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Post Office Wideband Distribution Network at Washington New Town

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U.D.C. 621.395.97:621.395.743

This article briefly describes the long-term objectives underlying the provision by the Post Office of a new local-line network for the distribution of television and other wideband services in the very-high-frequency band. Some of the main features of the transmission system, including program assembly and performance objectives, are also outlined.

INTRODUCTION

For some years there has been a growing awareness of the benefits to be gained by rationalizing the local distribution of telecommunication services by means of a network offering fully-integrated facilities.[1,2] In July 1966 the British Post Office Board decided that detailed technical and economic studies should be undertaken and be followed as soon as possible by a practical trial in the form of a pilot scheme in a new town.

The long-term objective might need to be approached in several stages, each taking advantage of new technological processes. This will probably lead to the development of a general-purpose local-line network operating on a digital basis, which could provide customers with any telecommunication services desired, including the broadcast sound and television services, telephone, viewphone and miscellaneous data and signalling services. It is conceivable that such comprehensive facilities could be delivered to each user by means of a single communication "pipe" providing connexion to a general-purpose communication "main."

As a first step in the progress towards the long-term objective, a short-term scheme has been evolved in which two cable networks will be provided simultaneously. The first network, which will be of conventional telephone-pair type, will exploit the frequency range 0–150 kHz for ordinary exchange-line connexions and other facilities requiring relatively low-speed information rates. The second network will be used for the transmission of television, sound-radio services, or other wideband facilities, and will consist of coaxial cable equipped for frequency-division multiplex transmission in the frequency range 40–225 MHz. Connexions from both networks will be made to every dwelling in the area served.

The two cable networks will be electrically separate, and the main economic benefits of this first stage of rationalization will accrue from the sharing of common plant such as ducts, trenches, jointing boxes and cabinets. Additionally, in a new town there will be some benefits from the common planning required in the simultaneous provision of the conventional and coaxial cable networks. The conclusion reached after detailed studies of available equipment and techniques, and of conditions in a number of new towns, was that the scheme would be technically and economically viable and that the Post Office could offer these facilities at competitive prices. Moreover, the Post Office could expect that early experience of providing wideband facilities would prove valuable when considering new and more advanced designs, and, from the planning point of view, would give a useful indication of the type of problem which could arise in situations other than new towns.

After considering many factors, chiefly dates of commencement of new-town development and rates of growth, the site chosen for the pilot scheme was Washington New Town in County Durham. The present population, including that of the old town, is about 20,000 and it is planned to increase this to 80,000 by the year 2000. Most of the growth will occur in the next 10 years.

WIDEBAND NETWORK

The transmission of wideband information can be achieved, using known techniques, by the methods of space-division multiplex or frequency-division multiplex. Space-division systems require the use of multi-pair coaxial or symmetrical-pair cables operating either without modulation at video frequency or at relatively low frequencies in the high-frequency (h.f.) range by amplitude modulation and vestigial sideband transmission. In contrast, frequency-division multiplex systems require a distribution cable consisting of a single coaxial pair on which wideband information is multiplexed in a frequency range extending over a considerable portion of the very-high-frequency (v.h.f.) band.

The potential traffic capacity of the Post Office v.h.f. system is very great, corresponding, with present equipment, to some 185 MHz of bandwidth. In addition to several channels of broadcast television there is capacity for other wideband services such as educational and closed-circuit television, viewphone and data. If a sufficient proportion of this capacity is exploited the cost per channel on v.h.f. systems is usually less than that of other systems. The elements of the system are also likely to be adaptable for use with more advanced systems which may be introduced as rationalization proceeds.

The present task of the Post Office is to supply a communication network to which customers may connect their own television receivers. It is, therefore, necessary that the Post Office v.h.f. line system should operate over a frequency range including the whole of broadcast bands I and III to which the majority of television receivers can be tuned. Some

† Line and Radio Branch, Telecommunications Development Department, Telecommunications Headquarters.

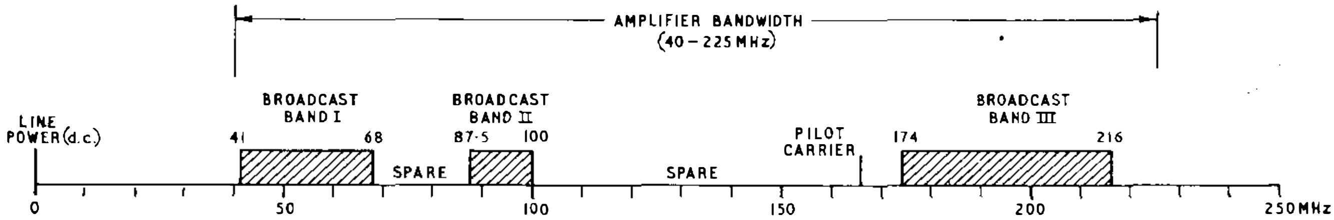
[1] BARRON, D. A. Science and the Post Office. *Royal Society of Arts Journal*, No. 5128, Vol. CXV, Mar. 1967

[2] MERRIMAN, J. H. H. Future Possibilities in Exchange and Terminal Equipment. Document 101 of the Conference on "European Cooperation in Telecommunications," 15 and 16 June 1967, sponsored by the British Council of the European Movement. Reported in the *Post Office Telecommunications Journal*, Vol. 19, p. 35, Autumn 1967.

dual-standard receivers will require a minor inexpensive modification for the reception of 625-line programs in the v.h.f. bands.

Initially, the television and sound programs to be distributed will be B.B.C. 1 and I.T.A. on 405-lines and B.B.C. 2 on 625-lines in broadcast bands I and III, together with the B.B.C. Radio 1, 2, 3 and 4 and the Durham local-radio programs in broadcast band II. The positions of these bands within the frequency range are shown in the illustration. Equipment will be installed in readiness for the distribution of the B.B.C. 1 and I.T.A. programs at 625-line standards as soon as the duplicate services are available in the area.

The v.h.f. system consists of three main sections: the central station, the main highway and the distribution highway. The programs will be received, processed and combined at the central station before being connected to the main highway. The main highway transmits the programs from the exchange to the various distribution highways, which spread outwards to serve individual dwellings from the same cabinet as the telephone distribution network. Cables will be wholly underground and routed in the same ducts or trenches as the telephone cables.



Location of broadcast bands and spare capacity in the Post Office line system

Central-Station Equipment

Until the new telephone-exchange building is completed, the central-station equipment will be housed temporarily in a hut on the same site. Separate arrays for each of the broadcast bands I, II, III and V will be mounted on a mast 50 feet high that will be erected alongside the temporary hut. To avoid co-channel interference the two 405-line television programs will be converted to other standard channel frequencies. B.B.C. 2, received in broadcast band V, will also be converted to a channel in the v.h.f. band. The B.B.C. Radio 2, 3 and 4 programs and the Durham local-radio program will be distributed at their "off-air" frequencies, but the medium-wave Radio 1 program will be converted from amplitude modulation (a.m.) to frequency modulation (f.m.) before distribution in broadcast band II. Before application to the converting and combining equipment, each television channel and the output from the broadcast band II aerial will be separately amplified and level corrected. A pilot generator will provide a signal which will serve as a lining-up signal for all parts of the network, as an aid to maintenance, and as a reference signal for the gain control of amplifiers in the main highway.

Main Highway

The cable, which should be rugged and resistant to water, has a solid polythene dielectric and an outer conductor in the form of seam-welded copper tube of 0·345 in. diameter. Its characteristic impedance is 75 ohms, and the attenuation per mile is 110 dB at 230 MHz. Line repeaters, specially protected for underground mounting and having a gain of 23 dB, will be provided at intervals of about 0·2 mile, although the actual spacing of the repeaters will depend on the location of existing jointing points on the route.

Distribution Highway

To allow for leading in and out of individual dwellings a more flexible cable will be used in the distribution highways. The greater flexibility is obtained by using longitudinal corrugated copper tape for the outer conductor. An aluminium-foil water barrier is included in the polythene sheath. The characteristic impedance is 75 ohms, and at 230 MHz the attenuation is about 120 dB per mile. The line repeaters will generally be mounted above ground in protected accommodation, but, in a few instances, specially-protected repeaters will be mounted in joint boxes. The number of repeaters required will depend on the housing density and other local conditions but, in broad terms, one repeater will be required for every 30 dwellings.

Overall Performance

The performance objectives have been set to ensure an acceptable quality of reception throughout the system. Of particular importance in the planning of the system are the operating levels and noise levels. The signal levels, when measured across a 75-ohm termination at any viewer's outlet terminals, should be between 750 microvolts and 3 millivolts r.m.s. for the vision carriers and not less than 350 microvolts r.m.s. for the f.m. sound carriers. The r.m.s. signal-to-random-noise ratio of the system should be better than 47 dB, and intermodulation products resulting in undistorted vision crosstalk should be at least 52 dB below the level of the vision signals.

MAINTENANCE ASPECTS

It is important on this type of system, where customers' reaction to any failure will be prompt and no doubt emphatic, that the system should be inherently reliable and that any fault can be quickly located and remedied. Reliability will be built into the Washington system by the use of rugged cable and solid-state equipment. Amplifiers will be energized from d.c. supplies fed along the cable from float-charged secondary batteries. Monitoring points will be provided at the input and output terminals of all active devices, and, to allow for speedy replacement, amplifiers will be connected in the network by means of plugs and sockets.

PROVISION OF SERVICE

The first houses in Washington New Town to be cabled by the Post Office are due for occupation early in 1969, but the system operational date will be somewhat earlier to ensure that service is given immediately houses are occupied. There will be a continuing commitment to extend the service as additional houses in the New Town estates are completed, and very close co-operation with the New Town Corporation, the Architect and the building contractors will be necessary.

Group Automatic Gain-Control Equipment

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U.D.C. 621.395.665

Following the introduction of the group reference-pilot in the h.f. network there has been developed an automatic method of maintaining the gain of the path over which the group reference-pilot is transmitted. The group automatic gain-control equipment performs this gain regulation and at the same time gives alarms when the gain excursion exceeds a pre-determined amount.

