committee, which compiles a list, as complete as possible, of references to appropriate articles in magazines and books published in all languages. The papers ranged over the whole field of telephone traffic study and included subjects such as those mentioned below.

System Descriptions

The most usual and effective method used in traffic engineering is to construct a mathematical model of the system being examined, and this involves a good understanding of the system. A number of papers described the trunking and traffic principles of new systems being introduced or still under examination; for example, several papers covered link systems, in which connexions are set up through an exchange on a marking basis, under the control of a central register, instead of being set up by Strowger pulses as in a step-by-step system. Link systems employing different forms of electronic switching were described, as well as one which uses a mechanical crossbar switch. There was also a paper on the pulse code modulation (p.c.m.) system, in which speech is not transmitted, as in the normal way, by varying the current in the line to correspond with the speech, but is first sampled at frequent intervals and a numerical code allotted for each sample according to the band in which the amplitude lies; the code is then transmitted as a series of pulses and the speech reassembled at the distant end from this sequence of codes.

General Traffic Theory

A large proportion of the papers presented throughout the congress dealt with the more fundamental issues of traffic and queueing theory, some of them being also appropriate to applications other than telephone traffic, and formed an important contribution to a subject which still gives plenty of scope for original work.

Network Planning

Traffic theory not only has to deal with the effects at individual switching stages but is also concerned with the behaviour of complete telephone networks. Nowadays, because of the advent of electronic computers and their ability to process large amounts of data, it is possible to develop more refined procedures for network planning, and a great deal of emphasis is being given in a number of countries to the planning of multi-exchange systems. Several papers were presented giving some of the interesting solutions that have been developed and, in some instances, used in various countries.

Simulation Studies

The mathematical studies of switching systems and their application have always been hampered by the complexity of the task, even for simple configurations. A recent development is to simulate a system using an electronic computer, and study its behaviour by performing sampling experiments on this model with, perhaps, several hundred thousand simulated calls and measuring traffic flow at convenient points. A session was spent presenting papers describing simulation methods and some of the results that have been obtained using these methods. This is still a very recent innovation, but it is clear that simulation techniques have already been accepted as almost indispensable tools in traffic theory, although there seemed to be differences of opinion on whether they were prime tools in mathematical research or whether their main use was to check theories arrived at without their use.

The chairman of the session particularly welcomed Mr. G. F. O'dell at the congress, who, during his work on traffic engineering in the British Post Office, had pioneered simulation studies (using manual methods) during the 1920s.

Alternative-Routing Theories

Papers were presented by several authors continuing their important contributions in this field, which is becoming of greater practical use with the rapid growth of telephone systems and the introduction of automatic alternative-routing techniques.

Interconnexion Schemes

Although interconnexion schemes, including various types of gradings, have been the subject of study for many years, satisfactory conclusions on the most efficient designs have still to be reached, and a number of papers dealt with this topic and also with the associated investigations into the characteristics of traffic carried by and overflowing from gradings. Because of the difficulty of exact solutions of grading problems, these are ideal subjects for the application of simulation techniques to compare the traffic-handling abilities of the various grading arrangements, and it is expected that major contributions will result from the use of computers in the fairly near future.

Grade-of-Service Considerations

One session was devoted to papers concerning definitions of grade of service and the factors concerning the choice of grades of service in the operation of telephone systems, and it was evident that this is a subject in which widely different views are held. The problems of choosing the most suitable period for traffic recording on international circuits were dealt with in a paper reporting the recommendations of a C.C.I.T.T. working party.

It is not possible in such a short report to give other than a brief outline of the broad topics under discussion; other papers on particular specialized subjects were also presented, however, and were discussed with interest. It was apparent that the high standard of earlier congresses had at least been maintained by the 4th I.T.C. and will have stimulated fresh thoughts on many of the problems, all the papers having something to add to the existing knowledge of traffic theory and its application. The official illustrated report of the proceedings of the congress will appear in a special issue of the *Post Office Telecommunications Journal* to be published at 1s. 6d. towards the end of 1964. Copies will be obtainable from the Editor, *Post Office Telecommunications Journal*, Public Relations Department, Headquarters, G.P.O., London, E.C.1.

The closing ceremony was conducted by Sir Ronald German, C.M.G., the Director General of the British Post Office, at 4.30 p.m. on Tuesday 21 July 1964.

At the invitation of Bell Telephone Laboratories Incorporated and the United States Independent Telephone Association, the Fifth International Teletraffic Congress will be held in the U.S.A. in 1967.

J.A.P.

Transportation of Aerials by Helicopter

U.D.C. 621.396.67:629.135.45

During the replacement of temporary aerials and equipment on the Cardiff–West Wales microwave radio-relay link by a fully-engineered link and permanent aerial towers, difficult road access to the sites for two of the radio stations led to delays in provision of three large horn aerials. The aerials were eventually delivered to the sites by helicopter.

THE Cardiff–West Wales microwave radio-relay link, which carries television signals to Blaen Plwyf, Presely, and Haverfordwest, has been in service for some time using temporary aerials and equipment while awaiting completion of the fully-engineered link and permanent aerial towers. By June 1964 the permanent towers at Wenallt and Llanllawddog were the only two without aerials, the delay being due to the difficult road access to the sites for large horn aerials; the aerials are 26 ft long, 14 ft 9 in. wide, and 12 ft high when placed "face" downwards on a road trailer.

The radio-relay equipment is being provided by the General Electric Co., Ltd. (G.E.C.), and, because of the difficulty of delivering such loads by normal means, they decided to use a helicopter to transport the aerials from convenient sites as near the radio stations as possible. The size of an aerial and its weight (17 cwt) were apparently outside the capabilities of most of the helicopters commercially available, but eventually a firm, World Wide Helicopters, was found with helicopters equipped to lift such loads.

A reconnaissance of the two radio-station sites and convenient pick-up points was made. As a result, it was decided to pick up the horn aerial for Wenallt from the open space near the road at the top of Caerphilly mountain and the two horn aerials for the Llanllawddog station from the car park in front of the Telephone Engineering Centre at Carmarthen. The date set for the air lift was Thursday 25 June, weather permitting—a very necessary qualification as operations could take place only in reasonably calm weather.

The morning of 25 June was calm and sunny; one horn aerial on its trailer,previously brought from Messrs. Thornycroft of Southampton, was conveyed by British Road Services and accompanied by police escort to the pre-arranged spot on Caerphilly mountain by 8.30 a.m. At 9 a.m. the helicopter arrived, reconnoitred the route and landed at each location to put down a marshal. The marshal is an essential member of the helicopter team, as the pilot relies completely on the marshal's hand signals when manoeuvring close to the load to be lifted.

Meanwhile, the horn aerial was prepared for lifting by attaching slings to the lifting holes on the back of the horn and by fixing steadying ropes to four points on the horn, which was lying face downward on the trailer with a large aeroplane tire fastened to its 1 ft square end. The pilot, guided by signals from the ground, lowered the helicopter towards the horn, had the patent hook coupled to the shackle at the end of the slings, and gradually took up the load, the horn being steadied by the ground crew manipulating the steadying ropes. When lifted, the horn assumed a position with its face approximately 60° to the horizontal, and during travel it rotated.

When the Wenallt radio-station site was reached, the helicopter commenced a controlled descent with the horn aerial; the tire was the first point to make contact with the ground, and it was necessary to control lateral movement of the horn by men pulling on the steadying ropes as it was lowered on to its face, which was supported above the surface of the ground on sleepers. When the horn was fully resting on the sleepers the pilot released the shackle from the patent lifting hook. In general, this type of helicopter, without an internal winch, cannot manoeuvre with the degree of precision which would have been required to locate the horn in its fixings; furthermore, the superstructure of the tower protrudes above the aerial plaform and would have rendered such an operation extremely hazardous to the helicopter and the horn. The aerial was, therefore, hoisted on to the tower at a later date using a conventional derrick pole.

The two horn aerials for the Llanllawddog radio station were transported by British Road Services to the Telephone Engineering Centre (T.E.C.) at Carmarthen, where the car park had been cleared for use as the helicopter landing area. The first horn was prepared in a similar manner to the Wenallt horn. It was then lifted from the trailer and the helicopter started to go in the direction of Llanllawddog. Unfortunately, at a height of 300 ft and about 300 yd from the T.E.C. the horn fell from under the helicopter, disintegration occurring on impact with the ground.

On Friday 26 June it was learned that G.E.C. intended to use the helicopter to transport the remaining horn aerial to the Llanllawddog radio station. Prior to attempting this lift, the helicopter pilot and representatives of G.E.C. spent the morning and part of the afternoon at Roose Airport, Cardiff, testing the helicopter lifting gear with concrete blocks; all the tests were satisfactory.

On arrival at the T.E.C. the pilot decided that, due to a 180° change in the direction of the wind from that of the previous day, it was now unfavourable for lifting the load as it would be necessary to pass over the adjacent hospital. An alternative site was suggested at Peniel, 6 miles from Carmarthen, but its use entailed the closure of a public road. The police Chief Inspector present agreed to organize this closure, and the horn aerial was dispatched by road to Peniel.

At Peniel the horn was prepared in the same way as the other two, but before the load was taken up by the helicopter, the lifting-hook closure was checked by two people (one G.E.C. representative and one World Wide Helicopter representative) for correct locking. This time the horn aerial was successfully transported to the Llanllawddog radio station.

As the helicopter had to be out of the country by 1 July, a replacement for the dropped aerial was rapidly organized by G.E.C. with the co-operation of the Ministry of Transport, British Road Services, and Messrs. Thornycroft. The result was that another horn aerial arrived at Carmarthen on Monday 29 June and was successfully transported on 30 June from Peniel to Llanllawddog radio station.

All the aerials on the route have now been mounted in their correct positions on the towers, and the setting-up of the s.h.f. radio-relay links for the permanent system is proceeding satisfactorily.

D.W.E.

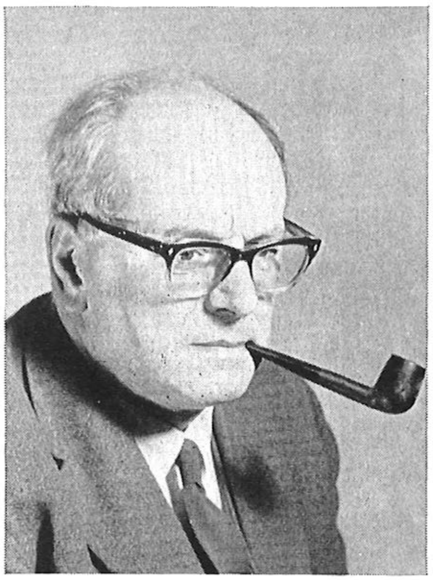
Notes and Comments

Special Commendation

The Board notes with pleasure that the Postmaster-General has personally commended Mr. R. Booth, Technical Officer, Blackburn Telephone Area, to whom the Royal Humane Society has awarded its Resuscitation Certificate, for saving the life of a six-year-old boy, crushed between a runaway van and a wall on 8 March 1964.

Retirement of Mr. R. J. Hines, B.Sc., M.I.E.E.

Mr. R. J. "Ronnie" Hines—son of Capt. J. G. Hines, whom many will remember as Staff Engineer, Lines Branch—retired on 31 July 1964. Mr. Hines received his early training at Royal School and at King's College, London. After an initial spell with Messrs. Siemens Brothers, on automatic-telephony circuit design, he entered the London Engineering District of the Post Office as an unestablished skilled workman (U.S.W.) and soon



passed the competitive examination for Probationary Inspector. This was the celebrated intake of Probationary Inspectors which became known as the "forty thieves"; many were destined to hold senior posts in the Department.

After 2 years cable testing, Mr. Hines passed the open competitive examination for Assistant Engineer (old style) and was then appointed to the automatic-telephony training school in King Edward Building. After a spell at Colchester he was promoted to Bournemouth as Sectional Engineer, and within 4 years became Regional Engineer (Internal) in the North Eastern Region—the beginning of a 14-year attachment.

In 1942 Mr. Hines accepted a commission in the Royal Signals: his chief duties were the replanning of communications on the Continent, first as Civil Affairs Officer in Belgium and Holland, and later as Lt.-Col. in the American-occupied port of Bremen.

In 1950 he was promoted to the post of Chief Regional Engineer, Scotland, in which capacity he now retires. As C.R.E., Mr. Hines' shrewd and perceptive mind was largely directed to problems of management and staffing. He spared no effort to ensure that talent was brought to notice and deployed to the best advantage.

"Ronnie's" piquant and sometimes unorthodox comments made in committee, or in the course of his "thinking aloud," are well known. A minor accomplishment was his ability to dictate, extempore, the pithy and well-directed memorandum when Headquarters failed to respond with matching enthusiasm to an "E.B., Scotland" initiative.

Mr. Hines intends to continue to live in Edinburgh.

R.M.

H. J. Revell, B.Sc. (Eng.), A.C.G.I., M.I.E.E.

The appointment of Mr. H. J. Revell as Chief Regional Engineer, Scotland, on 4 August 1964, is somewhat novel in that it is rare for a Telephone Manager to move in this particular direction. His engineering background, training and experience have been considerably enhanced by his wider managerial experience as Deputy Telephone Manager and Telephone Manager over a period of 11

years. Since nearly all his time with the Department has been spent in Scotland, during which he has worked, in one capacity or the other, in each of the five Telephone Areas making up the Directorate and also in the Regional Office, his appointment as C.R.E. Scotland is particularly fitting.

Mr. Revell gained his early experience as an apprentice in H.M. Dockyard, Devonport. Following 3 years at the City and Guilds Engineering College, he entered the Department as a Probationary Inspector in 1934. His initial training in Scotland was followed by a brief period in the private-circuit group of Telegraph Branch, after which he returned to Scotland to serve in the Edinburgh and Aberdeen Telephone Areas. Promotion to Assistant Engineer (old style) through the limited competition resulted in his appointment to the

Lines Group in the C.R.E.'s office, Edinburgh, in 1938. His war years were spent as Post Office Communications Liaison Officer to Headquarters, No. 18 Group R.A.F., with headquarters at Dunfermline, Fife, and in the War Office, London. Here, as Assistant Principal in the Civil Affairs Directorate he was concerned with the progressive restoration of telephone and postal facilities in the liberated territories of Europe and the Far East. Returning to the Post Office, and Scotland, in 1945 he became involved in post-war recovery, of a more local nature, in the Accommodation Duty at Scottish Regional Headquarters until his promotion to Area Engineer, Aberdeen, in 1947. He remained at Aberdeen for 6 years, during which time he served on the Committee of the Scotland North Sub-Centre of the Institution of Electrical Engineers.

In 1953 Mr. Revell was appointed Deputy Telephone Manager, Glasgow, and for the next 7 years took special interest in the recruitment, training and promotion of an expanding engineering staff. For the past 4 years as Telephone Manager, Scotland West Area, he has been responsible for the complete reorganization of the engineering staff on a functional basis to meet a rapidly growing program of automation and S.T.D. and the staff expansion to carry it through. He will bring to his new post a notable capacity for sustained effort and attention to detail which, together with his close personal knowledge of most of the very wide territory under his charge, should augur well for Scottish engineering affairs and staff.

Mr. Revell's main hobbies are gardening and philately—he is an active member of the Caledonian Philatelic Society.

His many friends and colleagues wish him every success in his new post.

R.R.B.

Reprint of Articles from the Special S.T.D. Issue of the Journal (Vol. 51, Part 4, Jan. 1959).

Copies are still available of the reprint of selected articles from the special subscriber trunk dialling issue of the Journal (Vol. 51, Part 4, Jan. 1959). This 32-page reprint, price 2s. 6d. (3s. post paid) per copy, contains some notes drawing attention to developments that have taken place since the original publication of the selected articles and which affect the information contained in these articles. The articles in the reprint are as follows:

The General Plan for Subscriber Trunk Dialling.
Controlling Register-Translators, Part 1—General Principles and Facilities.
Local Register for Director Exchanges.
Periodic Metering.
Local-Call Timers.
Metering over Junctions.
Subscribers' Private Meter Equipment.

Orders and remittances, which should be made payable to *The P.O.E.E. Journal* and crossed "& Co.," should be sent to *The Post Office Electrical Engineers' Journal*, G.P.O., 2–12 Gresham Street, London, E.C.2.

Reprint of Article Entitled "Outline of Transistor Characteristics and Applications."

Copies are available of a reprint of the article entitled "Outline of Transistor Characteristics and Applications" (Vol. 56, pp. 122, 196 and 268, July and Oct. 1963, and Jan. 1964). The 22-page reprint, price 3s. (3s. 6d. post paid) per copy, contains the three parts of the article, which had the following subsidiary titles:

Part 1—Transistor Parameters and Stabilization of Characteristics.
Part 2—Application of Linear Characteristics.
Part 3—Application of Non-Linear Characteristics.

Orders and remittances, which should be made payable to *The P.O.E.E. Journal* and crossed "& Co.," should be sent to *The Post Office Electrical Engineers' Journal,* G.P.O., 2–12 Gresham Street, London, E.C.2.

Correction

It is regretted that a printing error occurred in the article by Mr. J. V. Miles and Mr. M. G. Turnbull entitled "Switching Arrangements for International Subscriber Dialling of Calls to Europe" (Vol. 57, p.75, July 1964). The last sentence of the last paragraph of the "Introduction" should have read: The country code allocated to the United Kingdom is 44; hence, a London subscriber with a national number 01 ABC 1234 would have an international number 44 1 ABC 1234.