INTRODUCTION

Long-distance transmission of h.f. signals inevitably involves certain variations in the overall gain of the transmission path. These variations in gain are produced by such phenomena as changes in cable temperature, aging of components in amplifiers, fluctuations in the supply voltage to amplifiers and action taken by working parties during maintenance work. In many instances the long-term variations are automatically compensated by level-regulating equipment incorporated in the h.f. line system, but residual errors will occur which are not constant over the transmitted frequency band. Automatic gain-control (a.g.c.) equipment has been developed to automatically reduce these residual errors and also to correct any short-term variations that may occur. It has been found that the most satisfactory point for final regulation is at the point where the frequency band has been subdivided into 12-circuit groups, and so the equipment described in this article is known as group a.g.c. equipment.

The group a.g.c. apparatus operates under the control of the group reference-pilot signal, which is injected into each 12-circuit group at its point of formation. It should be noted that if the group reference-pilot signal is injected into the 12-circuit group at a known constant level then measurement of its level at the other end of the link will enable a measure of the gain of the link to be obtained. The level stability of the group reference-pilot signal generating equipment is thus a determining factor in the level stability of the whole system, and its security must be ensured. Details of the group reference-pilot signal and its method of injection are given in an earlier issue of this Journal.*

The receive terminals of 12-circuit groups are now being equipped with group a.g.c. equipment on the basis of one group a.g.c. apparatus per 12-circuit group-end of channel-translating equipment. The group a.g.c. apparatus automatically measures the level of the group reference-pilot signal, and, if it has deviated from its setting-up level, restores it to a level very nearly equal to the setting-up level. The equipment also gives the following facilities.

(*a*) Continuous gain-correction, as opposed to correction only during routine testing.

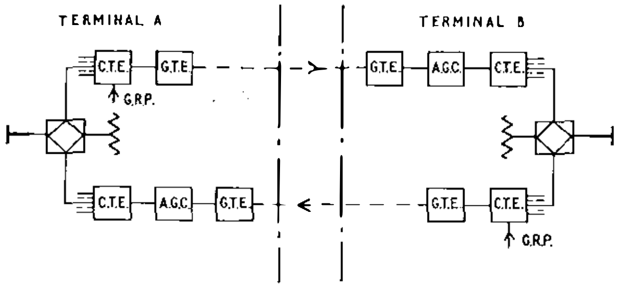
(*b*) Audible and visual indication that the gain of the transmission path (preceding the group a.g.c. apparatus) has deviated by between 5 dB and 7 dB from its original setting-up gain.

(*c*) Facilities for the initiation of automatic circuit-busying following the occurrence of a gain change as detailed in (*b*).

The introduction of group a.g.c. equipment into the h.f. network has resulted in a great improvement in the gain stability of circuits, and it has made a significant impact on the amount of routine maintenance required. Before the introduction of group a.g.c. equipment, routine measurement of the gain of a 12-circuit-group transmission path was required with a periodicity varying between one day and four weeks, depending on the length of the 12-circuit group. Where group a.g.c. equipment has been installed it has been found satisfactory to simply carry out these measurements on an annual basis, irrespective of the length of the 12-circuit group. These annual routines are simply intended to reveal faults which are hidden by the regulating action of the group a.g.c. apparatus and which may ultimately result in a complete transmission failure.

POSITION IN H.F. TRANSMISSION SYSTEM

The group reference-pilot signal is injected into the 12-circuit group at its point of formation, in the transmit section of the channel-translating equipment (terminal A, say), and the group a.g.c. apparatus is situated at the other terminal station of the 12-circuit group (terminal B) as shown in Fig. 1. Another group reference-pilot signal is injected into the 12-circuit-group path at terminal B and another group a.g.c. apparatus is located in terminal A.



C.T.E.—Part of channel-translating equipment
G.T.E.—Part of group-translating equipment
A.G.C.—Group a.g.c. apparatus
G.R.P.—Group reference-pilot

FIG. 1—Position of group a.g.c. apparatus in system

The group a.g.c. apparatus is being retrospectively provided for association with existing 12-circuit groups, and where this is done the inputs and outputs of the group a.g.c. apparatuses are cabled to the group distribution frame ("free" provision*). For new work, where channel-translating equipment and group a.g.c. equipment are installed at the same time, the outputs of the group a.g.c. apparatuses are cabled directly to the appropriate inputs of the channel-translating

† Line and Radio Branch, Telecommunications Development Department, Telecommunications Headquarters.

* NAULLS, R. W. The Group Reference-Pilot Signal. *P.O.E.E.J.*, Vol. 55, p. 237, Jan. 1963.

* See footnote on next page.

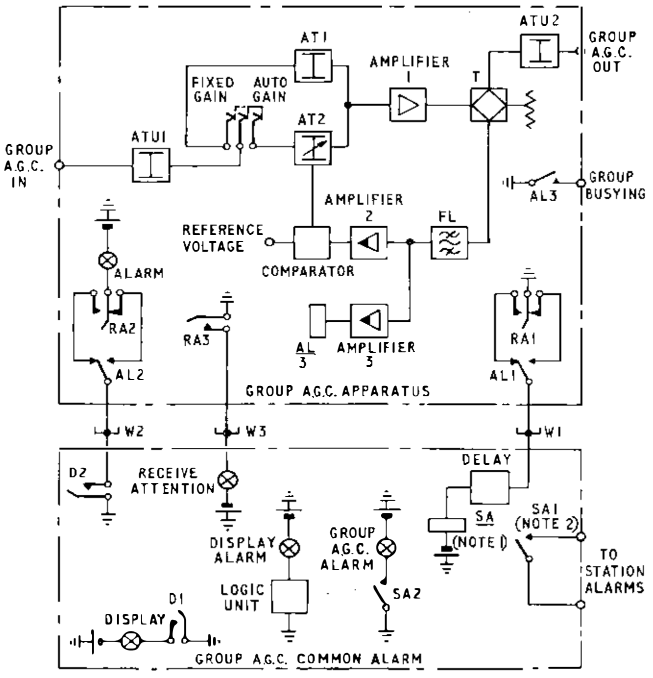
equipment ("fixed" provision*), thus reducing the amount of station cabling required for the interconnexion of equipments.

The present practice is to equip every 12-circuit group with group a.g.c. apparatuses. However, with the application of frequency-division multiplex techniques to short routes and the provision of regulated-line systems for the transmission of the h.f. signals, the provision of group a.g.c. apparatuses on routes under 25 miles in length is under review. This review may prove to be unnecessary, because pulse-code-modulation techniques will probably be adopted for circuits up to 25 miles in length. If pulse-code-modulation techniques are not adopted in the way anticipated and if it is necessary to employ frequency-division multiplex techniques on routes under 25 miles in length then it will be necessary to arrive at a decision concerning the provision of group a.g.c. apparatuses on these routes. In reaching this decision it would be necessary to consider the difficulties that would be encountered if it was necessary to provide a group a.g.c. apparatus on some 12-circuit groups but not on others.

System studies have shown that supergroup a.g.c. equipment† is not at present required in the United Kingdom inland network and that only one group a.g.c. apparatus is required on any one 12-circuit group. It would therefore be convenient to associate the group a.g.c. apparatus with the channel-translating apparatus, and future designs of channel-translating apparatus may well incorporate the group a.g.c. apparatus.

EQUIPMENT PRINCIPLES

The 12-circuit group occupying the frequency band 60–108 kHz enters the group a.g.c. apparatus at GROUP A.G.C. IN (Fig. 2), and the signal is normally routed through the apparatus via control attenuator AT2 to GROUP A.G.C. OUT.



Notes:
1. Relay SA is normally operated
2. Contacts SA1 and SA2 are shown operated

FIG. 2—Block schematic diagram of group a.g.c equipment

The apparatus is a nominally 0 dB gain device, but the gain may be varied by the control attenuator AT2. The attenuation of control attenuator AT2 depends on the output of a comparator that compares a d.c. reference voltage with the d.c. voltage produced by the filtered and detected group reference-pilot signal selected at the output of the apparatus.

It would be ideal if the gain of the apparatus were dependent only upon the level of the incoming group reference-pilot signal. However, the pilot signal is present with other signals in the transmission band, and it is necessary to separate it from the rest of the signals being transmitted over the system. The method employed to select the group reference-pilot signal should be such as to prevent signals (other than the pilot signal) changing the gain of the apparatus by more than 0·1 dB under normal working conditions. Filter FL is provided to achieve this aim, and it is designed to pass a band of 84·080 ± 0·003 kHz and to discriminate against signals outside this band. A typical discrimination/frequency characteristic for filter FL is shown in Fig. 3.

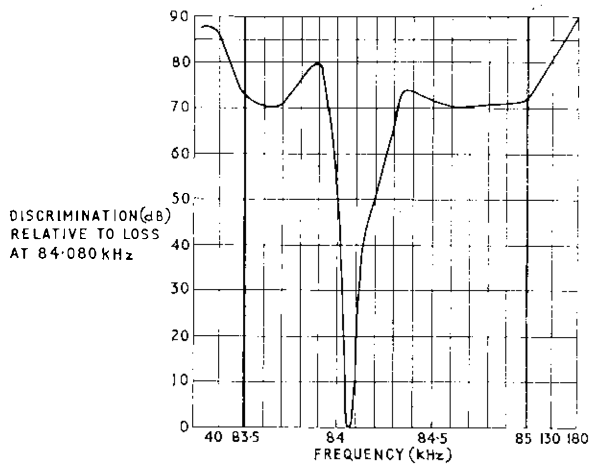
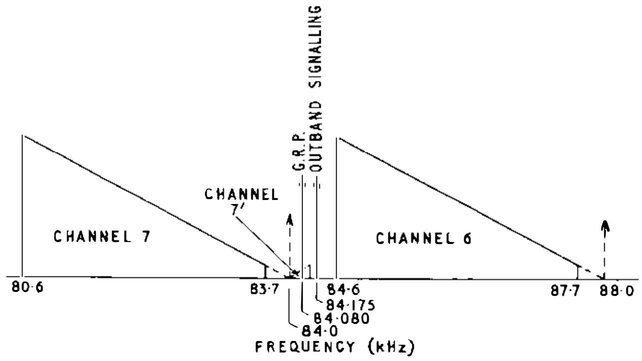


FIG 3—Discrimination/frequency characteristic of group reference-pilot selection filter

In order to appreciate the discrimination requirements for filter FL it is useful to consider the utilization of the frequency spectrum in the region of the group reference-pilot signal (Fig. 4). The wanted sideband of each channel is shown as



G.R.P.—Group reference-pilot

FIG. 4—Position of group reference-pilot within the 12-circuit-group spectrum

channel x, and the corresponding unwanted sideband is channel x'. The audio bandwidth transmitted by each channel is limited to 0·3–3·4 kHz, and so between 83·700 and 84·600 kHz the channel-translating apparatus band-restriction filters will limit the level of the wanted sidebands of channels 6 and 7. The balance of the necessary discrimination over this band is introduced by filter FL. However, over the

* The terms "free" or "fixed" are used to indicate, respectively, wither the group a.g.c. apparatus is free to be associated with any channel-translating apparatus via interconnexions on the group distribution frame, or whether it is cabled direct to a specific channel-translating apparatus.

† Supergroup a.g.c. equipment—a.g.c. equipment controlling the transmission-path gain over the basic supergroup band, 312–552 kHz.

band 84·080 ± 0·003 kHz filter FL cannot introduce any discrimination, and so special measures are taken within the channel-translating apparatus so that sufficient discrimination is given against channel 6 signals that lie in this band.

Parts of the unwanted sidebands of channels 7 and 8 also lie in the band 83·700–84·600 kHz, and discrimination against these signals is introduced by the channel-translating apparatus and filter FL. Filter FL also introduces at least 19 dB discrimination against channel 7 carrier leak at 84·000 kHz, and at least 21 dB discrimination against out-band signalling at 84·175 kHz. Outside the band 83·700–84·600 kHz all the necessary discrimination against the 12-circuit-group signals in the band 60–108 kHz must be introduced by filter FL. Carrier leaks (in the range 420–612 kHz) from the group-translating apparatus may appear at the input of the group a.g.c. apparatus at the same level as the group reference-pilot signal (−20 dBm0). The unwanted upper sidebands from the group-translating apparatus will appear at the input of the group a.g.c. apparatus in the range 732–1,164 kHz (depending which group of the super-group is being considered), and these may be at the same level as signals in the wanted sideband. Filter FL must discriminate against both the group-translating apparatus carrier leaks and unwanted sidebands.

The effect which any given interference signal (frequency other than that of the group reference-pilot signal) has on the gain of the group a.g.c. apparatus depends on the detection characteristic of the apparatus as well as the discrimination introduced by filter FL. In determining the discrimination limits for filter FL it was assumed that the detector within the group a.g.c. apparatus had a mean linear rectified detection characteristic. If the characteristic of the actual apparatus differs from that assumed, the difference in the margin of interference (required to give the appropriate apparent increase in signal level) between that given by a mean linear rectified detector and the particular detector employed by the group a.g.c. apparatus should be added to the discrimination requirements of filter FL.

A change in the level of the group reference-pilot signal at the input of the group a.g.c. apparatus results in a change in the attenuation of control attenuator AT2, and the change is in such a sense as to oppose the change in level of the incoming pilot signal. It is not possible to restore the level at GROUP A.G.C. OUT to exactly its setting-up level, because a small servo-error must exist to maintain the attenuation of control attenuator AT2 at its abnormal value. Level variations of the group reference-pilot signal at GROUP A.G.C. IN are in fact reduced to approximately one-tenth of these variations at GROUP A.G.C. OUT, within a range ±3·5 dB from the setting-up level at GROUP A.G.C. IN. The group a.g.c. apparatus introduces no additional control after the level of the group reference-pilot signal has deviated by more than 6 dB from its setting-up level at GROUP A.G.C. IN, and it is not permitted to increase the gain of the 12-circuit-group path by more than 5 dB. This limit is required to ensure the stability of the circuits on restoration of a disconnexion affecting both directions of transmission, as the gain introduced by the group a.g.c. apparatus at this instant will be at its maximum value (10 dB reduction in margin of stability). It is also desirable to limit the noise level under fault conditions, and so the amplification introduced by the group a.g.c. apparatus must be restricted. A typical control characteristic is shown in Fig. 5.

Generally, the group a.g.c. apparatus reduces the amplitude of any gain change in the transmission path traversed by the controlling group reference-pilot signal. However, for certain rates of change the group a.g.c. apparatus can enhance the gain change, and the magnitude of the change and the rate of change at which the maximum change occurs is determined by the magnitude and phase of the feedback signal produced within the apparatus control loop. This effect is known as gain enhancement and is expressed as the ratio of the group reference-pilot signal variation at GROUP A.G.C. OUT to that at GROUP A.G.C. IN. This problem is currently being studied by the C.C.I.T.T.,* and their draft recommendations are:

(*a*) the group a.g.c. apparatus should be designed in such a way that the output level variations as a function of time, resulting from a step change in the level of the incoming group reference-pilot signal, should never exceed that of the change which caused them, and

(*b*) the gain enhancement produced by the group a.g.c. apparatus should not exceed 0·26 dB.

Any variation in the gain of the path between the hybrid transformer, T in Fig. 2, and the input to the comparator will result in an equal variation in the gain of the group a.g.c. apparatus, and so every attempt is made to design very stable devices for inclusion in this path. Variations in the gain of the path between GROUP A.G.C. IN and the input to hybrid transformer T will be equivalent to changes in the gain of the system and will be automatically corrected. The stability of the devices in this path is, therefore, not as critical as the

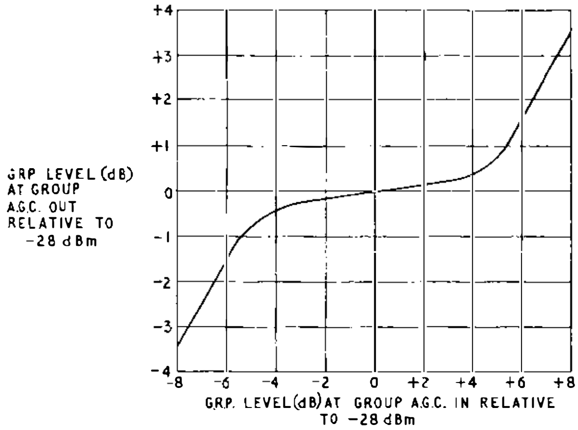


FIG. 5—Group a.g.c. apparatus control characteristic

stability of the devices in the former path. It should also be noted that a very stable d.c. reference voltage is required for application to the comparator, as this will also determine the gain of the apparatus.

It would be ideal if any variations in the level of the group reference-pilot signal were corrected instantaneously, but the apparatus is designed to have a response such that it takes about 20 seconds to bring a 4 dB step change in the pilot-signal level back to within 0·2 dB of its final controlled level at GROUP A.G.C. OUT. The first reason for this is that it has been found uneconomical to completely filter out at source all transient interferences with the group reference-pilot signal. The most troublesome source of transient interference is the l.f. energy that is produced by such things as incoming and outgoing signalling relay-sets, and switching transients in exchange and subscribers' equipment. This l.f. energy is at a high level and, if it is applied to channel 7, the resulting unwanted sideband frequencies (channel 7′ in Fig. 4) lie in the passband region of filter FL. The second reason for the slow response-time is that it is undesirable to change the gain of the apparatus when a transient break occurs in the transmission of the group reference-pilot signal. The slow response is normally achieved by making the variable element of control attenuator AT2 an indirectly-heated thermistor with a large time-constant.

The FIXED GAIN/AUTO GAIN link is provided so that the apparatus may be adjusted to give a fixed gain during setting-up. The link disconnects the control attenuator AT2 and connects in its place a fixed attenuator AT1.

* C.C.I.T.T.—International Telegraph and Telephone Consultative Committee.

Group a.g.c. equipment is at present being manufactured for the British Post Office by four contractors, and one of these equipments, in 62-type construction practice, is shown in Fig. 6. This equipment includes six group a.g.c. apparatuses, one group a.g.c. common alarm and, if required, a plate mounting two test-trunk terminations. The group a.g.c. common alarm is capable of serving all the apparatuses mounted on the rack, and so the other equipments mounted on the rack need only contain group a.g.c. apparatuses.

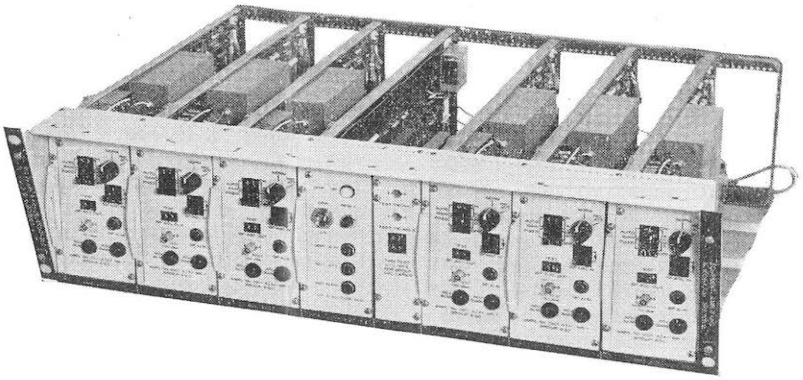


FIG. 6—Group a.g.c. equipment—Equipment, Amplifying, No. 1000

ALARM ARRANGEMENTS

The group a.g.c. apparatus is able to provide alarm facilities by making a very simple addition to the basic a.g.c. circuit. The alarms are operated when the level of the group reference-pilot signal at GROUP A.G.C. OUT deviates from its setting-up level by more than $\pm(1 \cdot 5 \text{ to } 2 \cdot 0)$ dB. At this deviation the input level has deviated from normal by about 6 dB. These alarm points were chosen bearing in mind the present maintenance standards whereby a circuit is adjusted if its gain changes by 2dB, and is taken out of service when it has deviated by 4dB or more from its setting-up value.

The alarm circuit is connected to the a.g.c. circuit at the output of filter FL. The filtered group reference-pilot signal appearing at this point enters amplifier 3 where it is amplified, rectified and the resulting d.c. voltage compared with reference voltages corresponding to the two alarm points. When the d.c. voltage lies between these reference voltages, relay AL is in its unoperated condition, but when the voltage lies outside this range relay AL is operated and an alarm is given.