Book Review

"International Series of Monographs on Electronics and Instrumentation, Fundamentals of Microwave Electronics." V. N. Shevchik, xxxi + 253 pp. 168 ill. 70s.

The book is a translation by L. A. Thompson from the Russian original published in 1959. The author devotes about half the book to the basic phenomena of electron bunching and energy exchange caused by the interaction between electron streams and alternating electromagnetic fields. The remaining half of the book relates to the analysis of microwave devices in three main categories: narrow-band. broad-band and those with electron-wave interaction in which the physical circuit is not defined so easily as in devices employing a resonator or a delay line. The last category includes voltage-jump amplifiers, diocotron oscillators, mitrons and strophotrons, and is the least satisfying part of the book due to the meagre understanding of these devices at the time it was written.

The book is based on a course of lectures given by the author at Sarator State University and maintains a clear logical style throughout, employing a simplified mathematical analysis to enlarge the understanding of the principles. The main defect of the book is that it covers developments only up to 1957, omitting, due to the dating of the Russian original. the rapid advances in the field from 1958 onwards. The deficiency is admitted in the English edition in an extensive foreword, ably written by Dr. D. G. Kiely. covering the development of the maser, parametric amplifier, tunnel diode, the ophitron, cylotron-resonance oscillators. the platinotron and its cousins the stabilotron and amplitron. Dr. Kiely adds a bibliography of 56 references to direct the reader to further details of the devices he outlines. Of the 116 references quoted by the author of the book, about 65 are to sources in English or French, the remainder being mainly of Russian origin.

The book will be of value mainly to the student who is searching for a physically clear and simplified exposition of the basic ideas in microwave electronics, but the applications engineer will find the omission of recent developments a severe handicap.

W.A.R.

Institution of Post Office Electrical Engineers

Essay Competition 1964–65

To further interest in the performance of engineering duties and to encourage the expression of thought given to day-to-day departmental activities, the Council of the Institution of Post Office Electrical Engineers offers five prizes, a first prize of six guineas and four prizes of three guineas, for the five most meritorious essays submitted by members of the Post Office Engineering Department *below the rank of Inspector*. In addition to the five prizes, the Council awards five certificates of merit. Awards of prizes and certificates made by the Institution are recorded on the staff dockets of the recipients.

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

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

Copies of previous prize-winning essays have been bound and placed in the Institution Central Library. Members of the Associate Section can borrow these copies from the Librarian, I.P.O.E.E., G.P.O., 2–12 Gresham Street, London, E.C.2.

Competitors may choose any subject relevant to current telephone, telegraph or radio practice. Foolscap or quarto paper should be used, and the essay should be between 2,000 and 5,000 words. An inch margin is to be left on each page. A certificate is required to be given by each competitor, at the end of the essay, in the following terms:

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

Name (in block capitals) ....

Signature ....

Rank ....

Departmental Address ....

....

Date ....

The essays must reach

The Secretary,
The Institution of Post Office Electrical Engineers,
G.P O.,
2–12 Gresham Street,
London, E.C.2,

by 31 December 1964.

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

Essay Competition 1963–64

The Council of the Institution is indebted to Mr. R. ●. Boocock, Chairman of the Judging Committee, for the following report on the 1963–64 Essay Competition, the results of which were published in the July 1964 issue of the Journal:

The number of entries was comparable to that of previous years and embraced a wide range of telecommunication subjects. Technical accuracy was generally of a high standard and left very little margin for the assessment of the merit of one essay over another. Originality and method of treatment, especially in how interesting a manner the account or argument was written, were, however, factors which differed appreciably. An essay which contained a mass of detailed numerical specifications, or in which the subject matter was described in an over-long or tedious way, lost marks compared with one which held the interest of the reader throughout.

Of the essays in the prize-winning class, "Is Your Journey Really Necessary?" by A. G. Hickson, Technical Officer, Northampton, was accorded first place. The essay describes a journey in wintry conditions to a remote microwave radio station, a journey which began as an ordinary routine visit but which became a battle with the elements. It ends as a race with time, using improvised and unorthodox measures to restore, with minutes to spare before the transmission of a television program, a microwave link affected by a damaged aerial.

The second prize was awarded to J. S. Lishman, Technical Officer, Slough, for his essay "Planning S.T.D. in an Empty Continent." Easy to read, this essay in a brief description conveys to the reader the vastness of the Australian continent and the problems facing communication engineers. It is an insight into things to come, describing in broad outline the system of S.T.D. it is proposed to adopt.

The third prize was awarded to F. Moverley, Technical Officer, Cardiff, for his essay "Labour Relations in the Post Office Engineering Department," in which the author first gives a straightforward description of "the present organizational structure in which negotiations at different levels are carried out" and then follows with a more critical treatise on "the general areas of conflict between labour and management."

The fourth prize was awarded to G. D. Richardson, Technical Officer, Stamford, for his essay "A Theme on Thor." It is a reverie as the last of the Thor missiles is airborne on its way back to the U.S.A., and describes the significance of the part which the Post Office had played with its "customary unrecognized anonymity."

The fifth prize was awarded to D. W. J. Smith, Technician I, Bletchley, for his essay "Mechanical Aids—Their Evolution and Application to Modern Line Plant Practice," a survey from the time when labour was squandered and the Pyramid of Cheops was built with the labour of 100,000 men, up to the modern age with its power-assisted man.

S. WELCH,
General Secretary.

Regional Notes

Scotland

DAMAGE CAUSED BY WOODPECKERS

The photograph shows a portion of a 30 ft medium pole, which had been damaged by woodpeckers. The entry hole is roughly elliptical, measuring 3 in. × 2 in., and was at a height of about 10 ft from the ground. The cavity in the pole is approximately 5 in. in diameter and 10 in deep, and was discovered during pole testing. It had escaped notice (even though the pole was on the A 9, the main road north on the east coast of Sutherlandshire) because the entry hole was on the side away from the road. Apparently, the woodpecker did not relish creosote as, apart from the entry hole, only the central portion of the pole had been attacked. Damage of this kind is very rare in the Aberdeen Area, which is fortunate when the number of poles in use (some 106,000) is borne in mind.

THE SECTION OF POLE DAMAGED BY WOODPECKERS

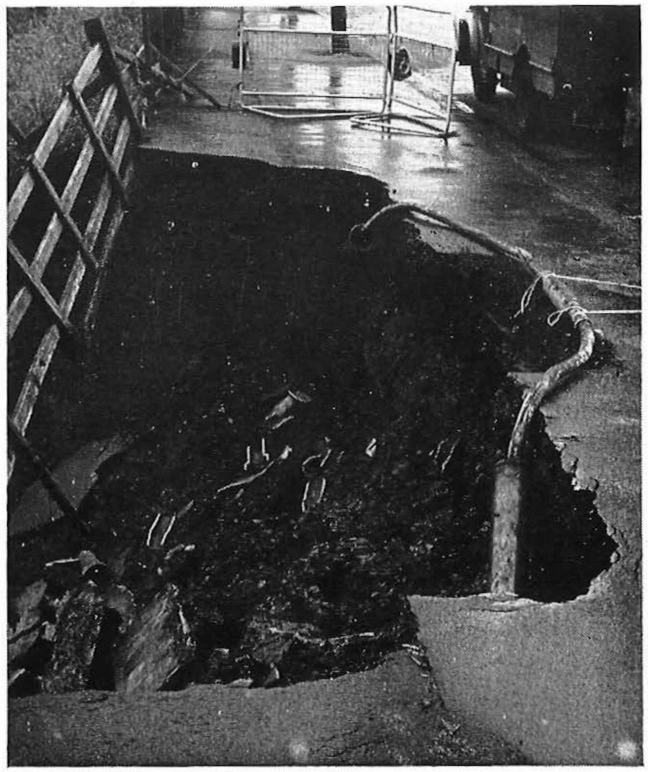
W.S.

North Western Region

FREAK STORM IN LANCASHIRE

On Saturday 18 July, a succession of violent thunderstorms swept in a great arc through Bolton, Blackburn, Darwen and Burnley, with 4½ in. of rain preceded by a bombardment of hailstones of golf-ball size. At the peak of the storm, around midday, at Turton Heights and Edgeworth Moor, halfway between Bolton and Blackburn, a new and unenviable national record was set up with 2½ in. of rain falling in 45 minutes.

Even the Lancashire drainage system is not designed for that rate of flow, and the resulting floods did extensive damage to buildings and roadworks, undermining foundations, scouring out reinstated trenches and ripping up road paving. Floods, up to 16 ft deep in places, were reported. At Rising Bridge, Haslingden, a parked car was swept into a culvert too small for it to pass through, and the flood water built up until the car was extruded through the hole. An elderly woman, unable to wade through the flood in her house, was drowned, and one house collapsed and several were made unsafe. At Astley Bridge, Bolton, a joint box was left swinging on a bight of 300 pr., 20 lb/mile junction cable which fortunately continued to work without interruption. The first photograph shows the cable, at that point, during the repair operations. Several lengths of track, recently laid for the Astley Bridge transfer, vanished without trace. At Rossendale, facia boards on the new automatic telephone exchange were chipped and dented by the hailstones, which were reported to be jagged lumps of clear ice up to cricket-ball size. The second photograph provides further evidence of the intensity of the storm.



EXPOSED JUNCTION CABLE AT ASTLEY BRIDGE

ROAD WASHED AWAY AT HOROBIN FOLD, TURTON

The floods deposited the hailstones in deep drifts at strategic points, and four days after the storm, workers at a mill at Haslingden were still patiently clearing with pickaxe and wheel-barrow a shed 50 yd long filled up to 8 ft deep with consolidated rock-hard ice.

Some 1,400 faults were reported over the area, and the count would have been much higher but for the fact that many towns were on holiday. Even the glimpse given by this incomplete picture soon proved misleading for many faults were found to be multiple disconnexions at bows and terminations on overhead open-wire routes (the same pair being broken at several points), and many other faults, due to lightning, proved to be single-wire damage inside cables. A P.A.B.X. No. 1, brought into service only on 10 July 1964 at India Mills, Darwen, disappeared under 9 ft of water.

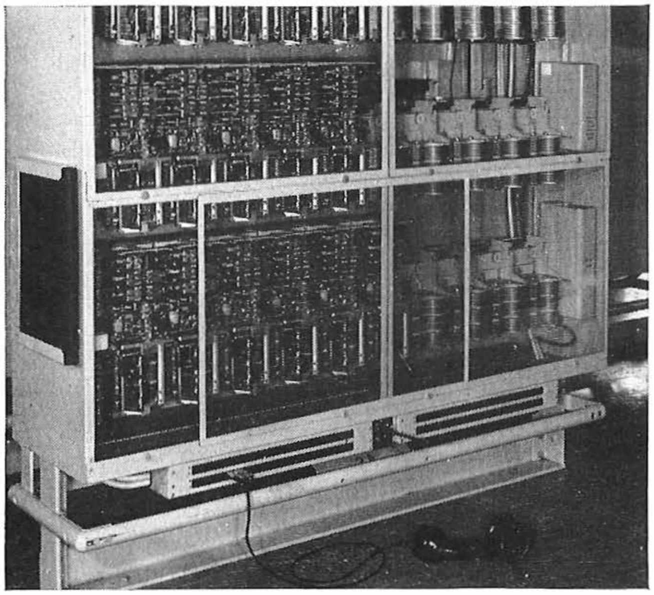
Repairs went on continuously until 21 July, when the situation was well under control, although the operations had been complicated by a return visit of the storm centre in the late evening of Saturday.

J.H.S. and J.C.E.P.

Midland Region

BAKEWELL NON-DIRECTOR EXCHANGE

Bakewell non-director telephone exchange, which was opened on 25 June 1964, contains some novel features, the most striking of which is the dust-proofing of the selector racks (see photograph), removable panels having been fitted to both front and rear of these racks.



By courtesy of Ericsson Telephones, Ltd.

DUST-PROOFED SELECTOR RACK IN BAKEWELL EXCHANGE

The selectors do not have individual covers, so that, as the panels on the fronts of the racks are transparent, it is possible to see which relays are operated without having to remove or disturb anything. Test jacks for all selectors are brought out to common access points at the base of the racks outside the covers and consequently much faulting and routine testing can be carried out without removing the dust-proofing. The front panels consist of transparent plastic sheets, which, as they adhere to a framework of iron bars on the racks by flexible magnetic tape along all four sides, are easy to remove and yet give a positive dust-proof seal. The rear panels are similar but of opaque plastic material matching the cream ironwork.

The general effect is very pleasing, the apparatus being less obtrusive and less noisy than in a conventional exchange. It is understood that there is a field trial of dust-proof racks in progress in another exchange elsewhere in the country, but the Bakewell equipment was installed at the request of the equipment contractors, Ericsson Telephones, Ltd., who have made a study of the problem of dust-proofing in connexion with the export business, and who wish to use Bakewell as a demonstration exchange.

Another special feature of the equipment is the use of flush-nylon bank construction on all first, second and final selectors to test whether the introduction of flush areas of nylon between contacts reduces wiper wear.

C.C.P.

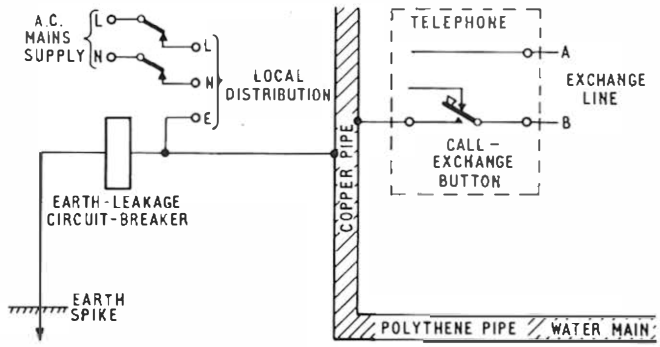
South Western Region

AN INVOLUNTARY BLACKOUT

An unusual type of fault, which has been observed on a number of occasions, is that which is liable to occur at a shared-service subscriber's premises where the main water supply is fed through the garden in polythene water pipe. The existence of this pipe is not apparent as small-bore copper is invariably used inside the house.

The symptoms of the fault are that operation of the joint-user call-exchange button on the telephone instrument puts all the lights out in the house, a defect that may be very alarming.

The fault occurs under the following circumstances, which are shown in the sketch. The electricity authority may have installed its equipment in a standard manner with an earth-leakage circuit-breaker, connecting one side of the operate coil to the copper water pipe, usually via immersion-heater equipment, and the other to a separate earth spike. The joint-user telephone may also be installed using the same copper water pipe to provide the earth for the call-exchange button. If now, because of the presence of the polythene pipe, the earthing of the water pipe is ineffective, the operation of the call button will allow current to flow from the negative wire of the telephone line through the coil of the earth-leakage circuit-breaker to the earth spike, so operating the circuit-breaker and cutting off the electricity supply.



SIMPLIFIED DIAGRAM SHOWING THE COMMON EARTH CONNEXION FOR CIRCUIT-BREAKER AND JOINT-USER TELEPHONE

It has been observed that the defect does not occur for a year or more after a new house is first occupied, and there seems to be two main reasons for this, which are as follows:

(*a*) Initially, the walls of the new house may have a water content sufficient to earth the copper pipe.

(*b*) When new, the pipe is in electrical contact with the water inside it. Scale is slowly deposited on the inside of the pipe, however, and eventually completely insulates the pipe from its contents.

R.S.

A COMPACT CARD-FILING RACK

The close association of card records with a seated person, so that a minimum of movement is incurred in making reference to the stored information, presents a problem when a large number of cards are involved. Using filing cabinets to store the cards at maintenance control centres may mean that additional staff are required to deal with the filing arrangements, or that the test clerk has to leave his seat and walk to the filing cabinets, which is inconvenient and constitutes a waste of time and energy. The arrangement of filing cabinets away from the test desk has been found to be necessary because of the space required for the accommodation of a large number of cards.

The whole organization of maintenance control centres is at present under active review at Headquarters, and the methods that will be adopted for card filing will largely depend on the size and shape of the cards eventually chosen, and the arrangement for their circulation. Meanwhile, various methods have been tried to provide compact storage of cards so that ready reference can be made to the records, but these have proved unsatisfactory for one reason or another. Mention was made in the Productivity Team Report, produced by those who visited the U.S.A. in 1953, of a three-turret rack for storing fault record cards that is designed to enable a female fault clerk to have seated access to the records for the whole exchange. It would appear from the photograph in the report that the clerk would have to expend much energy in extracting or replacing a fault card, owing to the size of the rack. The capacity was not quoted but clearly several thousands of cards could be accommodated.

The rack, which is the subject of this article, was produced at Southampton, where filtered engineering faults repair service is in operation, to attempt to overcome these difficulties and to provide a quick and effective access to the records in the minimum of time, and with little physical and mental effort. The rack, which is 4 ft 7½ in. wide, 4 ft ½ in. deep and 2 ft 7 in. high, consists of two large trays, each of which is divided into six compartments. Each compartment is equivalent in size to the metal card-tray employed in the normal card filing cabinet, which accommodates approximately 2,000 cards. Thus, space is provided for approximately 24,000 cards. Three, and possibly four, of the racks could be grouped around a fault clerk, if necessary, giving him access to approximately 72,000 cards.