In the previous section it was stated that the effect of transient interference is minimized by the slow response of the group a.g.c. apparatus. The suppression is achieved by delaying the change in gain of the apparatus and hence reducing the output-level variations during the transient effective level changes of the group reference-pilot signal. The operation of relay AL is, however, directly dependent upon the effective level of the pilot signal, and so it will operate to these transient effective level changes. Thus, a delayed-action alarm circuit is required. Where a common alarm-delay circuit is employed the delay time is determined by the need to avoid integration of the operate times of the AL relays of all the group a.g.c. apparatuses connected to the delay circuit. A delay time of 30 seconds has been found to be satisfactory in practice. A delay is also necessary to prevent short-term operation of the alarms if the level of the group reference-pilot signal at GROUP A.G.C. OUT would eventually be restored to a level at which alarm conditions are not given by the apparatus, the initial change in level of the pilot signal at GROUP A.G.C. IN remaining unchanged.

It is possible to share the delay network between all the group a.g.c. apparatuses mounted on a 62-type rack. The delay network is therefore mounted in the group a.g.c. common alarm, and this is connected to all the group a.g.c. apparatuses that it serves by three common wires, W1, W2 and W3 (Fig. 2). Relay AL, in operating, connects an earth to wire W1, and 30 seconds later relay SA releases and operates the station alarms. The GROUP A.G.C. ALARM lamp glows, and the maintenance engineer locates the particular group a.g.c. apparatus giving rise to the alarm condition by operating the DISPLAY key, D, and hence energizing the ALARM lamp on the appropriate group a.g.c. apparatus. The alarms may be ceased by operating the RECEIVE ATTENTION key, RA, but the alarms are again initiated if the level of the group reference-pilot signal is restored to within the alarm range while the RECEIVE ATTENTION key is in its operated condition. If the DISPLAY key is inadvertently left operated with all the apparatuses with which the group a.g.c. common alarm is associated in their normal condition or with RECEIVE ATTENTION keys operated on all those in which alarm conditions exist, then the DISPLAY ALARM lamp is lit and the station alarms initiated.

These alarm arrangements are being standardized, and when this is done it will be possible to associate a group a.g.c. apparatus of any design with the group a.g.c. common alarm that may already exist on the 62-type rack on which the apparatus is to be mounted.

When relay AL operates an earth is applied to an apparatus connexion point, and this may be extended to the telephone exchange where the appropriate telephone circuits may be busied. It should be noted that if the failure only occurs in one direction of transmission then only the telephone exchange at one end of the link will be aware of the failure. However, an alarm-transmission system is being investigated, which, if introduced, would enable both telephone exchanges to be made aware of a one-way transmission failure.

CONCLUSION

The introduction of group a.g.c. equipment into the h.f. network has automated the 12-circuit-group gain-correction function. Gain correction is continuous, and so a great improvement in the gain stability of 12-circuit groups has resulted. When the group reference-pilot level deviates by a pre-determined amount from its setting-up level, alarms are operated and an earth is applied to a connexion point. Additional equipment may be connected to this point to initiate the busying of the appropriate telephone circuits when alarm conditions exist within the group a.g.c. apparatus.

ACKNOWLEDGEMENT

The photograph used for Fig. 6 was provided by Standard Telephones and Cables, Limited.

Semiconductor Device Developments: Production and Testing of Highly-Reliable 4A-Type Transistors

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This article is one of the series on semiconductor device developments, and describes the manufacture and testing of a Post Office silicon planar transistor of high reliability. Such transistors have an important application in submerged-repeater systems, and a life of at least 20 years with no more than a 10 per cent change in electrical characteristics is required.

INTRODUCTION

An article on semiconductor device development was published in October 1966 in this Journal[1] as the first of a series. The present article, in the same series, outlines the manufacture and testing of a British Post Office silicon planar transistor of high reliability called the 4A type. The first application for this transistor is to 640-circuit submerged-repeater systems with 3 kHz channel spacing and transmitting frequencies between 312 kHz and 4·772 MHz. Typical repeaters with four transistors in the signal path would have a gain of about 43 dB at the upper frequency and would be spaced at some 7·5 nautical miles (n.m.) along a 1 in. diameter cable. For the longer systems (800 n.m. or more), in deep water for the most part, very high reliability is essential. Each transistor should have a forecast life of 20 years with no more than a 10 per cent change in electrical characteristics in that time (see Appendix for typical electrical parameter values for the 4A2B and 4A2C transistors), and the average gain-change for the system should not exceed 2 dB.

In this article it is assumed that the reader has a general knowledge of the technology of silicon planar transistors.[2] A brief description will be given of the design features, manufacturing processes, and the testing methods and precautions which contribute to the production of the reliable 4A2 type transistor. Results of some accelerated life tests are included.

DESCRIPTION OF 4A2-TYPE TRANSISTOR

The design of the 4A2-type silicon planar n–p–n transistor is, with certain differences, generally as described elsewhere.[2] One important difference is that the device is formed in an epitaxial film of silicon grown on a single-crystal silicon substrate. The epitaxial film has a uniformly-distributed impurity addition of phosphorus (n-type) with a concentration of about $2·5 \times 10^{16}$ atoms/cm^3 to achieve a resistivity of 2 ohm cm, which is generally consistent with the electrical performance required of the transistor. The substrate is also n-type and has a high concentration of antimony to obtain a low resistivity, 0·003 ohm cm, which permits a transistor to have a low resistance in the collector connexion.

Successive diffusions of impurities into the epitaxial layer, first of boron (p-type) and then phosphorus, as later briefly described, form two junctions separating the emitter, the base and the collector regions. Connexions are made to the two former by aluminium electrodes which are evaporated on parts of the areas where the base and emitter regions lie in the surface. The collector connexion is made to the back of the substrate. A single transistor thus formed in a silicon die 1 mm square is brazed directly to a gold-plated header of the TO-5* pattern so that the collector connexion is made to the base of the header. The braze is formed by an alloy of silicon from the die and gold from the thickly-plated header when the two are heated together briefly at a temperature of 380°C.

The terminal posts of the header are connected to the transistor electrodes by aluminium wires 0·001 in. in diameter which are eyelet-bonded[3] to posts and electrodes. The eyelet bond, another main difference in design, establishes a reliable connexion to the transistor and is able to break through a thick coating of aluminium oxide formed on the surface of the electrodes during a final bake of the slice at 500°C in air. This bake cleans up and stabilizes the device and contributes towards attaining reliability. As a further contribution to reliability the use of aluminium wire instead of the more usual gold avoids the presence of gold on the electrodes and the attendant risk of formation, in the course of time, of gold-aluminium silicon alloys which could increase the contact resistance and, by being mechanically weak, promote disconnexions.

PRODUCTION ORGANIZATION

The objective of the production unit is to manufacture transistors to close electrical tolerances and with a high degree of reliability, which is demonstrated by accelerated life testing. Confidence in life testing can only be achieved if the product is uniform, and it is imperative that all manufacturing processes and factors affecting the product must be well controlled and continuously monitored. Clean working conditions are essential.[4] Control must be exercised over not only the processes but also the materials, components and equipment as well as the procedures followed by operators. To make this control fully effective all procedures must be fully documented and comprehensive records kept and scrutinized.

A detailed instruction has been prepared for each step of production, including purchase and preparation of materials, inspection, preparation of parts and the many production processes. For each slice‡ processed, a detailed history is recorded showing values of controlled variables, inspection and sampling results, dates, time, operator identity and any

† Post Office Research Station.

* TO-5 defines the outline of the transistor encapsulation and is widely referred to in manufacturers' literature.

‡ A silicon slice 25 mm diameter and 0·25 mm thick is the unit which, ideally, could produce some 400 separate transistors.

observed data, all of which are recorded for reference and analysis. This information is used for production and quality control during production of devices, and, later, is combined with electrical measurement results to enable a final assessment to be made of the finished product.

This need for control is reflected in the organization of the production unit, which is shown schematically in Fig. 1. All materials and components used in production processes are given discrete batch identities on receipt and are issued for use in production only when their quality has been assured by preliminary tests. The identity of each batch is recorded and this is noted when materials and components are used. This information is of value when any subsequent significant variations in the product are being investigated and rectified.

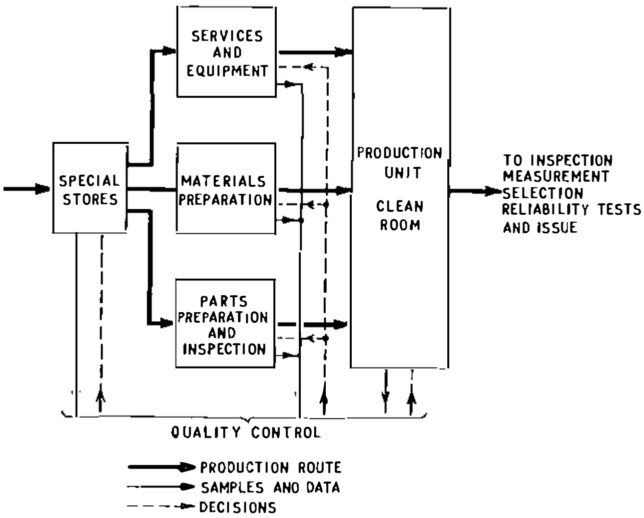


FIG. 1—Organization of production unit

PRODUCTION SEQUENCE

The outline production sequence shown in Table 1 and Fig. 2 has been developed from the basic technology.[2] The processes numbered 9, 10, 14 and 20 have been introduced to improve control and to give a more complete history of the end product. The final visual inspection of a device prior to encapsulation is purely subjective, but the inspector's assessment is backed by a colour microphotograph for the active area of the transistor. This photograph is used during the final assessment of a transistor prior to its certification for release for use in a submerged repeater.

The sequence shown in Table 1 is an outline only. Every step in the process listed requires much care and concentration on the part of the operator. There are also many routines, not shown in the table, for cleaning of work carriers and small tools, for example, and for the cleaning and adjustment of equipment to keep it in first-class condition.

Listed alongside each process is a brief description of the inspection applied to the product at that stage. The results of the inspections are recorded on a slice record sheet for full analysis later, and are used, where appropriate, for preservation of uniform methods and as an aid to the control of quality. Some inspection is carried out by the operators, who are encouraged to be objectively critical of their own work and to report any abnormality which they find.

TABLE 1

Outline Production Sequence

Process		Quality-Control Action
No.	Description	
1	Slice cleaning	100 per cent visual inspection of silicon slices for crystalline defects. Resistivity measurements.
2	1st Oxidation	One control slice per batch for evaluation. Examination of oxide thickness (Fig. 2(*a*)). Record: temperatures, duration, date and operator.
3	1st Photolithography: base pattern	Microscopic examination (×350) for definition and uniformity of pattern (Fig. 2(*b*)).
4	Boron diffusion	One control slice per batch for evaluation of surface concentration and junction depth (Fig. 2(*c*)). Record: temperature, duration, source, gas flow, dew points, slice position, operator, date.
5	2nd Oxidation	Occasional control slice for evaluation. Record: temperature, duration, date and operator.
6	2nd Photolithography: emitter pattern	Microscopic examination (×350) for definition, size, uniformity and alignment (Fig. 2(*d*)).
7	Phosphorus diffusion: emitter region	One control slice per batch for evaluation of surface concentration and junction depths (Fig. 2(*e*)). Record: temperature, duration, source, gas flow, dew point, slice position, operator and date.
8	800°C Bake. Oxide stabilization	Record: temperature, duration, data and operator.
9	3rd Photolithography	Ten contact-window patterns yield devices for 2-probe electrical measurements.
10	4th Photolithography: graticule and numbers	Microscopic examination (×350) for definition, uniformity and alignment.
11	5th Photolithography: contact areas	Microscopic examination (×350) for definition, size, uniformity and alignment (Fig. 2(*f*)).
12	Aluminium evaporation	Control slice per batch for thickness and uniformity of aluminium film. Record: temperature, pressure and duration of evaporation.
13	6th Photolithography: contacts	Microscopic examination (×350) for size, definition, alignment and uniformity (Fig. 2(*g*)).
14	Slice inspection	Microscopic examination (×350) of each device for defects in oxide, aluminium and photolithography. Record: the serial number of each defective device.
15	500°C Bake. Surface stabilization	Record: temperature and duration.
16	Dicing	Periodic inspection of dice edge for defects. Record: slice number, date and operator.
17	Header selection and cleaning	100 per cent microscopic examination (×50). Record: reject rate, quantities, date and operator.
18	Dice-to-header brazing	Two samples per batch of 25 destructively tested to show uniformity of braze. Record: slice number, tray number, operator and date.
19	Wire bonding	Two samples per batch of 25 destructively tested for bond strength.
20	Inspection and photography	100 per cent microscopic examination (×350) of devices. Microphotographs are taken of each good device. Record: rejects, dice numbers, exposure numbers, date and operator.
21	Can selection and cleaning	100 per cent microscopic examination (×50) for damage and engraving. Record: serial numbers, reject rate, operator and date.
22	Encapsulation	100 per cent visual inspection of welds. Record: defects, related dice and serial numbers, slice and batch details, date and operator.

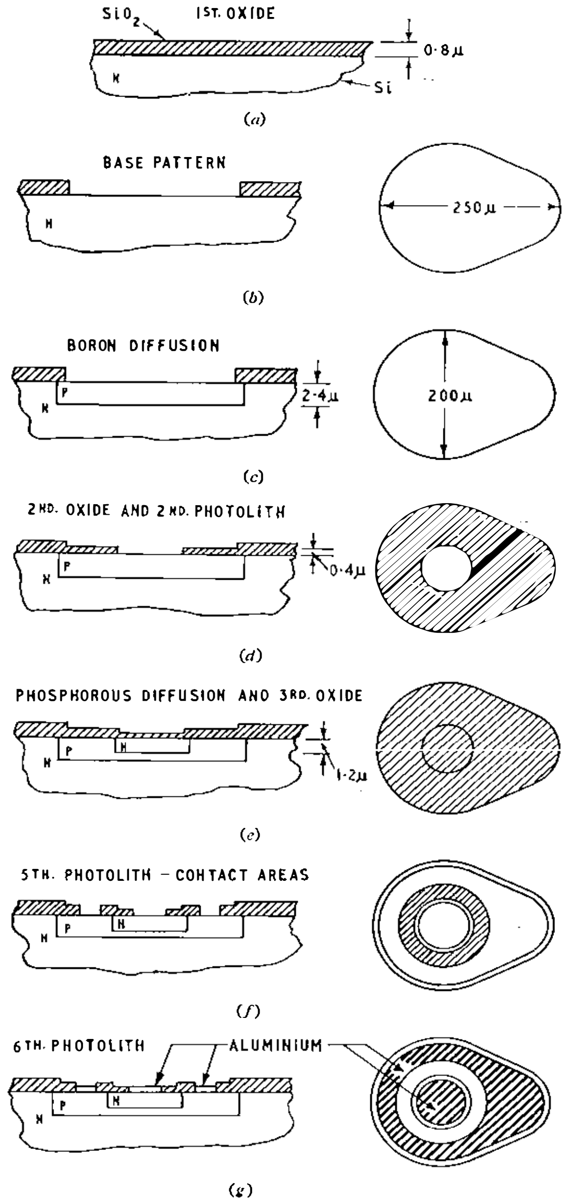


FIG. 2—Descriptive diagrams of devices referred to in Table 1

QUALITY CONTROL

Objectives and General Organization

The primary objective of both production and quality control is to provide a high yield of transistors manufactured to meet a user specification with early evidence of good potential reliability. With this aim in mind, quality control has been approached firstly as a scientific enquiry carried out by a section working in close collaboration with the production team. Manufacturing processes are studied and customary methods of sampling and inspection are employed. The results of information thus generated are carefully studied in order to provide production guidance and to ensure that the best promise of device-quality is achieved. The general deployment of this effort is shown in Fig. 3, where distinction has been drawn between the flow of samples and data used to judge a process and the function of control based on assimilated data.

Physical Parameters of Transistors

Some of the more important physical parameters are shown in Fig. 4. Control of these parameters together with the choice of planar geometry is of prime importance in determining the electrical performance of a completed transistor. All these parameters are subject to process variation and must be carefully monitored. The shaded area in Fig. 4 represents the dominant factor which often determines the current gain and cut-off frequency of this type of transistor, in which surface effects are negligible. The shape and major dimensions of this region are dependent on the processing factors listed in Fig. 3.

One of these parameters is junction depth, and this can be estimated by taking a section through a transistor at an oblique angle. A solution containing copper sulphate is used to stain the n-type regions, and a depth measurement of the now visible junction can be made using optical interferometry. Such a section is shown in Fig. 5. Another parameter is the concentration of impurity atoms at the surface plane. A measurement of the conductivity of the p-type layer formed by the diffusion of boron into a control slice is made with a 4-probe test equipment, and from this the surface concentration can be estimated assuming an impurity profile based on simple diffusion.* A knowledge of the quality, continuity and thickness of the silicon-dioxide layer is important in order to ensure adequate protection of the silicon against the diffusion of contaminants which may otherwise lead to early failures. Measurement and control of the thickness of aluminium is

* Such theory differs from practical reality in several aspects that will not be discussed here. However, this model presents a basic guide for the purpose of this article.

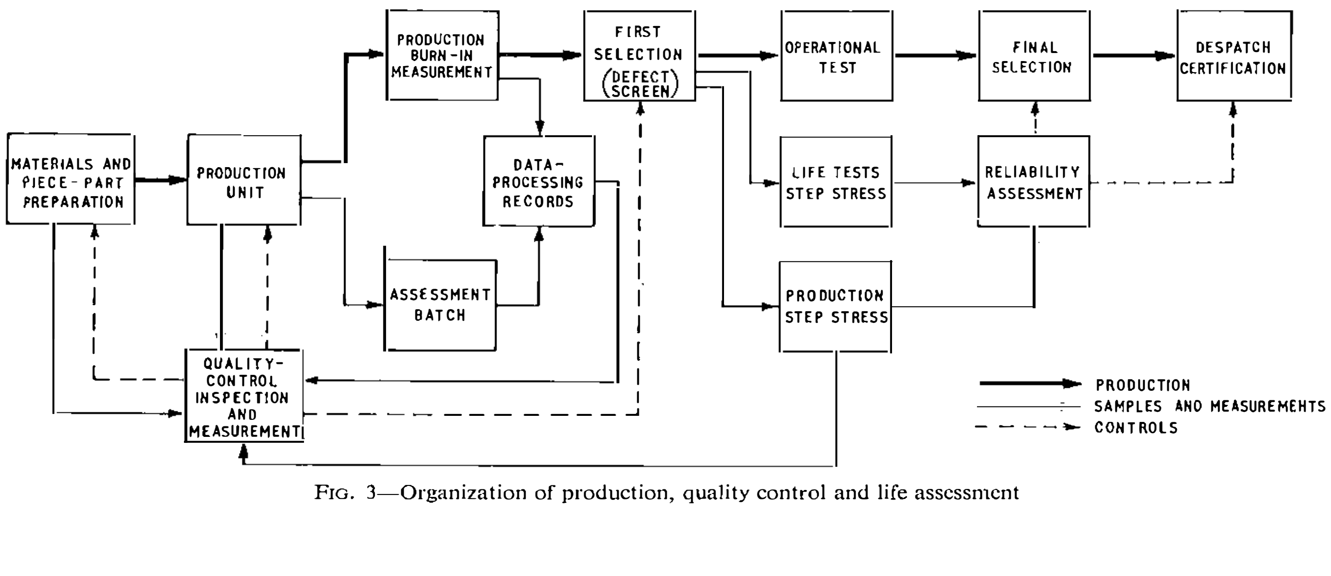
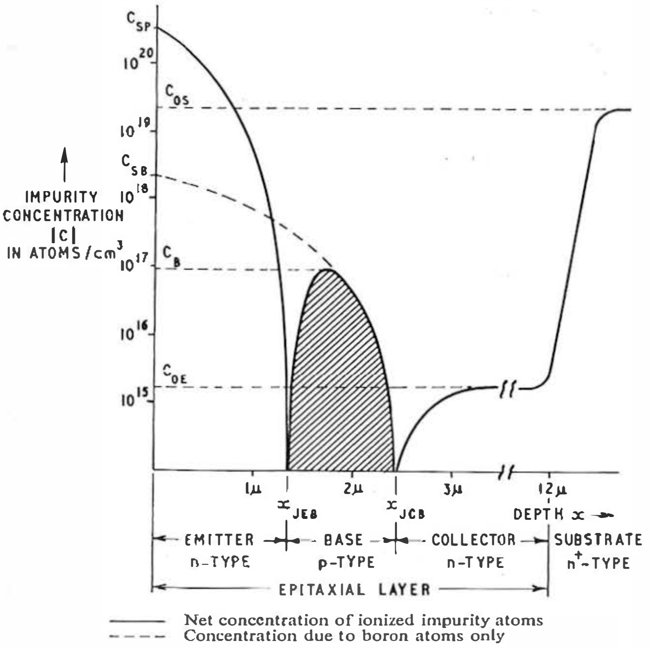