The lower tray is fixed and slopes away from the user so that the records in the front ends of the compartments are easily visible to a person sitting close to the rack. To allow access to this lower tray, the upper tray is mounted on ball-bearing wheels, which run on the main framework, so that it can be pushed backwards out of the way or pulled forward to be close to the user. The designation boards on the front and rear ends of the trays give a complete indication of the grouping of cards for particular exchanges. Thus, the user is guided straight to the fault record card required with the minimum of eye strain. These designation boards are also sign-written on the back so that any other person who desires to consult the records can see at a glance their actual location. Because of the open construction of the rack, more than one member of the staff can refer to most of the cards at any one time and in any event can see where the particular card is located. The bases of the trays are left open in order that the dust, usually associated with the record cards, falls down to the floor and does not contaminate the lower edges of the cards as happens with boxed trays, where the dust gets trapped. There is a fair amount of spare space behind the lower trays, and this has been utilized to provide additional trays for the storage of completed cards and the usual stock of spare cards. Wood blocks were used on the base of the rack so that it could slide along the wood-block floor without damage. These blocks were found to be preferable to castors, which caused the rack to move too easily, especially when the top tray came into contact with its stops.

Dexion angle-iron was used for the construction of the rack, but its open appearance was criticized on aesthetic grounds and so, to conform to normal furniture standards, all the racks constructed have now been boxed-in with French-polished sapele-faced plywood.

At the maintenance control centre at Winchester, where there is one test clerk, the number of cards to be accommodated was such that a fixed tray with only six compartments was necessary. A small rack, measuring 4 ft 7 in. wide, 2 ft deep and 2 ft 4 in. high, was produced embodying the principle of the sloping lower tray of the larger rack. This rack is shown in the photograph. It will accommodate

DEMONSTRATION OF THE SMALL CARD-FILING RACK AT WINCHESTER

approximately 12,000 cards, and is mounted on swivelling castors as the test clerk found this arrangement more convenient. An added refinement, not shown in the photograph, is a 6 in. wide shelf running the whole width of the rack. This enables the user to put the fault cards down during filing operations. A certain amount of spare space exists beneath the card trays for the storage of completed and spare cards.

The cost of the materials, excluding the sapele-faced plywood cladding, for the large and small racks was £12 and £6, respectively, and although more angle-iron was used in the larger rack, a saving was effected by not using swivelling castors. No great expenditure in labour was involved.

C.H.G.

Associate Section Notes

Edinburgh Centre

At the annual general meeting held on 8 April in the Gillsland Hotel, the following officers were elected for the 1964–65 session: *Chairman:* Mr. R. P. Donaldson; *Secretary:* Mr. J. M. Dixon; *Assistant Secretary:* Mr. J. Duncan; *Treasurer:* Mr. J. A. Coghill; *Librarian:* Mr. R. L. Harris; *Committee:* Messrs. D. Stenhouse, H. R. Phillip, J. H. King, I. A. Barclay, T. A. Woolard, and R. Elder.

During the past session membership continued to increase, and there are now 190 members. Attendances, both at visits and meetings, showed improvement, so with plans laid for a varied program this coming winter, we look forward to an interesting and enjoyable session.

J.M.D.

Dundee Centre

At the annual general meeting held on 5 May, the following officers were elected for the 1964–65 session: *Chairman:* Mr. R. L. Topping; *Vice-Chairman:* Mr. G. Deuchars; *Secretary:* Mr. R. T. Lumsden; *Treasurer:* Mr. D. L. Miller; *Committee:* Messrs. R. C. Smith, B. D. Mackie, R. Fraser, J. H. Marshall, A. Bannerman, and J. Patrick; *Auditors:* Messrs. J. A. Lamb and K. K. Summers.

A varied program has been arranged for the winter, our day visit being next April, when it is hoped to be possible to visit Rootes (Scotland) motor works at Linwood.

R.T.L.

Ayr Centre

In the 1963–64 session, five meetings were held and one visit organized. Two of the meetings were conducted by Mr. H. J. Revell, Telephone Manager, one by Mr. W. F. Leith, and one by Mr. A. Bagnall. The average attendance throughout the session was 17 members.

At the annual general meeting held on 29 April, the following officers were elected: *President:* Mr. H. M. Pringle; *Chairman:* Mr. A. Edgar; *Vice-Chairman:* Mr. W. F. Leith; *Secretary:* Mr. J. Halliday; *Treasurer:* Mr. R. S. Campbell; *Committee:* Messrs. R. Claymore, A. Bagnall, A. Graham, J. A. McIntyre and V. Whyte.

J.H.

Aberdeen Centre

The last meeting of our 1963–64 session, consisting of a combined annual general meeting and film show, was held on Thursday 23 April. The number of members present showed a very encouraging increase over previous years. The main item on the agenda was a motion proposing the formation of an Inverness Centre; the motion was carried unanimously.

The office bearers of the Aberdeen Centre were elected as follows: *Chairman:* Mr. R. T. Ross; *Vice-Chairman:* Mr. J. H. Lawrence; *Secretary and Treasurer:* Mr. D. White; *Assistant Secretary:* Mr. G. D. Adam; *Librarian:* Mr. P. McAnulty; *Auditors:* Messrs. E. D. Petrie and G. Milne; *Committee:* Messrs. A. Forster, G. Fox, D. C McLean, J. Pike, J. H. Robertson, R. Sandison, J. H. Simpson, J. A. Stephen, A. Webster, W. Williamson and R. Yule; *Out-station Representatives:* Messrs. J. D. Elder (Peterhead), G. C. McKee (Elgin), R. Mathewson (Lerwick) and A. Wilkie (Huntly). A special vote of thanks was made to the retiring out-station representatives for their valuable work in the past, some of whom will, no doubt, continue their good work with the Inverness Centre. The film, entitled "The Kariba Story," was thoroughly enjoyed by all.

Our 1964–65 program will include a number of visits as well as our usual monthly meetings, and we hope that the good attendance of last year will continue.

D.W. and G.D.A.

Inverness Centre

At a meeting in Inverness on 29 April, the following office bearers of the newly-formed Inverness Centre were elected: *Chairman:* Mr. J. C. Hines; *Secretary:* Mr. W. Catto; *Treasurer:* Mr. D. Neave; *Librarian:* Mr. R. R. Russel; *Committee:* Messrs. F. Downie, B. W. Fieldsend, J. W. Innes and W. Webster; *Auditors:* Mr. S. Fraser and Mr. K. Hall. The constitution of the new Centre was drawn up and agreed upon, and this was followed by a discussion on the forthcoming program.

D.W. and G.D.A.

Bedford Centre

After a successful winter session of lectures, at which the average attendance was 36, we are looking forward to the next session, the program for which is as follows:

Tuesday 15 September: Motoring Films.
Monday 26 October: "Engineering Training in the Post Office."
Wednesday 2 December: "Space Communication."
Thursday 14 January: "P.O. Mechanical Aids."
Monday 22 February: "Coal Mining."
Tuesday 6 April: "Television Switching."

During the summer we held a varied program of visits, including a visit to Texas Instruments, Bedford, who design and manufacture transistors, two visits to the Aston Martin/Lagonda car factory at Newport Pagnell, and two visits to the B.B.C. television centre at Shepherds Bush. At the Aston Martin factory it was refreshing to see cars being hand-made to individual customer's requirements instead of being mass-produced by the thousand on a production line. After seeing this, it is quite easy to appreciate why these cars are so expensive.

The annual general meeting took place in September, when we were able to look back on the first year of our existence with satisfaction, but not complacency.

E.W.H.P.

Bletchley Centre

The annual general meeting was held on Wednesday 10 June at the Swan Hotel, Fenny Stratford. The following officers and members of the Committee were elected: *Chairman:* Mr. M. Walduck; *Secretary:* Mr. W. J. Allen; *Assistant Secretary:* Mr. P. B. King; *Treasurer:* Mr. D. Castle; *Committee:* Messrs. E. P. Hughes, C. J. N. Richardson, N. Hall, C. Tooth, K. Peerless and R. Stainsby.

A party of Post Office engineers led by Mr. A. H. C. Knox, Chief Regional Engineer, Home Counties Region, visited Paris in April. During their weekend there, the party was shown over a telephone exchange and a training school as well as other departments of the French Post Office Engineering Department. The party consisted of members of both the Main Section and the Associate Section, and was organized by Messrs. W. J. Allen and P. B. King.

W.J.A.

Colchester Centre

The annual general meeting was held on 15 April, and the following officers were elected: *Chairman:* Mr. F. K. Radcliffe; *Vice-Chairman:* Mr. A. J. Russell; *Secretary:* Mr. T. T. Shanks; *Assistant Secretary:* Mr. G. Humm; *Treasurer:* Mr. J. R. Clare; *Committee:* Messrs. J. Palmer, M. H. Martin and J. R. Fisher; *Auditors:* Messrs. R. Cocker and J. Bare; *Librarian:* Mr. J. Cade.

The Chairman, Mr. F. K. Radcliffe, Area Engineer, who has given us great encouragement and support during his seven years at Colchester, has been appointed Telephone Manager, Bournemouth, and we wish him success and happiness in his new office.

A successful summer program has now been completed. including a visit, in August, to Bradwell atomic power station by water from West Mersea.

Arrangements have been made for an extensive winter program, which includes a talk on some aspects of satellite communication, by Mr. C. Purvis, Post Office Research Station, Castleton, a paper on the photographic illustration of technical articles, by Mr. W. A. J. Paul, Research Branch, Engineering Department, and a paper, on the pressurization of cables, by Mr. R. A. M. Light, Colchester Area. The visit of Mr. C. Purvis, who was in the Colchester Area for some time, will be an opportunity to revive old friendships, and is bound to be in the nature of a social occasion for most of us.

Membership figures are steadily increasing, and with the continued firm support we look forward to an interesting session for 1964–65.

T.T.S.

Swindon Centre

The 1963–64 program was completed in April with a very well attended meeting of the Swindon and Gloucester Centres at Cirencester. A paper on satellite communications was given by Mr. D. Wray, Space Communication Systems Branch, Engineering Department, to whom we were indebted for a most enjoyable evening.

The summer's activities included visits to Morris Motors, Ltd., Oxford, and the B.B.C. television centre.

A.J.B.

Exeter Centre

At the conclusion of a very successful winter session our members would like to express their appreciation to the following speakers for presenting papers:

October: "Transistors and Their Application to Post Office Equipment," by Mr. J. A. T. French, Research Branch, Engineering Department.

November: "Exchange Equipment Installations—Do We Get Value For Money?" by Mr. D. R. B. Ellis, Exchange Equipment and Accommodation Branch, Engineering Department.

December: Films on the laying of the TAT-3 submarine cable.

January: "Cable Laying and Submerged Repeaters," by Mr. G. A. Axe, Main Lines Development and Maintenance Branch, Engineering Department.

February: "Signalling Systems for Dialling Over Trans-oceanic Cables," by Mr. S. Welch, Telephone Exchange Systems Developments Branch, Engineering Department.

March: "Crime Detection," by Chief Inspector Evans, Exeter City Police.

For the summer session, visits were organized to the atomic energy power station at Winfrith, and to Start Point radio station.

Our Centre is now entering its third year, and the membership has progressed to a total of 220, thanks to an enthusiastic committee.

F.R.S.

Bath Centre

In January, through the help of Mr. C. A. L. Nicholls, O.B.E., Chief Regional Engineer, South Western Region, we were invited to attend a meeting of the I.E.E. Western Centre, at which Mr. F. J. D. Taylor, O.B.E., Space Communication Systems Branch, Engineering Department, presented his paper "Communication Satellites." Mr. Taylor is responsible for the work of the Space Communication Systems Branch, and it was extremely interesting to hear an account of the development and possible trends in future operational systems. The paper was well supplemented with film, slides and models.

February saw the social highlight of the Centre—the Annual Telephone Dance—held this year at the Assembly Rooms, Bath. It was very successful and well supported, with almost 600 people attending. Also during that month, a party of members visited Vauxhall Motors, Ltd., Luton. Visits to car factories are usually well patronized and this was no exception. Members spent a very enjoyable day at Luton, and thanks are due to Vauxhall Motors, Ltd., for the excellent hospitality provided.

The visit arranged for March, which was to have been to Harvey's Wine Vaults, Bristol, had to be cancelled due to lack of support.

April is the month of the annual general meeting, and the following officers were elected: *President:* Mr. C. L. Burgess; *Chairman:* Mr. L. F. Vranch; *Vice-Chairman:* Mr. M. J. Moxham; *Treasurer:* Mr. R. P. Bowers; *Secretary:* Mr. R. R. Darke; *Assistant Secretary:* Mr. W. J. Rossiter; *Librarian:* Mr. R. D. Cowley; *Committee:* Messrs. R. Faulkner, A. Roberts, J. Silcox, P. G. Martin, I. Jennings, R. K. Wall, M. Dean and A. Parfitt; *Auditors:* Messrs. A. Steer and D. Powell.

During May, a visit was made to the Central Electricity Generating Board grid control centre at Durley Park, Keynsham. Members were shown the telecommunications equipment used to send and receive information between power stations, switching centres and the control centre. The information is conveyed over private wires rented from the Post Office.

In June, a party of 20 members made the journey to Berkeley power station. Since this was a half-day excursion, the journey was made via the site of the new Severn Bridge, where a halt was made to view the progress of construction. Also visited was Berkeley Castle, which, although its history dates from the 12th century, is still a family residence. After tea, which was taken at the castle, the party made its way to Berkeley power station. This is one of the new atomic power stations, and members were shown the reactors, the fuel-handling equipment, the turbines and the control room.

R.R.D.

Books Received

"Waves and Oscillations." R. A. Waldron, M.A. D. Van Nostrand Co., Ltd. vii + 135 pp. 105 ill. 14s.

This book, Waves and Oscillations is No. 4 in a series of books known as Van Nostrand Momentum Books published for the Commission on College Physics of the U.S.A. In his preface the author explains his method of dealing with the subject, thus: "The study of waves is essentially mathematical, and it has not been possible to avoid using mathematics in this book, although it has been kept as simple as possible. Where it is necessary to use sophisticated concepts, mathematical details and rigour have been cast overboard in favour of qualitative descriptions."

The book deals with such matters as reflection and refraction, resonance, interference and diffraction, guided waves, and topics in network theory. The author's views on the presentation of much of this material can be summed up in the following passage taken from the opening chapter on elementary concepts: "Mathematically then, we can expect such systems as simple pendulums, weights hanging on springs, and alternating-current circuits to behave in analogous ways, so that we can use the behaviour of one system to help us to understand another. Electrical engineers, who learn about a.c. theory before they learn about waves, usually try to explain everything in terms of a.c. theory. This one-sided approach to the theory of waves and oscillations is sometimes helpful, but can often limit the understanding rather than advance it. The aim in this book is to try to broaden the reader's outlook so that he will learn to use analogies as a guide, but will not come to depend on them, or on a particular kind of analogy, slavishly."

"Matrices: Their Meaning and Manipulation." W. G. Bickley, D.Sc., F.R.Ae.S., A.C.G.I., and R. S. H. G. Thompson, B.Sc. The English Universities Press, Ltd. xiii + 168 pp. 9 ill. 21s.

This book is based on lectures given to third-year and postgraduate engineering students at Imperial College of Science and Technology, London. The aims of the book are to help the student to read with understanding the language of matrices in which the mathematics of so many problems is being written in the technological press, to assist the student in his first steps in writing his own problems in this language, and to give him an understanding of the techniques necessary for the arithmetical solution of large-scale problems which lead to linear equations.

Exercises, to which hints and answers are given, form an integral part of the book. They are intended to not only provide practice in routines, but to lead to deeper insight and to a widening of the areas of application of matrix language and ideas.