FIG. 3—Organization of production, quality control and life assessment



Symbol	Description	Controlled by	Typical Value	Related Electrical Parameter
C_{OS}	Concentration of antimony dopant in Si substrate.	{Substrate manufacturer	5×10^{19} atoms/cm³	$V_{CE(SAT)}$
C_{OE}	Concentration of P dopant in epitaxial layer.	Epitaxial growth.	$2\cdot5\times10^{15}$ atoms/cm³	$V_{BR(CBO)}$, C_{ob}
C_{SB}	Surface concentration of boron impurity.	Boron source, temperature, water content and transport.	2×10^{18} atoms/cm³	$V_{BR(CBO)}$
C_{SP}	Surface concentration of phosphorus impurity.	Source composition, furnace temperature.	5×10^{20} atoms/cm³	h_{FE} at high current
x_{jCB}	Collector–base junction (net impurity conc. zero).	Diffusion time and temperature. C_{OE} and C_{SB}.	$2\cdot4$ μ	
x_{jEB}	Emitter–base junction (net impurity conc. zero)	Diffusion time and temperature. C_{SP} and C_B.	$1\cdot2$ μ	h_{FE}, h_{fe}, f_T
C_B	Maximum net concentration in the base.	x_{jCB}, C_{SB}	$\sim10^{17}$ atoms/cm³	$V_{BR(CBO)}$
W	Base width.	x_{jBC} and x_{jEB}.	$1\cdot2$ μ	

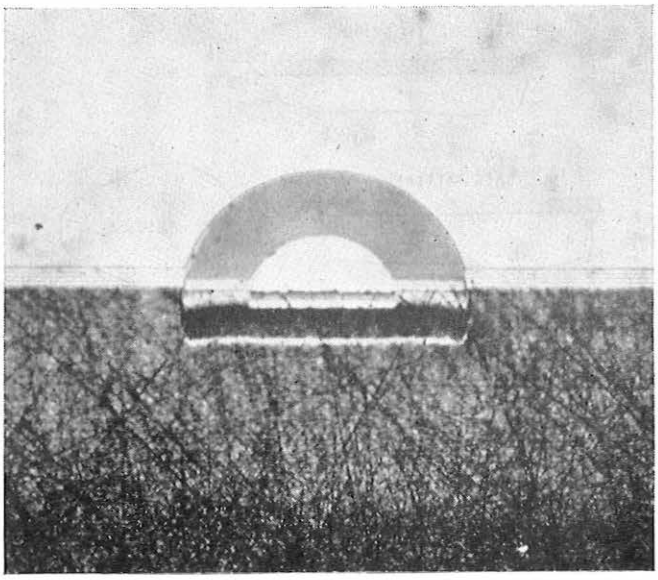
FIG. 4—Physical factors affecting electrical performance

essential if the contact areas are to be formed by selective etching while still retaining good edge-definition.

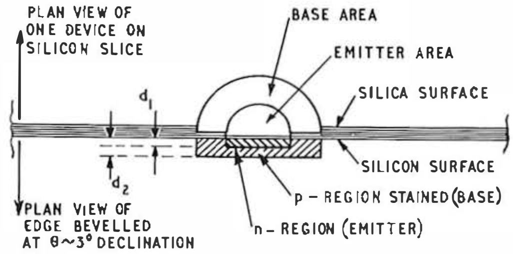
So far the factors enumerated provide a physical target area, and success is determined by the control marksmanship combined with variability introduced by factors that cannot be controlled sufficiently with equipment and methods currently available.

Factors Affecting Device Stability and Reliability

There remain now the factors affecting device reliability. Chemical residues[5] or contaminants arising out of the transfer or processing of piece-parts before encapsulation are likely to be detrimental to the stability and reliability of devices. It is hoped that such contaminants left after suitable washing in solvents are volatile or can be passivated. Either way the problem may be solved by baking; for example, steps 8 and 15 of Table 1. If contaminants on the surface or associated with the silicon dioxide are electrically polarizable they can migrate in the fringe field of the collector–base junction. Surface states may be formed which, during the operation of the transistor, can lead to a reduction in current gain and



(a) Photograph of Oblique Section of 4A-Type Transistor Showing Junction Depths



$d_1 = x_{jEB}\,\text{Cot}\,\theta$, $d_2 = x_{jCB}\,\text{Cot}\,\theta$

(b) Explanatory Diagram of Section

FIG. 5—Transistor section showing junction depths

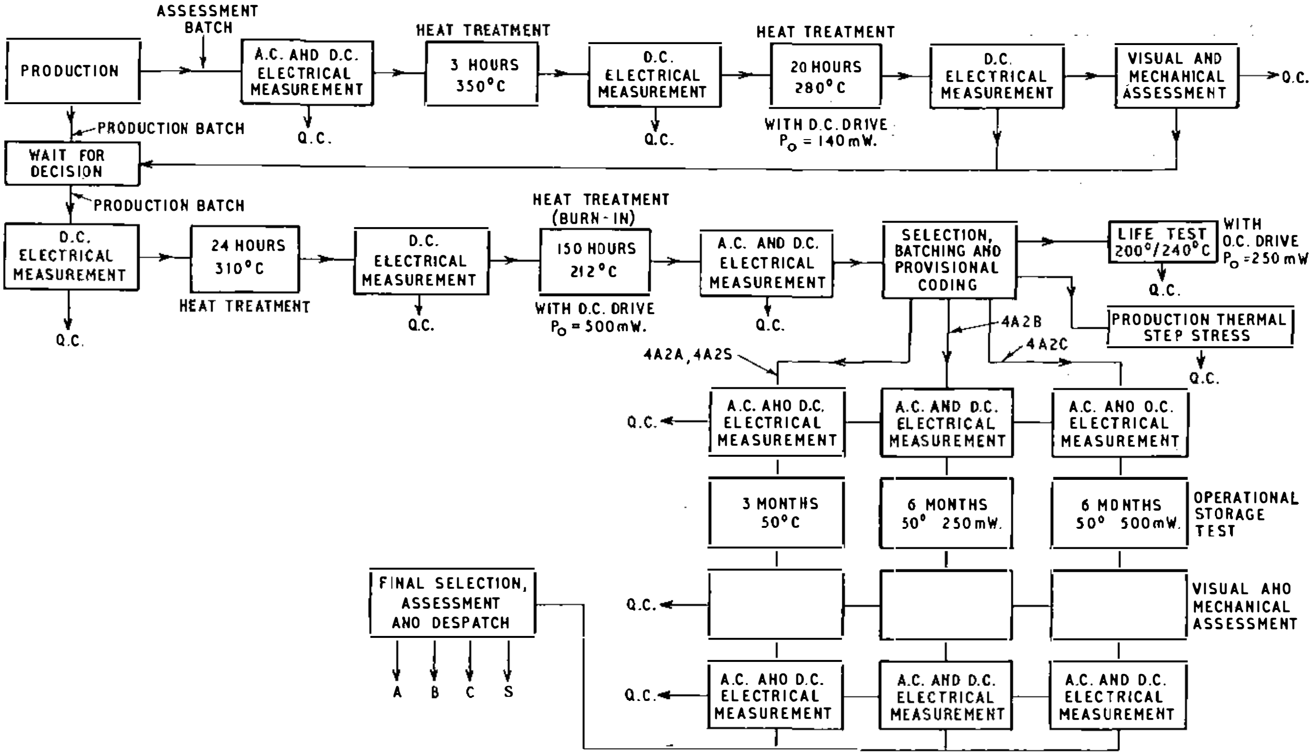
may cause a serious increase in leakage currents due to the formation of a conducting channel. Both effects would have catastrophic consequences were they to occur during the life span of a working system.

Normal chemical tests are often neither sufficiently sensitive nor conveniently adapted to reveal the presence of contamination at the time of manufacture. It is the practice to assess a 10 per cent sample of transistors drawn from each slice. The assessment starts with a period of storage, without current bias, at 350°C to accelerate any chemical reaction caused by contamination, to see if detrimental electrical effects can be induced. Treatment of the samples is followed by a period of steady over-stress, with electrical power applied, at 280°C in order to assess the potential reliability of each processed slice. Over-stress is important as a check on slice viability at the earliest possible stage in production, and it enables a forecast to be made of the potential device-yield before continuing with processing. This procedure also provides useful evidence of the effectiveness of process control, and, in the case of failed transistors, leads to early action in fault finding in batch treatment.

A continued study of the information accumulated by quality control provides the essential background leading to the evolutionary reduction of process variability by new and improved processing techniques. Eventual confirmation of the success of device production comes later, after a searching reliability exercise which combines both steady over-stress and operational life testing of transistors as described later.

MEASUREMENT IN DEVICE PRODUCTION

The operation of an effective system of quality control in the production of transistors depends on the acquisition of



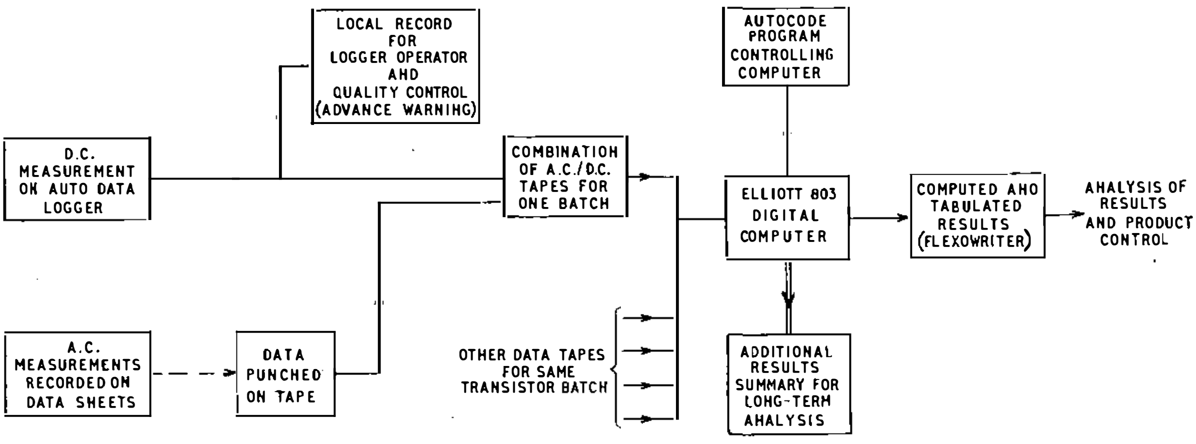
Q.C.—Information to quality control
A, B, C and S—Letters represent transistor type variants to meet specific user requirements

FIG. 6—Flow diagram of measurement procedure

accurate and reliable electrical measurement data at key points in processing. The measurement plan evolved for the 4A2 device is shown in Fig. 6. Commencing with a group of transistor elements processed from one silicon slice and awaiting bonding and encapsulation, a sample batch is first subjected to a series of a.c. and d.c. electrical measurements. After a 3-hour period of storage at 350°C without electrical bias, a second set of measurements is obtained. The devices are then given a 20-hour "burn-in," i.e. stressed at a temperature of 280°C under conditions of electrical power dissipation (140 mW), and a third set of measurements is taken. The sample data obtained in this way enable the potential quality and yield of the parent group to be assessed.

The remaining devices from the slice are then processed to form a production batch. After initial d.c. measurements the batch is subjected to thermal storage without electrical bias; then a second set of measurements is obtained. This is followed by a burn-in for 150 hours at 212°C with 500 mW dissipated in each transistor, and by further measurement. Assessment of the combined sets of results enables the devices to be provisionally coded into the main variants of the 4A2 specification and defective transistors to be rejected. Devices falling slightly outside the set of limits are diverted for life tests under thermal storage conditions and a proportion receive a thermal step stress.

Those devices provisionally allocated for repeater use are first given a full set of electrical measurements, then operated at 50°C for a period of 3 or 6 months, depending on their future use. After this the devices are tested mechanically and are measured again. Finally, from an analysis of the electrical



5-track Elliott-coded punched tape
8-track Elliott-coded punched tape

FIG. 7—Transistor-measurement data-processing system

history, an assessment is made of each transistor before a test certificate is prepared and the device is released for service in a system.

The compilation and processing of the electrical data make use of punched paper tape employing the 5-hole Elliott code. Each time d.c. measurements are made on a batch of transistors, a tape is produced which contains a sequence of 12 parameters for each device, suitably identified. Additionally, a separate tape is punched when a.c. parameters are required, and tapes are combined to form a composite record of the batch for a particular stage in processing (Fig. 7).

When the requisite number of such data tapes has been obtained for each batch measured, an autocode program is run into the Post Office Research Station Elliott-803 computer together with the tapes and certain selected limit criteria. The tape output from the machine containing the results of the computation is fed to a flexowriter to produce a page print-out which includes a statistical analysis of the batch results.

The print-out first lists the batch and slice numbers from which the devices were produced, together with other information identifying the measurement conditions. The parameters shown in Tables 2 and 3 are then listed, together with the serial number of each device.

TABLE 2

D.C. Parameters

Emitter–base leakage current	I_{EBO}
Collector–base leakage current	I_{CBO}
Collector–base breakdown voltage	$V_{BR(CBO)}$
Emitter–base breakdown voltage	$V_{BR(EBO)}$
Forward current transfer ratios at five specified bias currents	h_{FE}
Emitter–base saturation voltage	$V_{BE(sat)}$
Collector–emitter saturation voltage	$V_{CE(sat)}$
Collector–emitter sustaining voltage (under pulse conditions)	$V_{CEO(sust)}$

TABLE 3

A.C. Parameters

Forward current transfer ratio at 100 MHz	h_{fe}
Noise factor (at two specified conditions)	N
Collector output capacitance	C_{ob}
Additional h parameter measurements as required	—

For each transistor the measured values of each of the parameters shown in Tables 2 and 3 are recorded for each occasion of measurement. The print-out includes a classification of each transistor in terms of a set of specifications. It also includes certain statistical information on the sample, e.g. means and standard deviations for each parameter, and a summary of the specific yield in terms of the specification limits.

The d.c. parameter measurements are carried out on automatic data-logging equipment specially made for this purpose, which is programmed to work on a fixed cycle under the control of an operator. The punched-tape output consists of three types of "sentence" each containing a number of 4-digit "words." The first type of sentence provides the identifying information required by the computer, the second contains a record of the test conditions in the logging machine, and the third is a series of blocks each containing the 12 recorded parameters for each transistor being measured. As the measurements are made the operator receives a local record, printed in the machine language and derived from the punched-tape output. This is a useful monitor and also provides advance information for assessment purposes. The accuracy of measurement is better than 1 per cent.

Measurement of a.c. parameters is obtained manually, since a degree of flexibility in measurement conditions is required. The data so obtained are transferred to punched tape, and at the same time any necessary editing is done on both a.c. and d.c. measurement tapes.

The measurement laboratory is equipped to make measurements, on a sample basis, of other transistor characteristics. These include harmonic production in output devices, thermal resistance and small-signal h parameter characterization; the latter facility is available over a frequency range up to 1,000 MHz.

Production Thermal-Step Stressing

In order to collect information on the stability and potential longevity of the product and to investigate batch-to-batch variation, a continual thermal-step stress program is carried out on designated samples. A second automatic data-logger is associated with a dual-oven system. The d.c. parameters of the samples are first measured in one oven maintained at a temperature of 50°C. The samples are then subjected in a second oven to a first thermal step, e.g. 200°C for 20 hours, under "power-on" conditions, before return to the 50°C oven for a second measurement. The procedure is repeated several times, the thermal stress being raised progressively to an upper limit of 340°C.

The punched-tape output from the logger is processed as previously described, and failure criteria, typically a change of 10 per cent in h_{FE} at 10 mA, are allotted to the device parameters. The numbers of devices failing at each step are plotted on probability paper against the reciprocal of the absolute temperature. The relationship provides the basis for comparative analysis as outlined in the following section.

RELIABILITY ASSESSMENT

During the manufacture of the transistor the greatest possible care is taken to ensure that all devices are likely to prove reliable in service. Only transistors whose origins, as determined by production inspection and testing, appear impeccable are accepted for long-term reliability assessment.

Reliability assessment aims at establishing by destructive tests that there is no endemic weakness in the batch likely to cause failure. Failure is defined as a change in electrical characteristics which would adversely affect the performance of a system. Thus, a change of h_{FE} at 10 mA by more than 10 per cent in one transistor could cause the failure of a cable system. Reliability assessment also requires that each individual transistor destined for operation in a system is tested non-destructively to ensure that its behaviour is likely to be acceptable.

Possible causes of early failure in transistors may be divided into two groups. Broadly speaking, these are failures due to mechanical defects and failures due to chemical contamination. Mechanical defects are the easier to detect and eliminate since most of the faults are visible under the microscope. Flaws in production processing, such as faulty mask alignment, incomplete removal of the surplus aluminium and misalignment of the wire bonds, can be detected by visual inspection of all devices prior to encapsulation. One important fault which may not be detected is the inherent weakness of a wire bond placed over incompletely removed photo-resist residues. The bond may well look perfect under a microscope, as the remaining layer of Kodak Photo Resist may be too thin to be seen. Transistors with this fault can be eliminated by the use of a 30,000g centrifuge screening test, the force being applied in such a direction as to pull off weakly-bonded wires. The latest version of the "eyelet" bonder incorporates a facility for applying a predetermined safe stress to the bond immediately after bonding by pulling the wire. The force that can be applied in this way is greater than that applied to the wires at 30,000g in the centrifuge. Another, though possibly secondary, cause of failure in the "mechanical" category is a faulty weld on encapsulation. A "leaky" encapsulation means that control is lost of the composition of the gas inside the can, and the behaviour of the transistor may now be determined by its general environment. Mechanical faults can precipitate catastrophic failures, either open-circuits or short-circuits. The effects of chemical contamination can be just as serious, though their nature enables a more detailed study to be made of the time taken to cause failure.

A decade ago the philosophy of "life" assessment required the assembly of a large batch of components from a single source. Samples from this batch were subjected to some form of accelerated aging, and the reliability of the remainder was deduced from these results. The sample sizes were determined simply by the degree of statistical confidence required in the final answer. This system is satisfactory where it can be applied. However, with the increase in complexity of modern electronic equipment, and the extremely high level of reliability required for submarine-cable systems, it becomes both practically and financially impossible by this method to attain the required statistical confidence. The only alternative is to have a greater knowledge of the actual mechanisms of failure possible in a device. This is achieved by subjecting a "practical" number of devices to a form of accelerated aging, followed by a careful and detailed investigation of all failures initiated by the testing.

In order to carry out accelerated aging and produce some information on the life expectancy of a transistor, it is necessary to invent a physical model of the failure mechanism. It is generally accepted that failures, i.e. unacceptable changes in the device's electrical parameters, are caused by the diffusion of contamination over, or through, the protecting oxide. The diffusion may in some cases be preceded by a chemical reaction between the contaminant and one of the component materials of the transistor. This kind of mechanism follows a simple law.

If $[R]_t$ is the concentration of a contaminant at a time t,

$$\text{and } [R]_t = [R]_0 + A.t. \exp(-E/kT),$$

where T is the absolute temperature,
A is a constant,
k is Boltzmann's constant, and
E is an activation energy,

then the time, t_c, taken to reach a critical concentration of contamination, at which electrical failure occurs, is given by:

$$t_c \propto \exp(E/kT), \quad \text{or} \quad \log t_c \propto E/kT.$$

This relationship gives a basis for accelerated aging, since the time taken to reach the critical concentration for failure can be reduced by increasing the ambient temperature.

Consider the general curve for failure rate against time in Fig. 8. This is a very much idealized curve; in practice the region of constant rate of failure is probably formed by the superimposition of the "tails" of the production-defect and wear-out distributions. Since it may be assumed that the distribution of contamination within a production batch is random, the failures arc fitted to a Gaussian distribution. The defects in transistors for submerged repeaters are few, and defective transistors are removed after production burn-in (Fig. 3). The failure rate in the central region of the curve of Fig. 8 is insignificant.