Staff Changes

Promotions

Telephone Manager to Chief Regional Engineer

Name	Region, etc.	Date
Revell, H. J.	Scot.	4.8.64

Assistant Staff Engineer to Deputy Chief Regional Engineer

Name	Region, etc.	Date
Thompson, A. J.	E.-in-C.O. to L.T. Reg.	16.3.64

Area Engineer to Assistant Staff Engineer

Name	Region, etc.	Date
Carden, R. W. G.	L.T. Reg. to E.-in-C.O.	31.3.64

Senior Executive Engineer to Assistant Staff Engineer

Name	Region, etc.	Date
Mitchell, C. W. A.	E.T.E.	4.3.64
Horner, G. H.	E.-in-C.O.	23.3.64
Thomas, L.	E.-in-C.O. to E.T.E.	20.4.64
Harding, D. J.	E.-in-C.O.	23.4.64

Area Engineer to Telephone Manager

Name	Region, etc.	Date
Arnold, G. F.	H.C. Reg. to W.B.C.	20.4.64
Thompson, R. H.	N.E. Reg.	10.6.64

Executive Engineer to Area Engineer

Name	Region, etc.	Date
Paterson, A. E.	Mid. Reg. to H.C. Reg.	6.4.64
Brown, W. D.	H.C. Reg.	6.4.64
Sturdy, F. H.	H.C. Reg.	1.5.64
Bluring, J.	H.C. Reg.	5.6.64
Todd, D. W.	L.T. Reg.	16.6.64

Executive Engineer to Senior Executive Engineer

Name	Region, etc.	Date
Hales, J. R.	E.-in-C.O.	7.4.64
Davey, D. V.	E.-in-C.O.	20.4.64
Hughes, J. A.	E.T.E.	24.3.64
Robinson, A. J.	E.-in-C.O.	23.4.64
Reid, H. A.	E.-in-C.O.	23.4.64
Lowe, B. A.	E.-in-C.O.	23.4.64
Bronsdon, E. G.	E.-in-C.O.	23.4.64
Hough, R.	E.-in-C.O.	8.5.64
Williams, L. F.	Mid. Reg.	11.5.64
Smith, G. L.	E.-in-C.O.	13.5.64
Spry, B.	L.T. Reg. to E.-in-C.O.	25.5.64
Rendle, F. R.	H.C. Reg. to E.-in-C.O.	15.6.64
Blair, G. M.	Home Office to E.-in-C.O.	1.6.64

Executive Engineer (Open Competition)

Name	Region, etc.	Date
Fortin, G. E.	E.-in-C.O.	2.3.64
Prosser, R. D.	E.-in-C.O.	13.4.64
Elliott, J. L. C.	E.-in-C.O.	24.4.64
Moon, R. J.	E.-in-C.O.	3.6.64
Mitchell, P. A.	E.-in-C.O.	15.6.64

Executive Engineer (Limited Competition)

Name	Region, etc.	Date
Harby, B. W.	E.-in-C.O.	13.4.64
Lewis, K. C.	L.T. Reg. to E.-in-C.O.	20.4.64
Stoate, J. D.	E.-in-C.O.	20.4.64
Frith, C. L.	L.P. Reg. to E.-in-C.O.	20.4.64
Dudley, L. W.	E.-in-C.O.	20.4.64
Morling, K. F.	E.-in-C.O.	27.4.64
Byrnand, D. S. J.	E.-in-C.O.	20.4.64
Goodman, E. T. J.	E.-in-C.O.	11.3.64
Howe, F.	E.-in-C.O.	18.3.64
Scott, P. A.	L.T. Reg. to E.-in-C.O.	20.4.64
Emery, S. R.	H.C. Reg. to E.-in-C.O.	20.4.64
Churchus, D. B.	L.T. Reg.	20.4.64
Blois, A. H.	E.-in-C.O.	13.4.64
Dykes, J. L.	L.T. Reg.	20.4.64
Frame, P. B.	E.-in-C.O.	13.4.64
Barfoot, D. W.	E.-in-C.O.	20.4.64
Hughes, R. M.	E.-in-C.O.	20.4.64
Matthews, W. R.	E.-in-C.O.	20.4.64
Derbyshire, R. H.	E.-in-C.O.	20.4.64
Martin-Royle, R. D.	E.-in-C.O.	20.4.64
Hall, B. E.	E.-in-C.O.	13.4.64
Pope, D. G.	E.-in-C.O.	20.4.64
Gould, P. M.	E.-in-C.O.	20.4.64
Axon, J.	E.-in-C.O.	20.4.64
Harries, D. W.	L.T. Reg. to E.-in-C.O.	20.4.64

Executive Engineer (Limited Competition)—continued

Name	Region, etc.	Date
Peace, L.	E.-in-C.O.	20.4.64
Golding, J. E.	E.-in-C.O.	13.4.64
Welsh, D.	S.W. Reg. to E.-in-C.O.	6.7.64
Evans, R. J. L.	W.B.C.	4.5.64
Dick, G. C.	Scot.	4.5.64
Gaukrodger, D.	N.E. Reg. to Mid. Reg.	4.5.64
Davis, K. C.	E.T.E.	4.5.64
Young, J. W. A. F.	W.B.C. to Mid. Reg.	4.5.64
Yaxley, A. F.	H.C. Reg. to E.-in-C.O.	4.5.64
Harper, R. D.	E.-in-C.O.	1.5.64

Assistant Engineer to Executive Engineer

Name	Region, etc.	Date
Baker, L. M.	E.-in-C.O.	27.4.64
Lilley, M.	E.-in-C.O.	27.4.64
Pope, G. J.	E.-in-C.O.	27.4.64
Pariser, F. A. A. I.	Mid. Reg.	13.4.64
Stockton, A.	W.B.C.	13.4.64
Owens, E. H.	W.B.C.	13.4.64
Johnson, S.	W.B.C. to Mid. Reg.	13.4.64
Whiteley, R. G.	S.W. Reg.	13.4.64
Anderton, M. F. D.	N.E. Reg.	13.4.64
Watkins, S. B.	N.E. Reg.	13.4.64
Harrington, J. A.	H.C. Reg.	27.4.64
Mihell, R. H.	H.C. Reg.	17.4.64
Meaby, L. P.	H.C. Reg.	10.4.64
Layton, R. C.	H.C. Reg.	27.4.64
Powell, A. R.	Mid. Reg. to W.B.C.	4.5.64
Pook, C. H.	S.W. Reg.	13.4.64
Bowyer, G. A. R.	W.B.C. to N.W. Reg.	4.5.64
McCabe, F. P.	Mid. Reg. to N.W. Reg.	1.5.64
Robinson, H.	N.W. Reg.	11.5.64
Barlow, G. H.	E.-in-C.O.	4.5.64
Blackhall, R. W. E.	E.-in-C.O.	15.5.64
Cottingham, R. D.	Mid. Reg.	6.5.64
Flemons, J. C.	Mid. Reg.	26.5.64
Rogers, J. A.	E.T.E.	25.5.64
Minting, A. E.	E.T.E.	25.5.64
Masding, F. W. E.	Mid. Reg.	26.5.64
Wilson, R.	H.C. Reg.	10.4.64
Upchurch, S. W. J.	H.C. Reg.	4.5.64
Webb, R.	H.C. Reg.	26.5.64
Abbott, H. F.	E.T.E.	25.5.64
Harrison, T. A. B.	N.W. Reg.	17.6.64
Wright, R. H. (*in absentia*)	H.C. Reg.	2.6.64
Garnett, J. A.	L.T. Reg.	17.6.64
Heath, K.	L.T. Reg.	17.6.64
Warner, H. G.	L.T. Reg.	17.6.64
McBretney, P.	E.T.E.	17.6.64
Connell, D. R. W.	S.W. Reg. to H.C. Reg.	1.6.64
Rodwell, A. A. T.	H.C. Reg.	1.6.64
Hall, G. H.	E.-in-C.O.	1.6.64
Shires, N. N.	E.T.E. to E.-in-C.O.	22.6.64
Lock, J. H.	W.B.C. to N.W. Reg.	15.6.64
Baccus, F. J.	H.C. Reg.	1.6.64
Risby, R. M.	H.C. Reg.	1.6.64
Ainley, J. H.	E.-in-C.O.	1.6.64

Assistant Engineer (Special Selection)

Name	Region, etc.	Date
Headey, M. C.	H.C. Reg. to E.-in-C.O.	1.4.64
Clift, G. W.	H.C. Reg. to E.-in-C.O.	1.4.64
Long, R.	N.E. Reg. to E.-in-C.O.	6.4.64
Layton, R. A.	E.-in-C.O.	1.4.64
Wells, B. C.	E.-in-C.O.	29.4.64
Whiteside, L. T.	E.-in-C.O.	4.5.64
Burton, P. A.	E.-in-C.O.	5.5.64
Richardson, J. E.	H.C. Reg. to E.-in-C.O.	4.5.64
Strickland, L. F.	L.T. Reg. to E.-in-C.O.	26.5.64
Hedgecoe, R.	E.-in-C.O.	26.5.64

Inspector to Assistant Engineer

Name	Region, etc.	Date
Greaves, L.	N.E. Reg.	31.3.64
Ackerley, J.	N.W. Reg.	27.4.64
Gowland, J. W.	N.E. Reg.	28.4.64

Name	Region, etc.	Date
Inspector to Assistant Engineer—continued		
Bridge, L. A.	L.T. Reg.	27.4.64
Horslen, S.	L.T. Reg.	27.4.64
Pugh, F. S.	L.T. Reg.	27.4.64
Gentle, E. C.	L.T. Reg.	27.4.64
Coates, E. W.	N.E. Reg.	28.4.64
Heweston, T.	N.W. Reg.	4.5.64
Thompson, W.	N.W. Reg.	29.5.64
Settle, K. W.	N.E. Reg.	1.6.64
Richards, R.	S.W. Reg.	16.6.64
Robson, W. P.	S.W. Reg.	16.6.64
Technical Officer to Assistant Engineer		
Wilkins, J. E.	H.C. Reg.	6.4.64
Lemarshant, M. F.	S.W. Reg.	13.4.64
Simons, J. E.	N.E. Reg.	31.3.64
Fox, D. W.	H.C. Reg.	4.3.64
Wilson, P. G.	W.B.C.	17.4.64
Barrett, T. A.	H.C. Reg.	6.4.64
Woods, K. E. L.	H.C. Reg.	31.3.64
Gwens, D.	H.C. Reg.	31.3.64
Standen, W. H.	H.C. Reg.	13.3.64
Jackson, K.	N.E. Reg.	6.4.64
Wyllie, M. J.	N.W. Reg.	13.4.64
Baxter, P. D.	H.C. Reg.	31.3.64
Harris, G. W.	S.W. Reg.	24.3.64
Barclay, D.	N.W. Reg.	27.4.64
Dilnot, L. C.	H.C. Reg.	1.4.64
Gray, W. H.	H.C. Reg.	31.3.64
Wade, J. D.	H.C. Reg.	31.3.64
Duncan, R. B.	Scot.	18.3.64
Pigg, R. A.	H.C. Reg.	10.4.64
Robinson, F. J.	H.C. Reg.	10.4.64
Muir, P. R.	Scot.	14.4.64
Lewis, D. W.	N.E. Reg.	31.3.64
Desforges, D. H.	N.E. Reg.	28.4.64
Blacker, J.	Mid. Reg.	14.4.64
Barrett, A. W.	Mid. Reg.	14.4.64
Davies, B. R.	W.B.C.	17.4.64
Spence, W. J. M.	Scot.	1.4.64
Veale, F. J. R.	H.C. Reg.	30.4.64
Bevan, G. R.	L.T. Reg.	27.4.64
Loftus, J. N.	N.W. Reg.	11.5.64
Lovelady, P.	N.W. Reg. to E.-in-C.O.	25.5.64
Taylor, R. C.	N.W. Reg.	2.4.64
Driver, R. R.	H.C. Reg.	4.5.64
Shorrock, D. V.	W.B.C.	4.5.64
Williams, J.	N.E. Reg.	28.4.64
Johnson, W. H. L.	H.C. Reg.	12.5.64
Brandwood, G. W.	N.W. Reg.	11.5.64
Sears, K. S.	L.P. Reg.	26.5.64
Boraston, M. A.	Mid. Reg.	28.5.64
Catchpole, P. J.	E.T.E.	20.5.64
Roberts, D.	E.T.E.	20.5.64
Sutton, D. E. J.	E.T.E.	20.5.64
Penhallow, V. L.	E.T.E.	20.5.64
Mason, S. M.	N.W. Reg.	27.5.64
Buick, K. D.	N.I.	5.5.64
de Cruz, B.	E.T.E.	25.5.64
Barber, D. R.	E.T.E.	25.5.64
Stothard, H. E.	N.W. Reg.	4.6.64
Farmer, L. G. P.	N.E. Reg.	28.5.64
Haynes, W. J. C.	H.C. Reg.	3.6.64
Scamell, K. W.	S.W. Reg.	15.6.64
Murray, A. L.	Scot.	1.6.64
Wilson, W. M.	Scot.	15.6.64
Forbes, C. S.	Scot.	29.6.64
Henderson, I.	Scot.	29.6.64
Dawson, B.	Scot.	8.6.64
Taylor, B. C.	W.B.C.	3.6.64
Seaman, J. E.	H.C. Reg.	15.6.64
Woodthorpe, W. A.	E.-in-C.O.	8.6.64
Cattermole, C. R.	H.C. Reg.	9.6.64
Banyard, K. W. A.	H.C. Reg.	9.6.64
Swift, G.	H.C. Reg.	15.6.64
Gormer, L. R.	H.C. Reg.	29.6.64
Bollen, A. H.	S.W. Reg.	8.6.64
Tisdale, A. C.	Mid. Reg.	17.6.64

Name	Region, etc.	Date
Technical Officer to Assistant Engineer—continued		
Brace, D. J.	E.-in-C.O.	26.6.64
Evans, J. H.	E.-in-C.O.	26.6.64
Young, B. C.	S.W. Reg.	16,6.64
Poulton, W. G.	S.W. Reg.	16.6.64
Whaley, F.	S.W. Reg.	16.6.64
Aldridge, K. W.	Mid. Reg.	17.6.64
Shane, E.	N.W. Reg.	29.6.64
Technical Officer to Inspector		
Pomfret, F.	N.W. Reg.	8.4.64
Rhodes, P. J.	H.C. Reg.	30.4.64
Totton, A.	N.W. Reg.	19.5.64
Woodward, J. M.	H.C. Reg.	19.5.64
Cole, R. G.	H.C. Reg.	12.5.64
Shipp, A. W.	S.W. Reg.	29.5.64
Sellman, W. T.	S.W. Reg.	12.6.64
Technician I to Inspector		
Bradley, A. E.	H.C. Reg.	1.4.64
Groombridge, G. F.	H.C. Reg.	31.3.64
Grainge, I. C. E.	H.C. Reg.	31.3.64
Worth, D. G.	N.W. Reg	27.4.64
Cook, J. H.	L.P. Reg.	24.4.64
Belkway, L. F.	H.C. Reg.	27.4.64
Hughes, T. A.	H.C. Reg.	27.4.64
Wood, W. H.	H.C. Reg.	27.4.64
Kenchat, N. H.	H.C. Reg.	27.4.64
Sowden, H. W.	H.C. Reg.	27.4.64
Ward, T. A.	H.C. Reg.	27.4.64
Paynter, F. G.	H.C. Reg.	27.4.64
Upton, R. G.	H.C. Reg.	27.4.64
Pope, W. A.	H.C. Reg.	27.4.64
Saunders, R. F.	H.C. Reg.	27.4.64
Baker, R.	H.C. Reg.	27.4.64
Watson, W. H.	H.C. Reg.	27.4.64
Blackburn, J.	H.C. Reg.	27.4.64
Ramson, W.	H.C. Reg.	27.4.64
Elliot, B. D.	H.C. Reg.	27.4.64
Cass, A.	N.W. Reg.	19.5.64
Marks, J. N.	Mid. Reg.	30.4.64
Hadfield, M. H.	Mid. Reg.	30.4.64
Ewers, A. D.	S.W. Reg.	19.5.64
Mortimore, W. W.	S.W. Reg.	11.5.64
Hunt, W. G.	S.W. Reg.	27.4.64
Britton, V. J. A.	S.W. Reg.	6.5.64
Thomas, D. R.	Mid. Reg.	30.4.64
Alldridge, M. R. G.	S.W. Reg.	6.5.64
Sloane, R.	L.T. Reg.	21.5.64
Wenham, W. S.	L.T. Reg.	21.5.64
Whelpton, R. A.	N.E. Reg.	8.6.64
Brooks, G. B.	Mid. Reg.	28.5.64
Brown, J. E.	L.P. Reg. to L.T. Reg.	8.6.64
Cook, E. T.	Mid. Reg.	17.6.64
Preece, T. J. A.	W.B.C.	25.6.64
Senior Scientific Officer to Principal Scientific Officer		
Ellis, A. S.	E.-in-C.O.	23.3.64
Assistant Experimental Officer to Experimental Officer		
Bryan, I. E.	E.-in-C.O.	13.5.64
Constable, P. W.	E.-in-C.O.	13.5.64
Preston, P. F.	E.-in-C.O.	13.5.64
Royle, R. J.	E.-in-C.O.	14.5.64
Technical Assistant (Open Competition)		
Harrison, D. P.	H.C. Reg.	6.4.64
Horn, R. L.	S.W. Reg.	6.4.64
Workshop Supervisor III to Technical Assistant		
Jarrett, J. B.	H.C. Reg. to E.-in-C.O.	7.4.64
Mechanic-in-Charge to Technical Assistant		
Ridout, J. F.	S.W. Reg. to London Reg.	7.4.64

Promotions—*continued*

Name	Region, etc.	Date
Mechanic A to Technical Assistant		
Manning, J. T. M.	Mid. Reg. to E.-in-C.O.	7.4.64
Draughtsman to Technical Assistant		
Lord, H.	L.T. Reg. to E.-in-C.O.	7.4.64
Garland, A.	E.-in-C.O.	7.4.64
Senior Draughtsman to Chief Draughtsman		
Nichols, D. J.	L.T. Reg.	9.6.64
Taylor, E. W. E.	E.-in-C.O.	9.6.64
Rawlings, L. J. J.	L.T. Reg. to H.C. Reg.	9.6.64
Firth, D. I.	N.E. Reg.	9.6.64
Edwards, H. G.	W.B.C.	9.6.64
Wharmby, L. C.	Scot. to Mid. Reg.	9.6.64
Dodds, A. T.	N.W. Reg.	9.6.64
Williams, E. V.	Mid. Reg. to S.W. Reg.	9.6.64
Craig, G.	L.T. Reg. to Scot.	9.6.64
Draughtsman to Leading Draughtsman		
Hannaford, S. F.	N.W. Reg. to S.W. Reg.	18.3.64
Mellows, D. W.	L.T. Reg. to L.P. Reg.	3.3.64
Bedford, G. E.	E.-in-C.O.	7.2.64
Higher Clerical Officer to Higher Executive Officer		
Webster, A.	H.C. Reg. to E.-in-C.O.	16.3.64
Clerical Officer to Executive Officer		
Ewans, O. J. (Miss)	E.-in-C.O.	3.3.64
Palmer, G. N.	E.-in-C.O.	9.3.64
Vallance, A.	E.-in-C.O.	12.6.64
Lewis, A. B.	E.-in-C.O.	12.6.64
Orsborn, A. W. B.	P.O.S.D. to E.-in-C.O.	15.6.64
Fountain, J. C.	H.C. Reg. to E.-in-C.O.	22.6.64

Retirements and Resignations

Name	Region, etc.	Date
Chief Regional Engineer		
Hines, R. J.	Scot.	31.7.64
Assistant Staff Engineer		
Cameron, C. J.	E.-in-C.O.	20.3.64
Spears, G.	E.-in-C.O.	28.3.64
Cooper, W. D. (*Resigned*)	E.T.E.	17.4.64
Area Engineer		
Such, R. C. (*Resigned*)	H.C. Reg.	30.4.64
Wootten, L. G.	L.T. Reg.	31.5.64
Senior Executive Engineer		
Stewart, T.	E.T.E.	31.3.64
Harris, E. T. C. (*Resigned*)	E.-in-C.O.	30.4.64
Rudeforth, S.	E.-in-C.O.	1.5.64
Brovold, A. T.	E.-in-C.O.	31.5.64
Dolton, H. J.	E.-in-C.O.	23.6.64
Executive Engineer		
Groom, D. E.	E.-in-C.O.	13.3.64
Hardgrave, L. R.	E.-in-C.O.	31.3.64
Taylor, G. E.	L.T. Reg.	31.3.64
Hogge, D. M. (*Resigned*)	E.-in-C.O.	31.3.64
Buckingham, L. V.	E.-in-C.O.	23.4.64
Huxley, G. P.	N.W. Reg.	30.4.64
Lee, J. L. (*Resigned*)	E.-in-C.O.	30.4.64
Wallace, R. C.	N.W. Reg.	6.5.64
Crabb, G. T.	N.W. Reg.	10.5.64
Sutherland, J. C. C.	E.T.E.	31.5.64
Hartley, A. L.	H.C. Reg.	31.5.64
Assistant Engineer		
Jenkinson, H. C.	N.E. Reg.	2.4.64
Ganley, A. H.	Mid. Reg.	15.4.64
Bruce, J.	N.E. Reg.	19.4.64
Cooper, W. J.	W.B.C.	27.4.64
Rummings, W. C.	S.W. Reg.	29.4.64
Hughes, R. A.	L.T. Reg.	30.4.64
Harrison, T. C. R.	N.E. Reg.	1.5.64
Edgar, J.	L.P. Reg.	7.5.64
Assistant Engineer—continued		
Dalton, H.	N.W. Reg.	10.5.64
Serjeant, F.	N.E. Reg.	11.5.64
Ashpool, T. H.	L.T. Reg.	15.5.64
Payne, A. J.	L.T. Reg.	15.5.64
Morgan, E.	N.W. Reg.	20.5.64
Houghton, C. W.	S.W. Reg.	25.5.64
Stears, A. D. S.	Scot.	29.5.64
Cameron, J. W.	Scot.	19.5.64
Goldsmith, F.	L.T. Reg.	11.6.64
Gray, G.	Scot.	27.6.64
Barton, B. A.	N.E. Reg.	28.6.64
Hatton, R. G. (*Resigned*)	E.-in-C.O.	30.6.64
Chave, G. (*Resigned*)	E.-in-C.O.	30.6.64
Patmore, J. H. P. (*Resigned*)	E.-in-C.O.	30.6.64
Inspector		
Billings, S. T.	Mid. Reg.	18.4.64
Lee, A. E.	L.T. Reg.	7.5.64
Kindleysides, T. W.	N.E. Reg.	29.5.64
Griffiths, W. D.	L.T. Reg.	31.5.64
Barron, J. W. M.	Scot.	18.5.64
Stead, E. A. A.	L.T. Reg.	4.6.64
Bennington, H. F.	W.B.C.	18.6.64
Senior Experimental Officer		
Peirce, J. G.	E.-in-C.O.	15.5.64
Experimental Officer		
Steed, C. A.	E.-in-C.O.	8.3.64
Assistant Experimental Officer		
Jacobs, F. G. (*Resigned*)	E.-in-C.O.	30.4.64
Tims, D. J.	E.-in-C.O.	1.5.64
Assistant (Scientific)		
Rowe, M. J. (Miss) (*Resigned*)	E.-in-C.O.	20.3.64
Philpotts, A. (*Resigned*)	E.-in-C.O.	24.4.64
Executive Officer		
Watson, E. M. (Mrs.)	E.-in-C.O.	31.5.64

Transfers

Name	Region, etc.	Date
Assistant Staff Engineer		
Knight, N. V.	Nigeria to E.-in-C.O.	22.6.64
Regional Engineer		
Horne, F. A.	Approved Employment to L.T. Reg.	5.6.64

Transfers—*continued*

Name	Region, etc.	Date
Area Engineer		
Borge, M.	Approved Employment to L.T. Reg.	20.5.64
Senior Executive Engineer		
Hix, K. W.	H.C. Reg. to E.-in-C.O. ..	9.3.64
Hughes, C. J.	Approved Employment to E.-in-C.O.	16.3.64
Mitchell, G.	E.-in-C.O. to Ministry of Transport	31.3.64
Mead, A. C.	E.-in-C.O. to L.T. Reg. ..	15.6.64
Executive Engineer		
Chandler, K.	E.-in-C.O. to Mid. Reg. ..	16.3.64
Barnard, F.	E.-in-C.O. to H.C. Reg. ..	9.3.64
Wheele, D. W. E. ..	E.-in-C.O. to Ministry of Transport	2.3.64
Wherry, A. B... ..	Hong Kong to E.-in-C.O.	16.3.64
Parsons, A. P. ..	E.-in-C.O. to Mid. Reg. ..	25.5.64
Claydon, D. J. ..	E.-in-C.O. to Ministry of Health	15.6.64
Assistant Engineer		
Hastings, A. D. ..	E.-in-C.O. to Gilbert and Ellice Islands	3.4.64
Bates, E. J.	Mauritius to E.-in-C.O. ..	6.4.64
Heasman, C. S. ..	E.-in-C.O. to East Africa..	3.5.64
Jordan, H. J.	E.-in-C.O. to Mid. Reg. ..	19.5.64

Name	Region, etc.	Date
Assistant Engineer—continued		
Field, R. P.	E.-in-C.O. to Ministry of Defence	1.6.64
Lord, T. K.	E.T.E. to E.-in-C.O. ..	1.6.64
Inspector		
Purden, S. T. ..	W.B.C. to East Africa ..	31.5.64
Taylor, H. J. V. ..	N.W. Reg. to East Africa ..	28.5.64
Experimental Officer		
Hollingdale-Smith, P. A.	E.-in-C.O. to Ministry of Defence	30.6.64
Motor Transport Officer II		
Humphrey, M. C. ..	E.-in-C.O. to H.C. Reg. ..	8.6.64
Technical Assistant		
Pearce, V. I. C. ..	E.-in-C.O. to London Reg.	22.6.64
Draughtsman		
Eamer, E. C.	E.-in-C.O. to W.B.C. ..	31.3.64
Executive Officer		
Cheek, P.	E.-in-C.O. to C.M.B.D. ..	25.5.64
Mitchell, J. A. (Miss)	P.O.S.D. to E.-in-C.O. ..	1.6.64
Ransom, R. J. ..	E.-in-C.O. to P.O.S.D. ..	8.6.64

Deaths

Name	Region, etc.	Date
Executive Engineer		
Easton, W.	N.E. Reg.	4.6.64
Assistant Engineer		
Robertson, T. ..	Scot.	23.1.64
Stalker, R. J. C. ..	N.E. Reg.	8.4.64
Powell, W. T. ..	N.W. Reg.	9.4.64
Pilbrow, J. H. ..	E.-in-C.O.	27.4.64
Shaw, H.	L.T. Reg.	25.5.64

Name	Region, etc.	Date
Inspector		
Byrne, P. J.	N.I.	15.11.63
Lloyd, C.	W.B.C.	27.4.64
Anderson, R.	Scot.	22.4.64
Cuthbert, T.	Scot.	27.5.64
Fassnidge, H. J. W. R.	L.T. Reg.	14.6.64
Bain, R.	Scot.	14.6.64

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The Journal is published quarterly, in April, July, October and January, at 3s. per copy; the post-paid price is 4s. per copy (16s. per year) via inland mail, and 4s. 3d. (17s., or 2 dollars 75 cents Canada and U.S.A., per year) via overseas mail. Back numbers will be supplied, if available, price 3s. (4s. inland mail, 4s. 3d. overseas mail) per copy. With the exception of April and July 1961 Journals, copies of the January 1963 and all earlier Journals are no longer available. Orders should be sent to *The Post Office Electrical Engineers' Journal*, G.P.O., 2–12 Gresham Street, London, E.C.2.

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Model Answer Books

Books of model answers to certain of the City and Guilds of London Institute examinations in telecommunications are published by the Board of Editors. Details of the books available are given at the end of the Supplement to the Journal.

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a Fully Transistorised Walkie-Talkie!
the PYE Bantam
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Once again in the tradition of the outstanding Cambridge and Vanguard Radio-telephones, Pye have produced the Bantam, a brilliant fully transistorised Walkie-Talkie.

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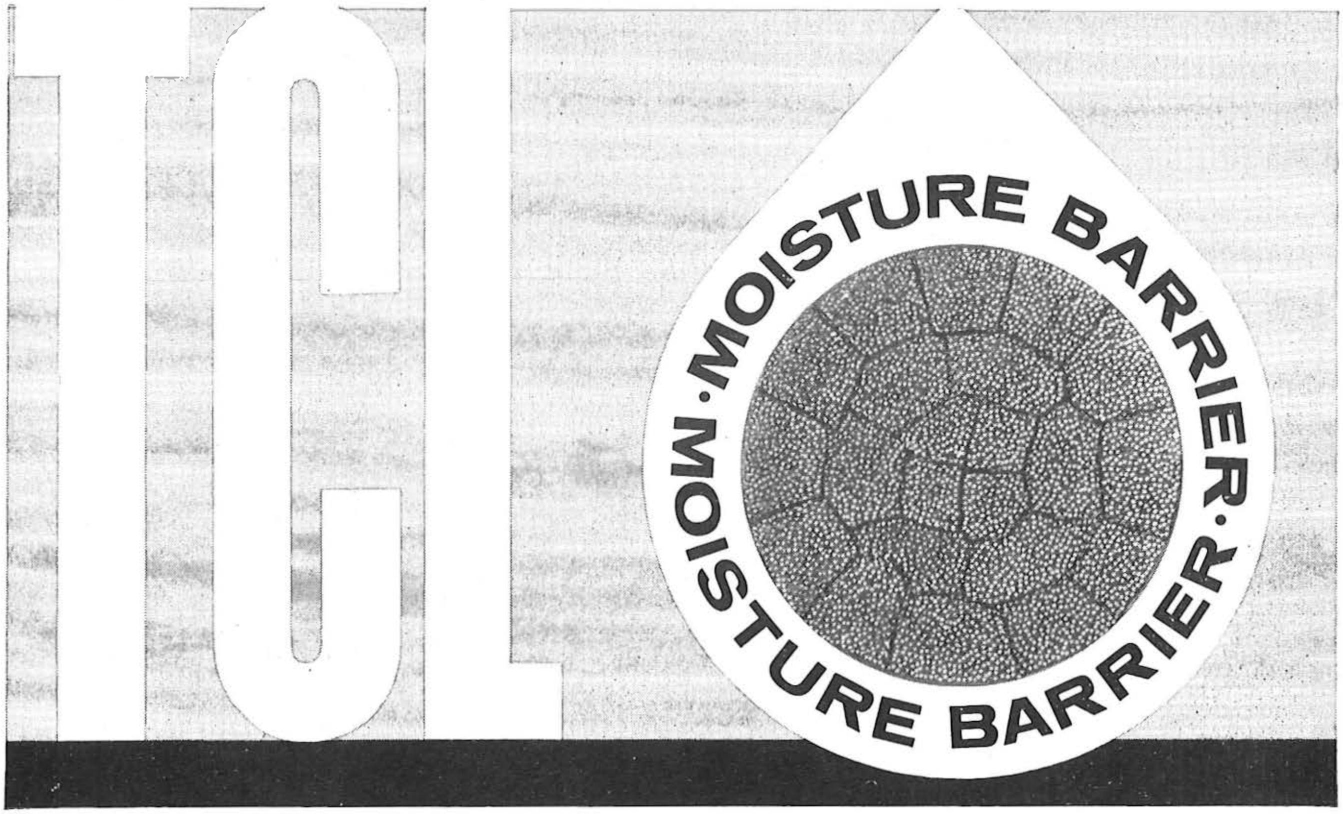
new paper-insulated plastic sheathed moisture barrier cable by



Lighter–for easier handling, longer lengths, fewer joints
Working life equal to lead sheathed and protected cable

Paper insulated plastic sheathed cable can now be employed under conditions hitherto confined to lead sheathed cables. Developed in conjunction with the British Post Office, this new T.C.L. cable incorporates paper insulated conductors sheathed with polythene having aluminium foil bonded to the inside of the sheath to form a moisture barrier.

This barrier effectively prevents the diffusion of moisture vapour through the polythene sheath which would result in a lowering of the insulation resistance.

This produces a cable having electrical characteristics equal to a lead sheathed cable and being light in weight has many economic advantages, plus freedom from sheath corrosion. Besides forming an electro-static screen, the aluminium foil can also be used to detect insulation failure due to any mechanical damage.

T.C.L. moisture barrier cable at Windsor Castle.

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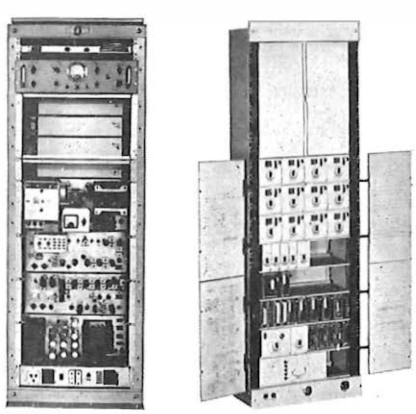

The versatile AT & E Type 900, which is in use in many parts of the world, is ideal for:

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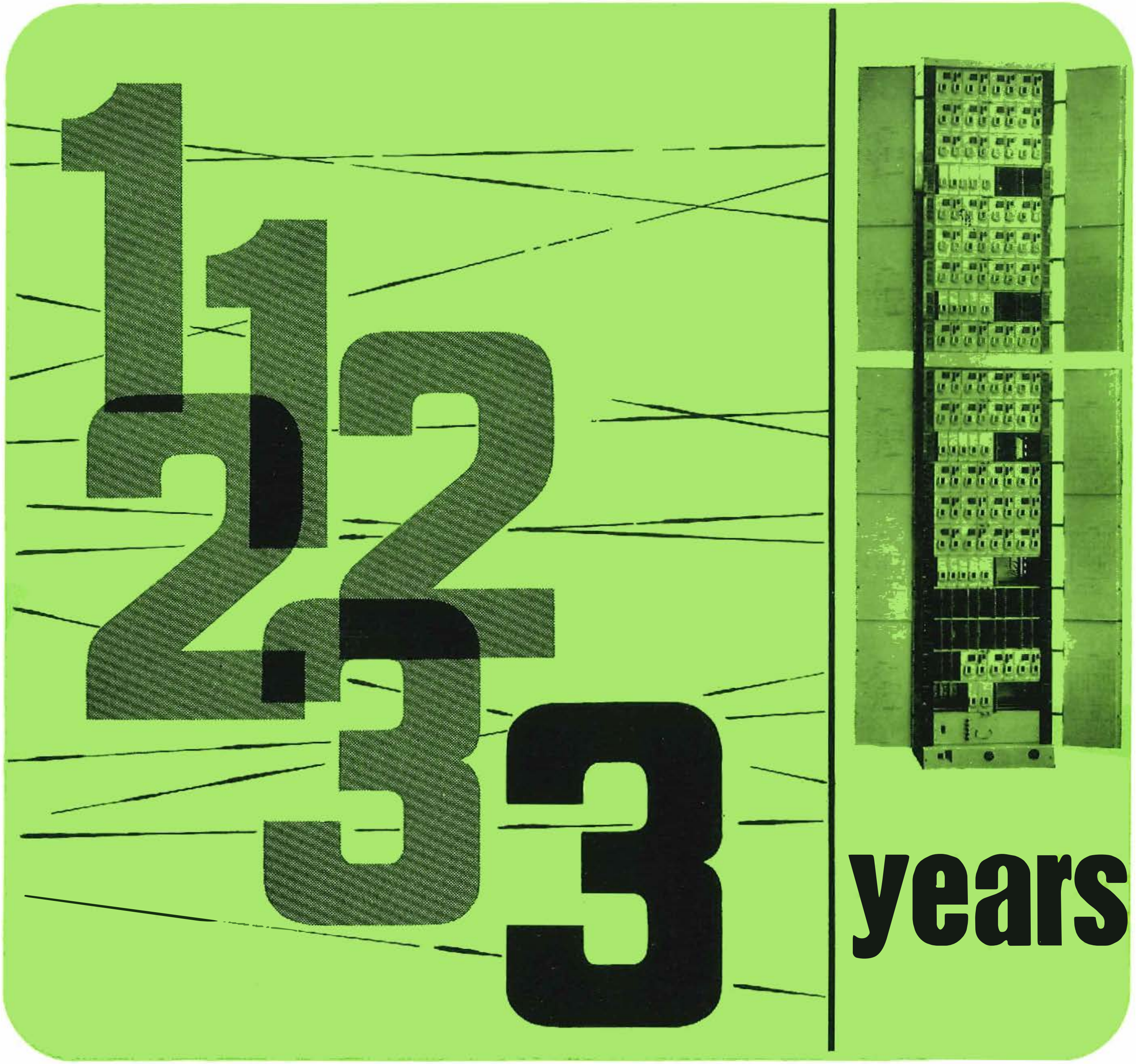
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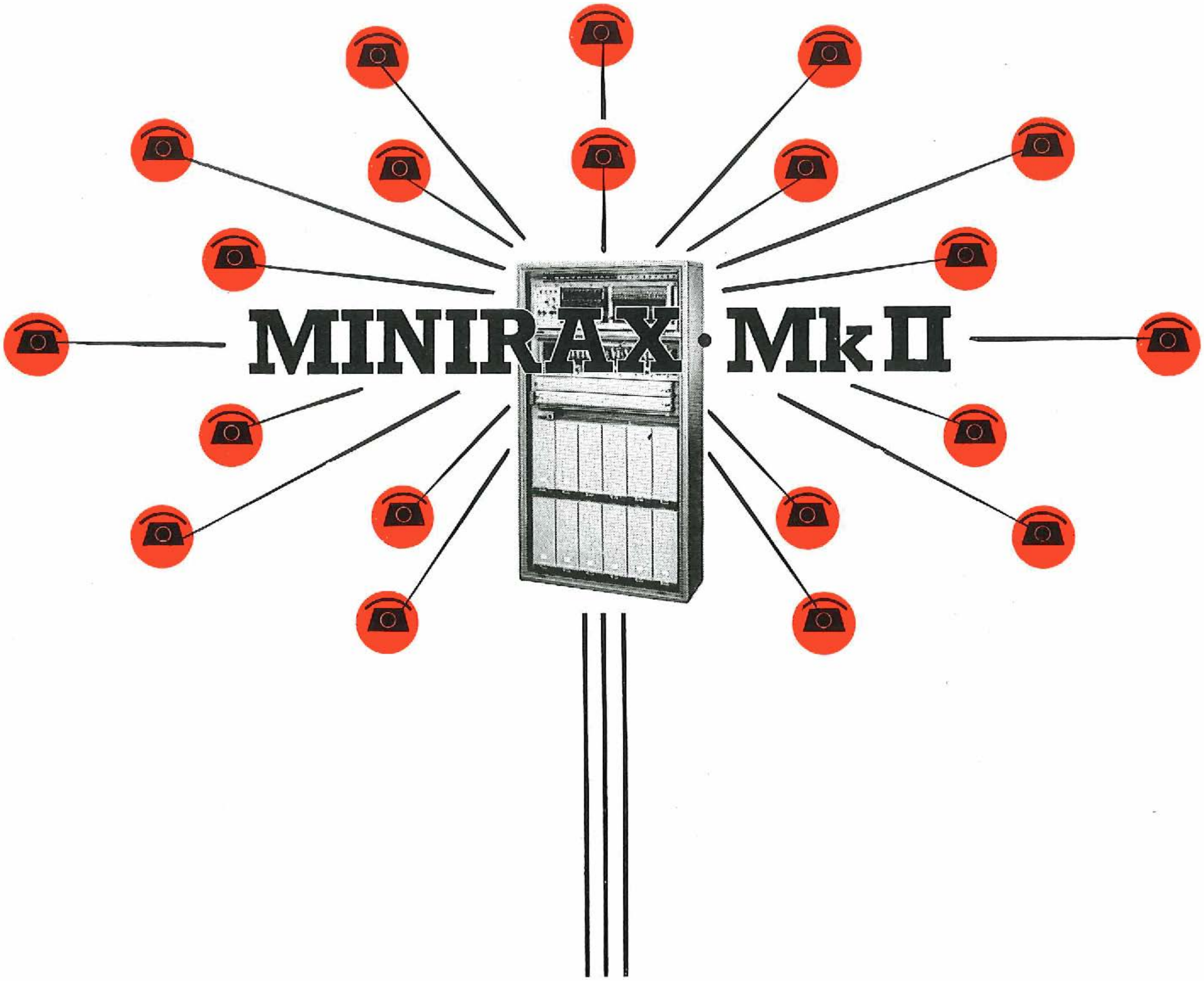
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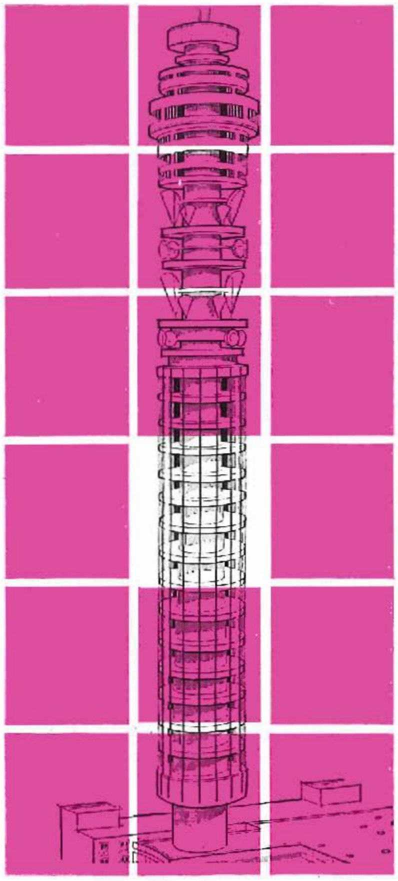

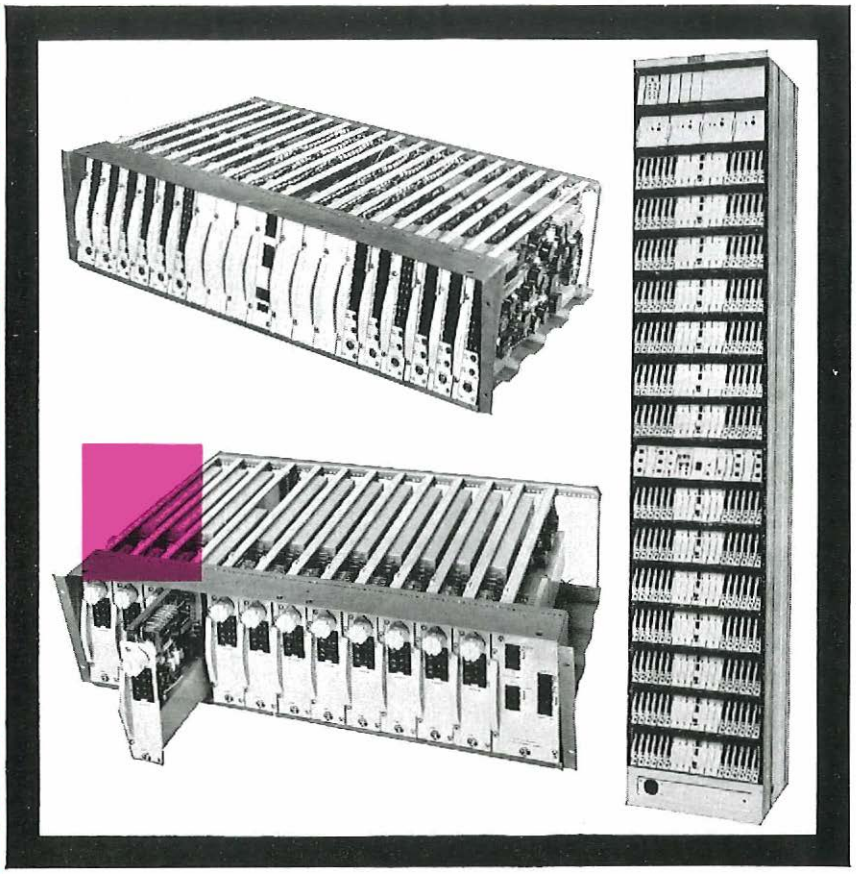

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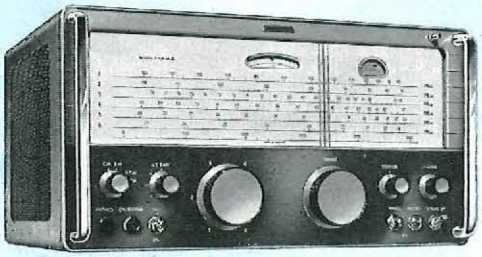

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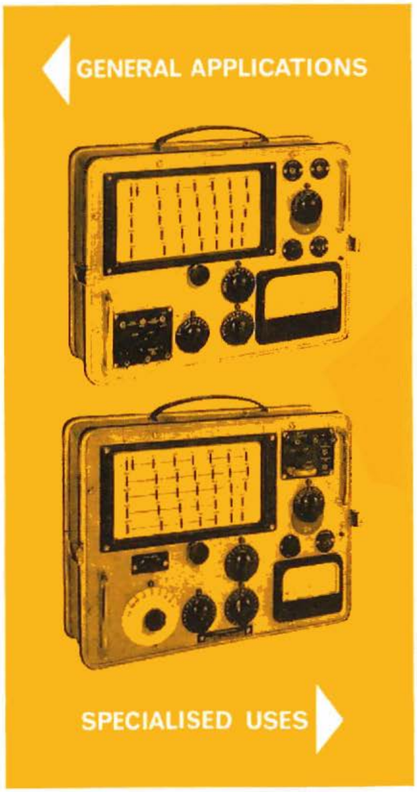

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The 74222 Oscillator and 74223 Selective Level Measuring Set offer a comprehensive range of facilities on submarine cable systems, and at terminals and repeaters on small-diameter coaxial cable systems. They may also be used for laboratory and other measurements at frequencies up to 1·5 Mc/s. The oscillator gives crystal accuracy at each 50 kc/s point, together with low harmonic content, and automatic tuning of the S.L.M.S. is available when required. Both sets cover the frequency range 10 kc/s-1·5 Mc/s in five bands on 75 Ω circuits, and can be used on 140 Ω and 600 Ω circuits up to 300 kc/s. Output levels of 0 to −80 dbm are available from the oscillator. The S.L.M.S. makes through and terminated level measurements from +25 to −95 dbm, and as a harmonic analyser it will measure discriminations up to 60 db. Operation is from internal dry batteries or an external d.c. supply. Write, 'phone or Telex for leaflets: Standard Telephones and Cables Limited, Testing Apparatus Division, Corporation Road, Newport, Mon. Telephone Newport 72281 (STD: ONE 3 72281), Telex 49367. London Office: Telephone ALBert Dock 1401 (Ext. 758).

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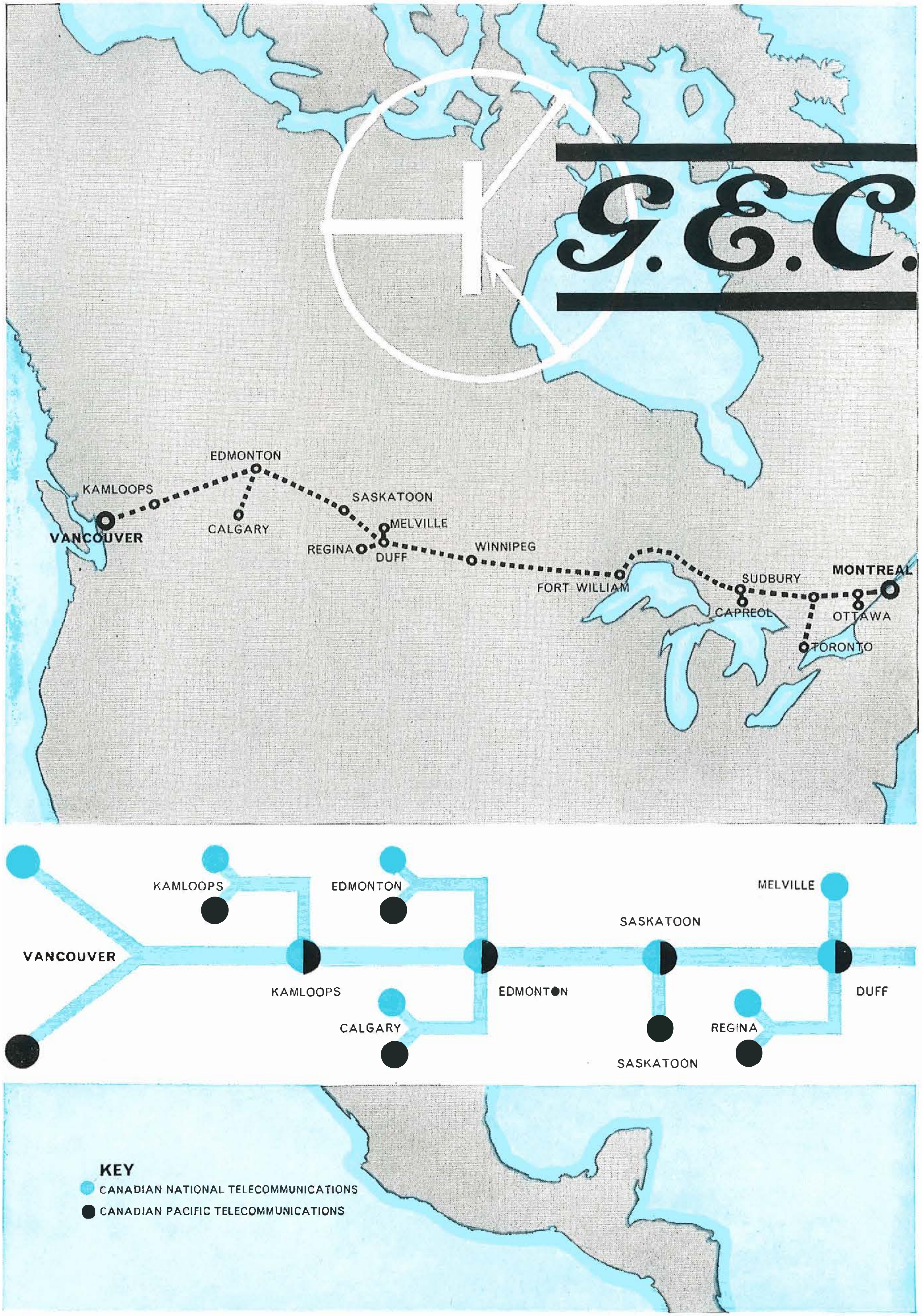
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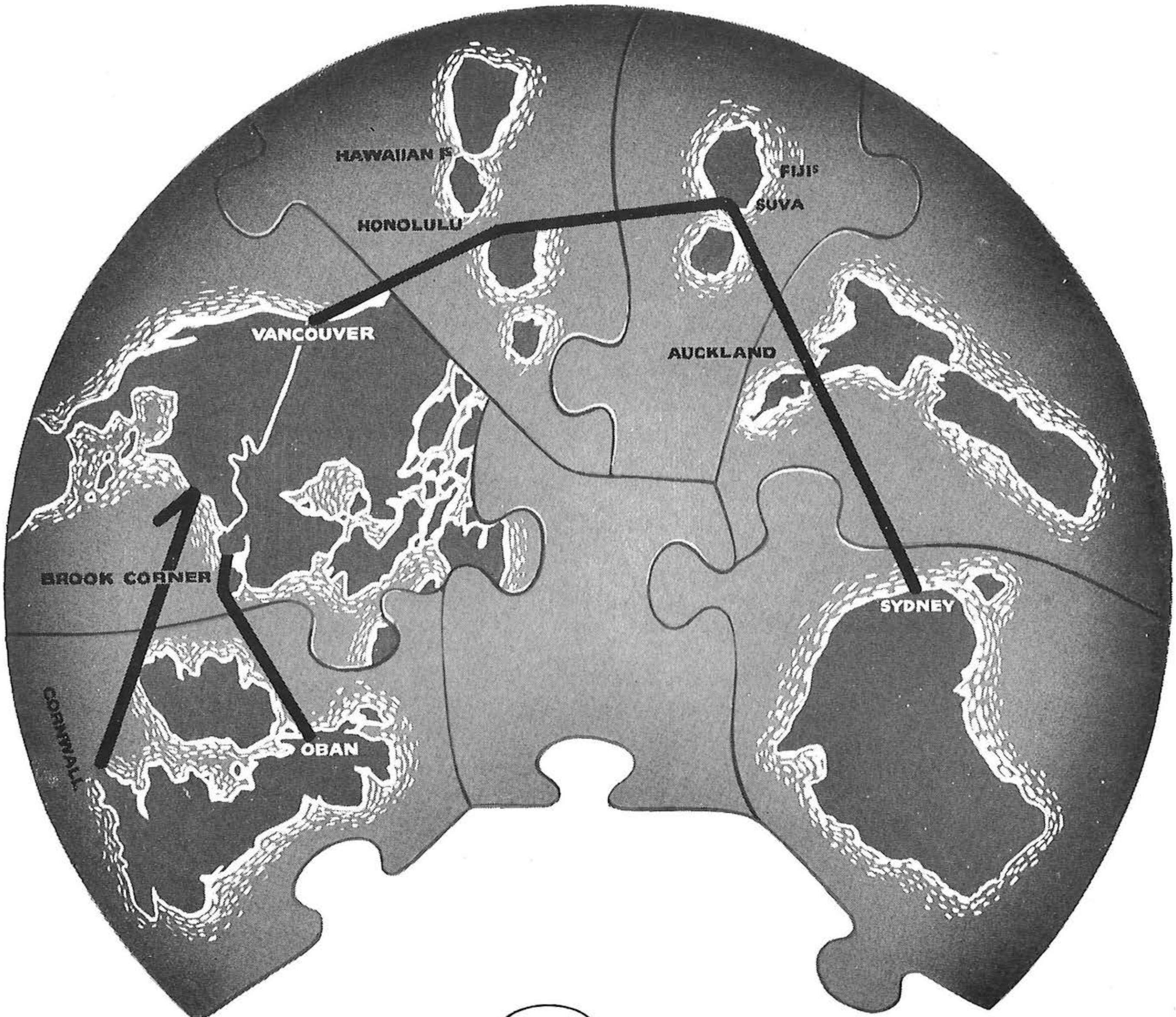
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O.B. MONITORING TELEVISION RECEIVER TYPE WJ.11

This portable weatherproof receiver provides standard level video and audio outputs suitable for feeding video monitors and associated audio equipment. No picture tube is incorporated, but a built-in loudspeaker enables the television sound channel to be monitored. The receiver is designed to accept signals in Bands I and III on the 405 line system and in Bands IV and V on the 625 line system.
Features include black level AGC and the provision of automatic frequency control on the UHF bands.
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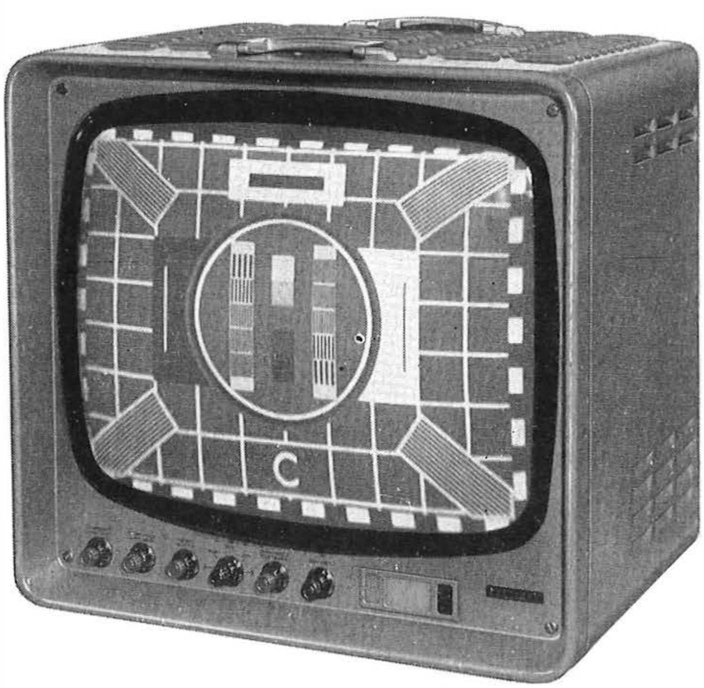

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These Thorn monitors are intended for general purpose studio applications. They incorporate a 110° picture tube with bonded face plate thus ensuring minimal physical size and avoiding the need for a separate implosion guard.
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The monitors feature high picture brightness with stabilised E.H.T. and 8 Mc/s video bandwidth. Picture centering controls are on the front panel. Single standard and non-automatic 3-standard models are also available.

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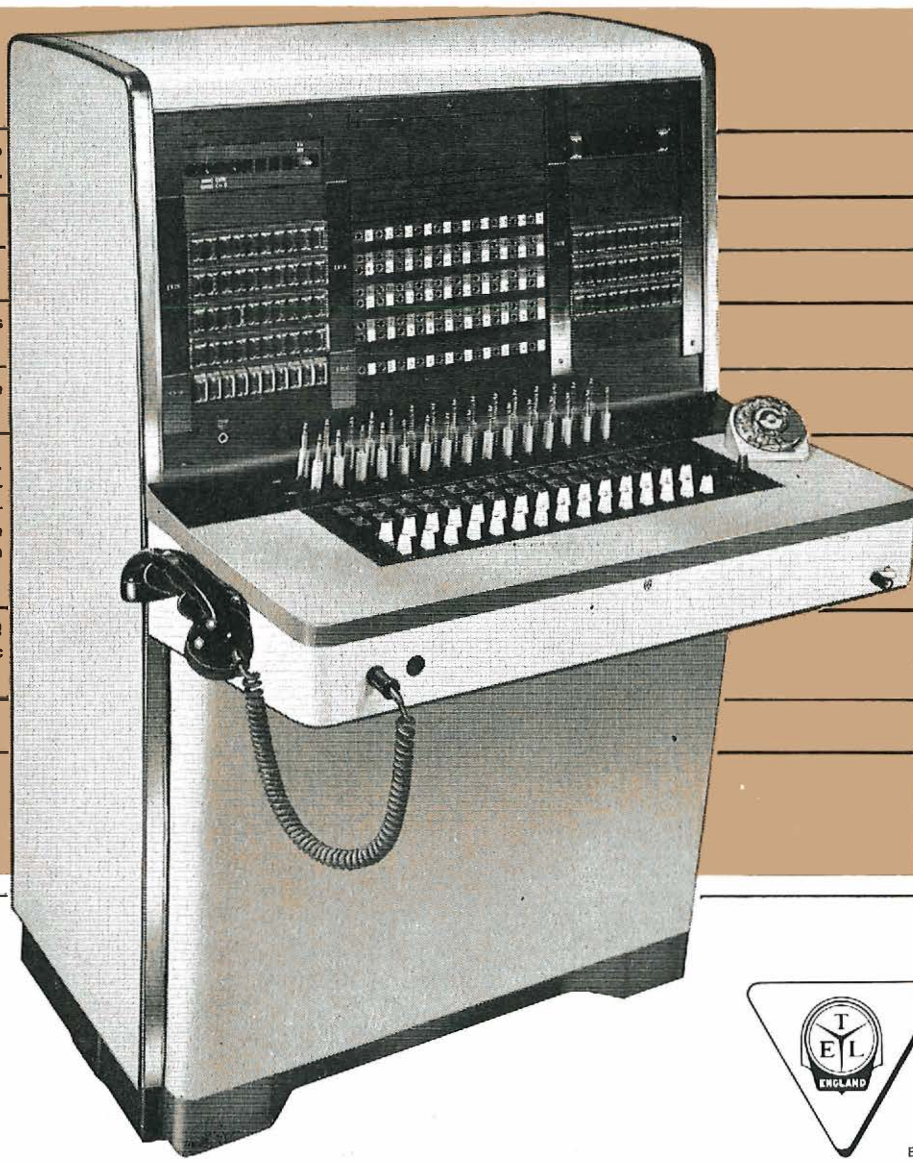

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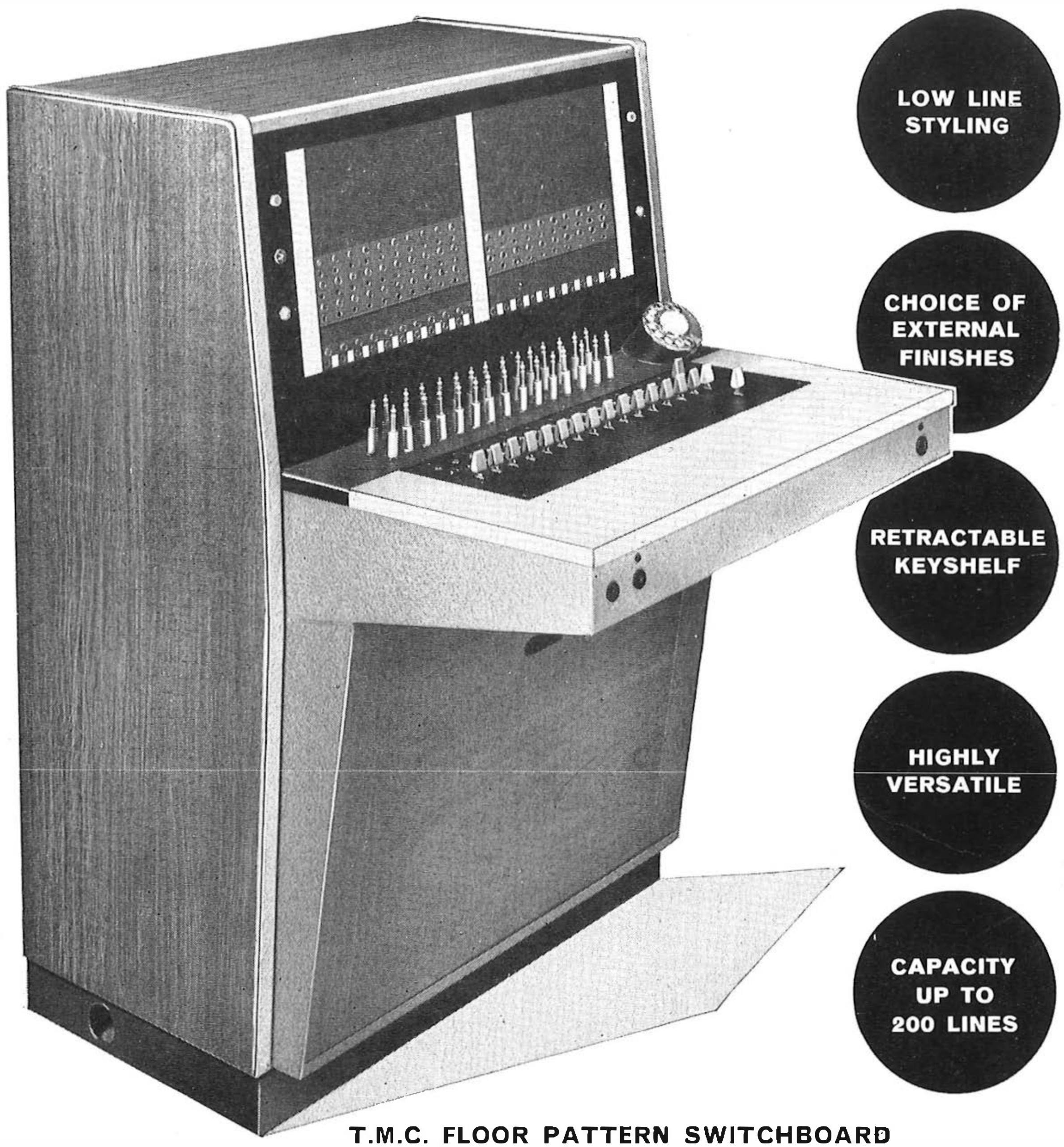

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Leading industrial designers, top circuit engineers, and a production team with years of accumulated switchboard experience have worked together to evolve this superb TMC switchboard. The result is a product which in appearance and performance will fulfil the needs of many years to come. It will blend with the decor of the most modern office or reception hall. It is highly adaptable and can be variously equipped, as a multiple or non-multiple. This switchboard will serve subscribers, operators and engineers throughout a long working life—and serve them well.

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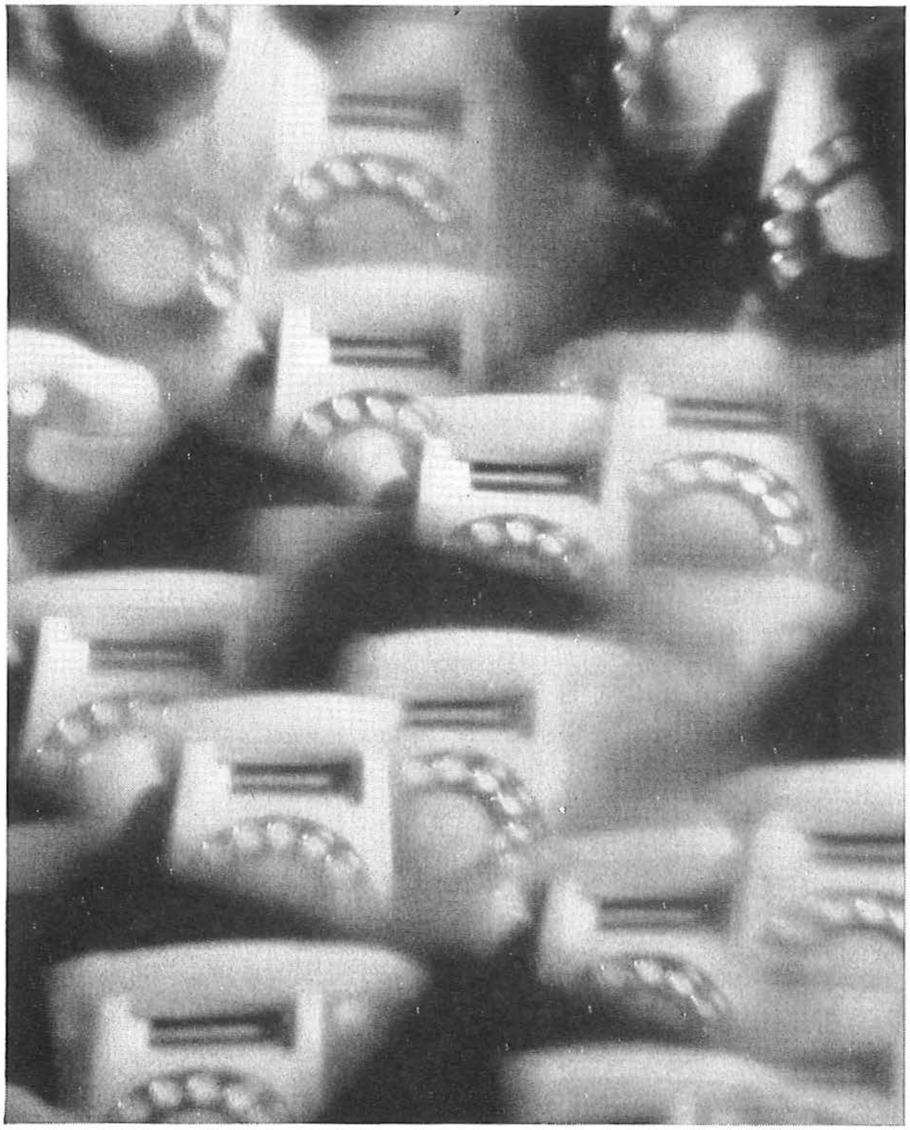
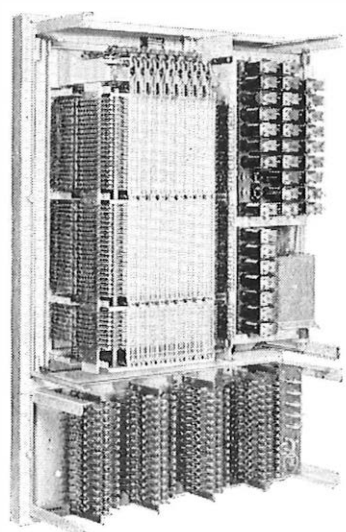
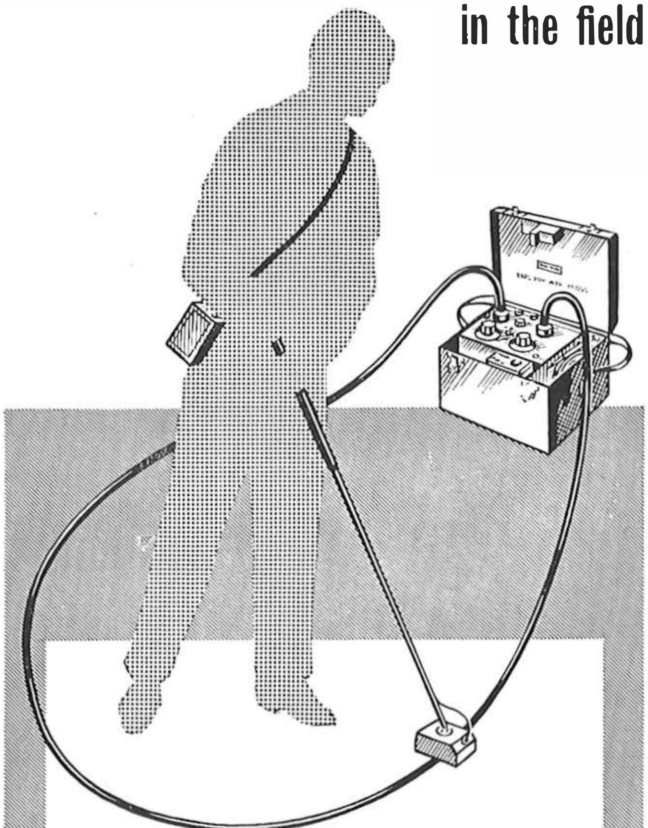




WHITELEY

cable test equipment in the field



With Whiteley field equipment, both breaks and shorts in sheathed multiple conductor cables can be quickly located to within a fraction of an inch.

A capacitative probe run along the cable rapidly and accurately reveals the position of a broken conductor. To locate, with equal speed and accuracy, shorts between conductors, an inductive probe is used. For initial detection of a faulty conductor, a lamp type continuity tester is provided.

The equipment incorporates a battery-operated transistor oscillator, and a transistor amplifier. The oscillator frequency is 1000 c.p.s. $\pm 2\frac{1}{2}\%$ and can be continuous or interrupted according to the setting of the potentiometer.

Whiteley Field Cable Test Equipment is among the most efficient of its type, and because it is built to stand arduous working conditions, is completely reliable. For full technical details, please write to

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WB169

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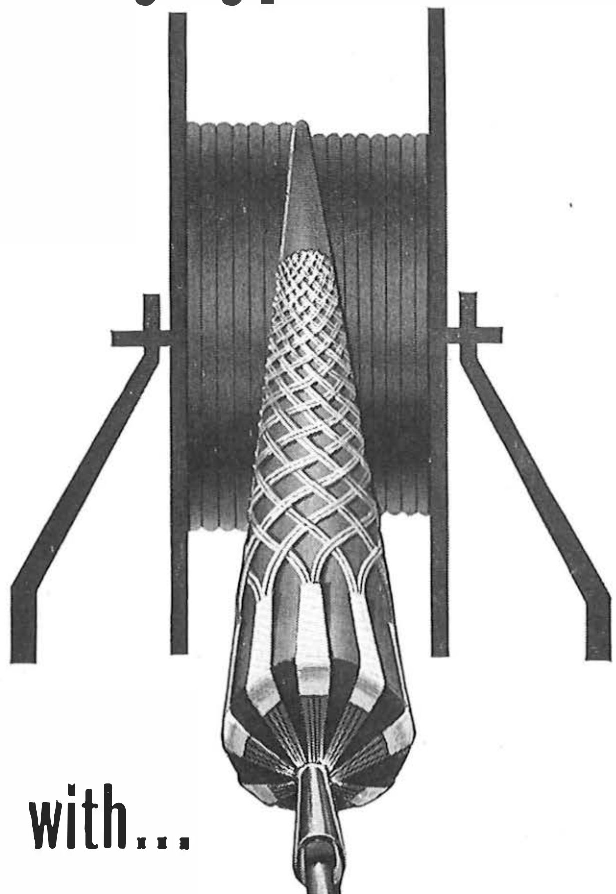

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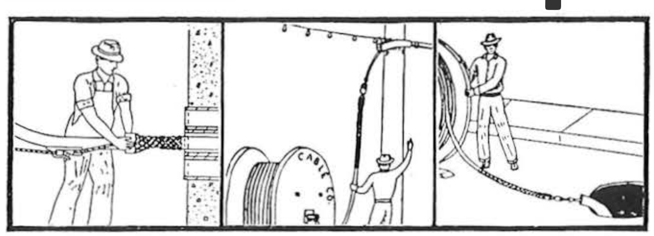

Kellems grips for pulling support or strain relief are quickly installed, adjusted or removed. They are neat in appearance, safe to handle and fully salvable. In stainless steel or bronze, they are of simple construction and light weight. Available in sizes and shapes for most cable applications.

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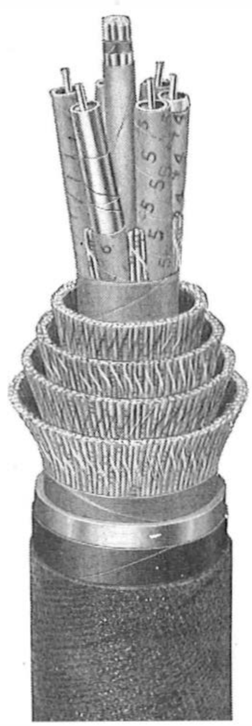

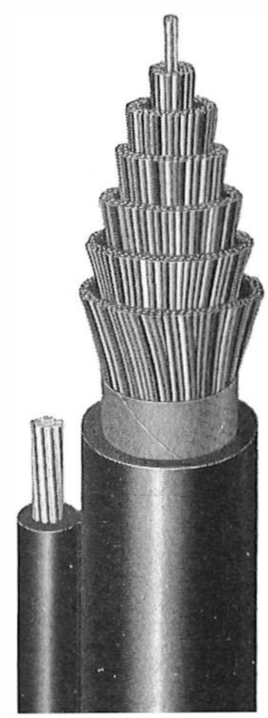

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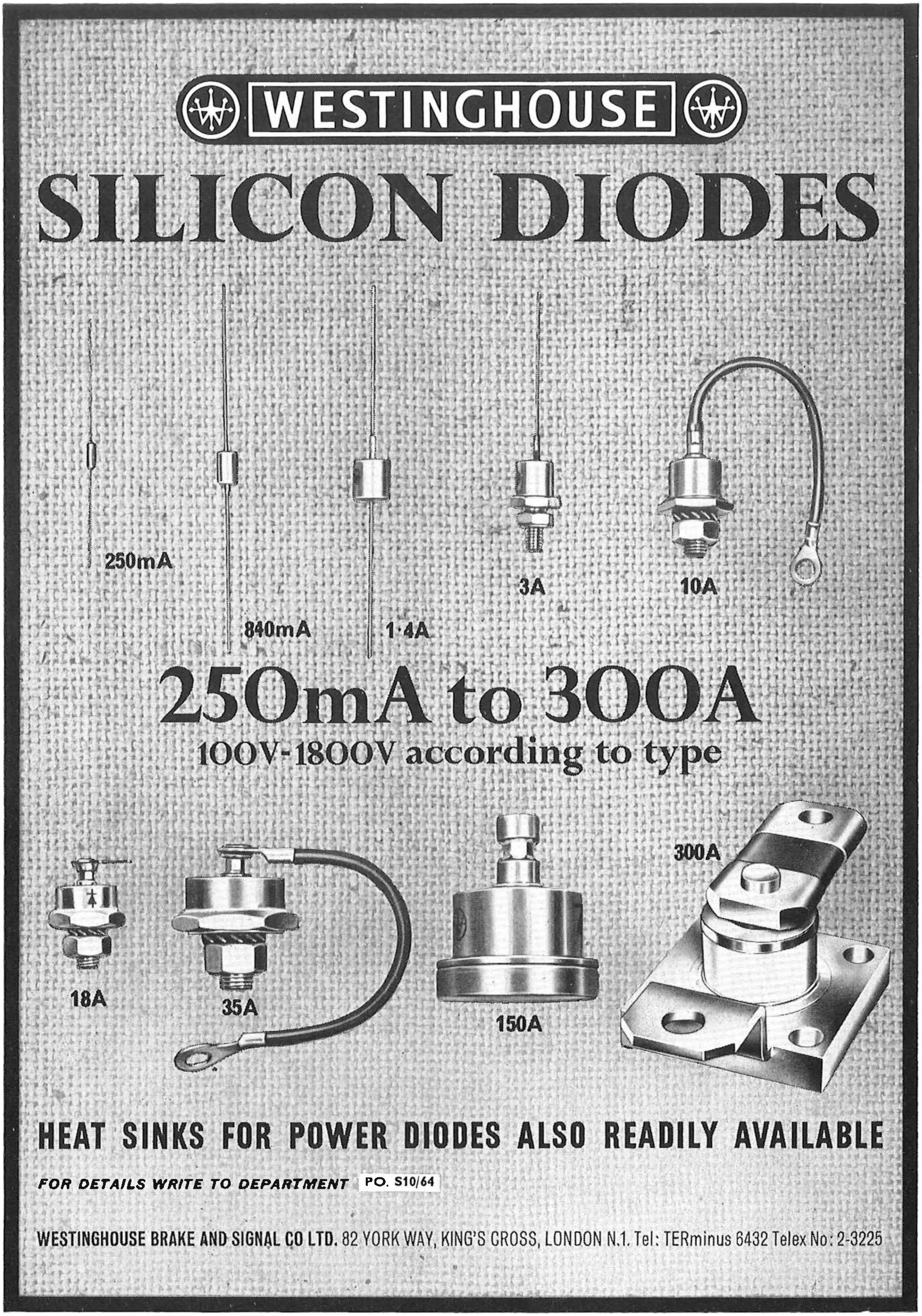
Large cables of unit construction are specially suited to the systematic arrangement of a dense telephone subscriber network. Units of 25, 50 or 100 pairs are first assembled, then the required number of units are combined and sheathed to form the complete cable. Paper insulated, lead or polythene sheathed cables or all-polythene types are available.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breakthrough

MST drive systems for h.f transmitters

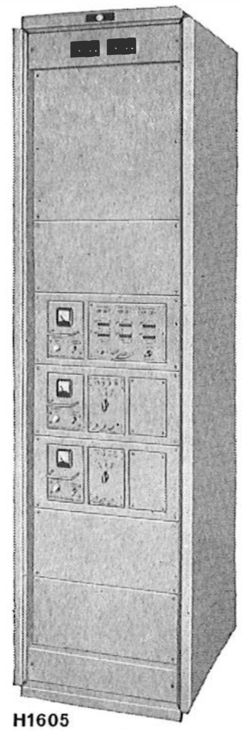
MST drive systems meet all CCIR Recommendations

H1601

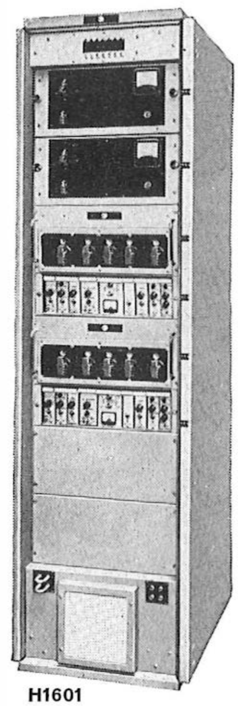
Comprehensive synthesizer drive assembly for two independent transmitter channels
Inputs: audio frequencies (6 kc/s bandwidth) or d.c
Outputs: modulated signals at radiated frequencies, 2 W p.e.p
Types of modulation: i.s.b with floating carrier, pilot carrier or fully suppressed carrier; d.s.b; c.w 400 bauds; f.s.k 200 bauds or 3500 bauds; frequency shift diplex
Frequency range: 2—27.9999 Mc/s
Frequency selection by decade dials on frequency synthesizers
Stability: determined by 1 Mc/s master frequency

H1605

1 Mc/s master frequency source
Frequency stability: $\pm$ 1 part in 10^8



H1605



H1601

one-man control

With the compact MST drive system, self-tuning transmitters and MST control and monitoring equipment, one man can operate an entire transmitting station from a central point.

reliability

All units (except the distributed amplifier) are fully transistorized and use printed wiring. Each unit has a separate power supply. The 1 Mc/s master signal distribution is duplicated, and the master frequency source uses three oscillators to ensure immediate automatic changeover in the event of output failure or excessive frequency drift.

versatility

Any drive channel can generate any type of modulation. F.S.K and f.s diplex signals are generated by shifting the frequency of 2 kc/s or 4 kc/s tones—thus one transmitter can radiate simultaneously two or more telegraph channels and an s.s.b channel.

Plug-in modules give switch selection of services normally required. Logic circuits prevent selection of two conflicting services. Extra plug-in modules can be supplied for any other types of modulation. A wideband amplifier simplifies frequency selection to a single operation—adjustment of the synthesizer decade dials.

Marconi telecommunications systems

The Marconi Company Limited, Communications Division, Chelmsford, Essex, England

LTD/H52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1
GHI
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JKL
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MN
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PRS
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TUV
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WXY
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New standards of accuracy, using an individually calibrated scale plate: d.c. ranges 2.25% of full scale deflection, a.c. ranges 2.75% of full scale deflection.

Available accessories include a 2500V d.c. multiplier and 5, 10 and 25A shunts for d.c. current measurement.

The Mk.4 MULTIMINOR is an entirely new version of this famous Avo instrument and supersedes all previous models. It is styled on modern lines, with new high standards of accuracy, improved internal assemblies, and incorporating pan-climatic properties.

The instrument is supplied in an attractive black carrying case, which also houses a pair of leads with interchangeable prods and clips, and an instruction booklet. It is packed in an attractive display carton. Robust real leather cases are available, if required, in two sizes, one to take the instrument with leads, clips and prods, and the other to house these and also a high voltage multiplier and a d.c. shunt.

Mk 4 MULTIMINOR

Dimensions (including case):— 7⅜ x 4 x 1⅞ ins. (197 x 102 x 41 mm.) approx.
Weight (including case):— 1½ lbs. (0.675 kg.) approx.

D.C. Current: 100μA f.s.d.—1A f.s.d. in 5 ranges.
A.C. Voltage: 10V f.s.d. —1,000 f.s.d. in 5 ranges.
D.C. Voltage: 2.5V f.s.d. —1,000 f.s.d. in 6 ranges.
D.C. Millivolt range: 0 —100mV f.s.d.

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MM 17

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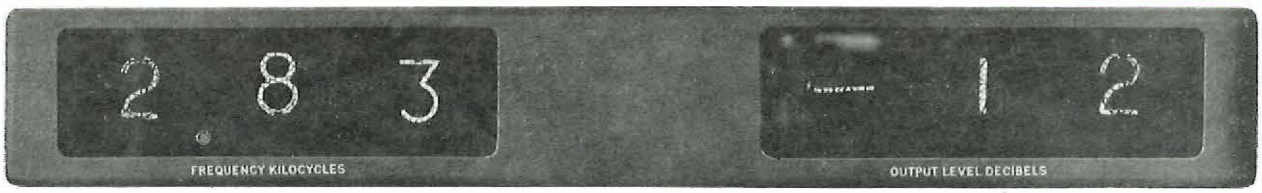

You may take it as read!

And read accurately. Operation of the 74355-A Digital Oscillator is simple, both frequency and level being displayed numerically, from 20 c/s to 299 kc/s and from +20 dbm to −49 dbm. The oscillator can be used for testing audio, broadcast, and multi-channel telephone systems, and in the laboratory.

The frequency range is covered in four bands, displayed in steps of 1 c/s on the lowest band, increasing to 10 c/s, 100 c/s and 1 kc/s on the others. The frequency is shown in kc/s, a decimal point automatically appearing in the correct position.

Accuracy of output level is also automatic—the level display will not appear unless the output is correct to within ±0·2 db. The level, which is adjustable in 1 db steps, is shown by two digits and a plus or minus sign.

The oscillator is transistorized, portable, and operates from 210-250 volts a.c. mains.

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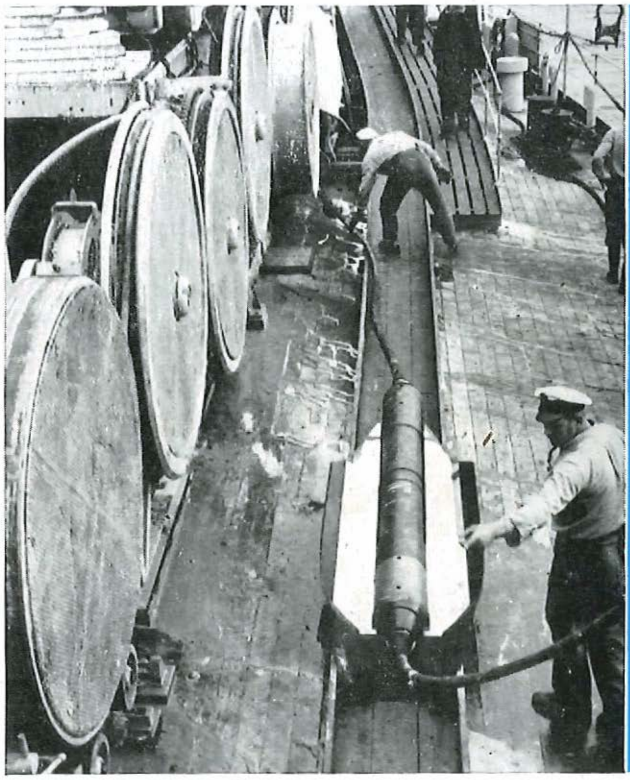

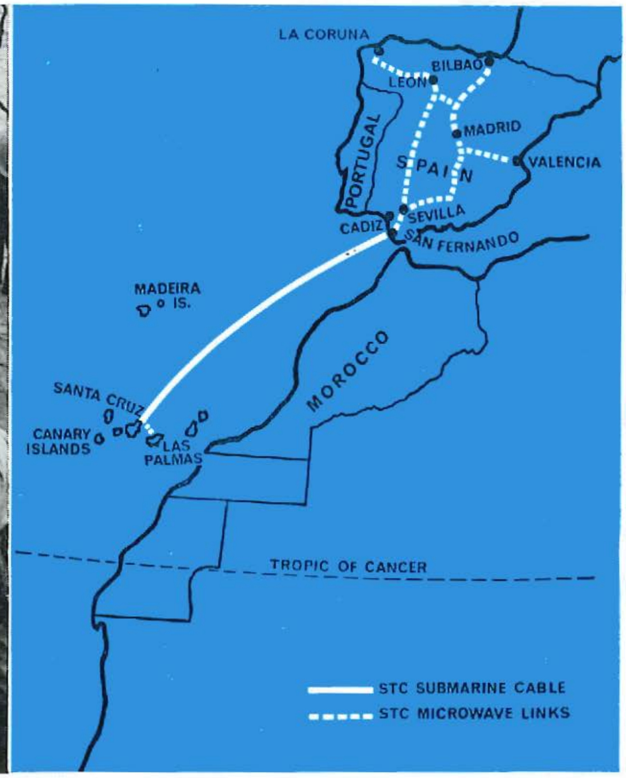

Canaries on the line

STC are to make and lay Spain's first-ever submarine telephone cable link between the Peninsula and Canary Islands. The system will be designed for 160 telephone circuits in both directions over a single cable and thus will be the highest capacity long-distance cable yet installed. This £2,500,000 order represents a key feature of Spain's major expansion in telecommunications. Laying will commence in the late spring of 1965. Service will open in the summer. The link, measuring 750 nautical miles—710 miles of deep-sea lightweight cable and 20 miles of shallow-water armoured cable at each end—will connect San Fernando, 10 miles south of Cadiz with Santa Cruz de Tenerife.
45 STC deep-sea repeaters, 3 adjustable submarine equalizers and terminal equipment will be supplied with the cable. STC with its associated company Standard Electrica S.A., will also provide a microwave link between Tenerife and Las Palmas which will form part of the service. High-quality speech circuits will be provided, day and night, with Europe (direct dialling to Madrid) and North America.

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