The failure of transistors is achieved by operating them under over-stress conditions with power applied. The stress in the case to be considered will be temperature only. Two main kinds of experiment are in common use: step stress and steady stress. In the former, as already mentioned, the devices are subjected to equal periods of time at increasing steps of temperature, measurements of the device parameters being taken before and after each step. In the steady-stress type of test the temperature is constant and measurements are made over a longer period of time.

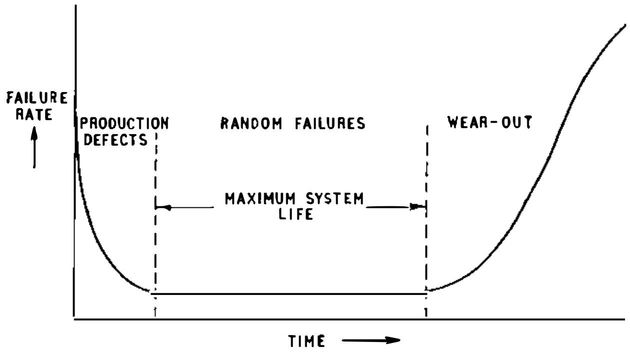
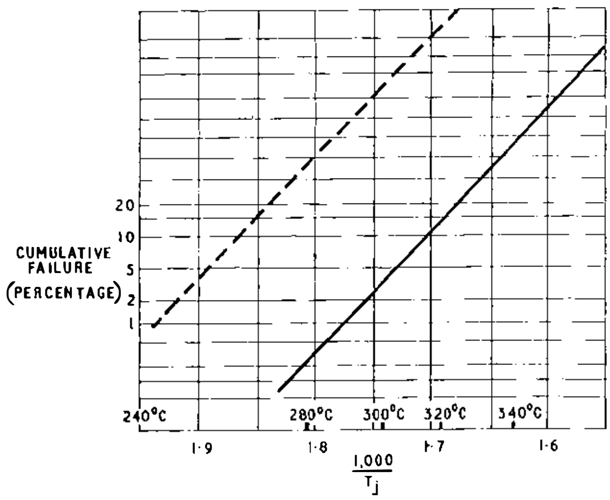


FIG. 8—General form of failure rate with time

The temperature steps on the step-stress test must be sufficiently large for the effect of the previous step to be small. The usual step is 20°C. Once the acceleration factor for the failure mechanism has been found a correction factor, Δt, representing the effect of the previous step, can be added to the step time for use in plotting a "life" prediction line. After each step the changes of parameters of the transistors are compared with the end-of-life criteria and the cumulative number of failures after each step is calculated. This is then plotted on cumulative probability graph paper against $1/T_j$ (see Fig. 9). T_j is the junction temperature derived by adding



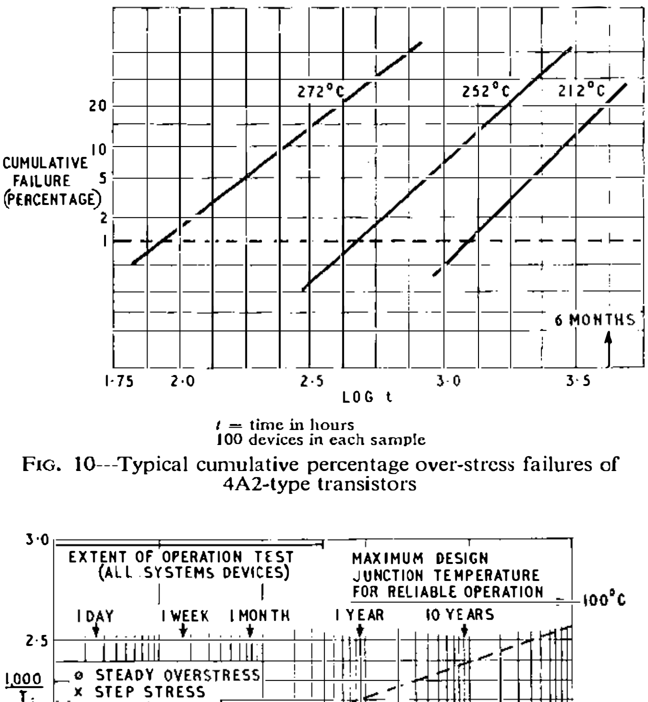
- - - - 165 hours —— 20 hours
T_j = Junction temperature (°K)

FIG. 9—Typical step-stress failure results for 4A2-type transistors

the temperature due to power dissipation inside the device, 80°C per watt for a 4A device, to the ambient temperature. The fitted straight line is then extrapolated to the required failure level, the 1 per cent level in this case. The point representing the temperature at which 1 per cent of the devices would fail in the period of a step is then noted, together with the correction factor for step size if this is necessary. Step-stress experiments on 4A transistors are carried out using 20-hour and 165-hour steps with samples of 30 to 50 transistors. The main purpose of these tests is to give an indication of the acceleration factor, and a rapid check on the quality of the output from the production line. Its most important function is to show that devices in the large failure-rate region attributed to production defects have been removed by an adequate screening process. The results from step-stress experiments are not as useful for life prediction as those from steady stress, since temperatures in the region of 300°C to 360°C must be used to cause failures. In this range it is impossible to maintain the normal operating potentials across the transistor, and the simple model for the failure mechanism is invalid. This is, in particular, the case where failure is caused by the migration of ions on the oxide of the device.

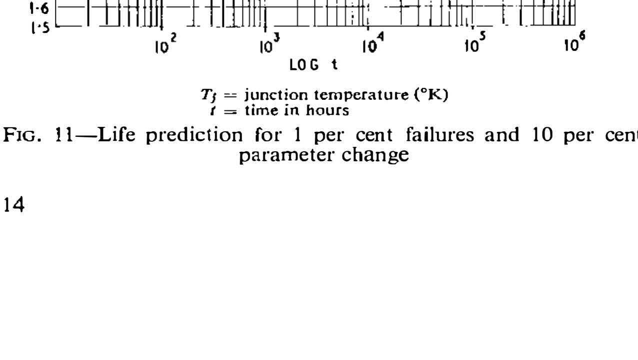
Steady-stress experiments are made at lower temperatures, the usual maximum 280°C being the highest temperature at which normal operating voltages can be maintained across the silicon transistor. The lowest practicable temperature is that which will give, say, 20 per cent failures inside 5,000 hours, a reasonable maximum economic duration for holding a supply of transistors for a system. Since, from the simple model, failures should occur normally with the logarithm of time, the period between measurements is made to increase on an approximately logarithmic basis. The actual measurement times might be 20, 40, 80, 160, 300, 500, 1,000, 2,000 and 4,000 hours. The cumulative number of failures at each time of measurement is plotted on probability graph paper against log(time) (see Fig. 10). When the experimental points have been fitted to a normal distribution, the intercept of time for the 1 per cent failure level is transferred to the life-prediction graph (Fig. 11) for each stress level, together with those points obtained from step-stress results.

The results of the over-stress experiments have been used to produce an extrapolated life-prediction line. However, the confidence that can be placed in these results as applied to other transistors from the production run depends simply on the size of each batch tested. To be able to say that, in 98 lots in every 100, the 1 per cent failure level at junction temperatures below 100°C would be greater than 20 years, would require about 10,000 devices on test. If, however, the production processes are carefully controlled and extrapolated life is an order better than required, a different procedure may be used. A production screen is introduced to remove contaminated transistors that could otherwise fail early. A small sample of these devices, 500 to 1,000, is subjected to over-stress to check that the main mode of failure will not cause trouble during active life.



t = time in hours
100 devices in each sample

FIG. 10—Typical cumulative percentage over-stress failures of 4A2-type transistors



T_j = junction temperature (°K)
t = time in hours

FIG. 11—Life prediction for 1 per cent failures and 10 per cent parameter change

In order to provide a further safeguard, all transistors selected for use in the system are subjected to 5,000 hours at their normal operating dissipations at an ambient temperature of 50°C. This is, in effect, monitoring the devices under laboratory conditions for the first 2 years of their life. Any devices showing even small changes in gain are rejected; present measuring apparatus can detect changes of 3 per cent over the 5,000-hour period with certainty. Smaller changes than this are within random fluctuations in measuring equipment and temperature stability of the measuring ovens.

The final stage in the analysis of reliability is the careful investigation into each individual failure produced in the over-stress tests. This examination may reveal flaws in the visual and thermal screening stages, and enable information to be passed back to the processing group to improve the overall standard of output. Also, the careful investigation into the basic physical processes of failure may lead to early recognition of the mechanisms and provide valuable theoretical information to their dependence on temperature. It is, of course, essential that all failures should be attributed to physical mechanisms which obey the simple model. The main difficulties arise either where there are two failure mechanisms operating together, or where a change of state occurs between the operating and over-stress temperatures. Either of these cases would nullify the over-stress results, and methods for detecting such failures are being developed.

ACKNOWLEDGEMENT

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References

[1] HOLMES, M. F. Semiconductor Device Developments: General Introduction. *P.O.E.E.J.*, Vol. 59, p. 202, Oct. 1966.

[2] HENDERSON, J. C., and WILSON, SYLVIA, J. Design and Technology of Silicon Planar Transistors. *P.O.E.E.J.*, Vol. 56, p. 238, Jan. 1964.

[3] BAKER, D., and BRIAN, J. E. An Improved Form of Thermo-compression Bond. *British Journal of Applied Physics*, Vol. 16, p. 865, 1965.

[4] CORKE, R. L., and SEARLS, A. W. A Clean Room for the Production of Silicon Planar Transistors. *P.O.E.E.J.*, Vol. 59, p. 34, Apr. 1966.

[5] SCARBROUGH, R. J. D., and AUCHTERLONIE, J. A. The Isolation of a Failure Mode in Silicon Planar Transistors caused by Organic Residues Associated with Aluminium Wire. *Microelectronics and Reliability*, Vol. 6, p. 319, 1967.

APPENDIX

Characteristic	Conditions with Case Temperature 25°C	4A2B Input and Intermediate Stages		4A2C Output Stage	
		Minimum	Maximum	Minimum	Maximum
I_{EBO}	V_{EB}: 3V	—	100 nA	—	100 nA
I_{CBO}	V_{EB}: 15V	—	10 nA	—	10 nA
h_{FE}	I_E: 10 mA; V_{CE}: 10 V	100	200	—	—
h_{FE}	I_E: 35 mA; V_{CE}: 15 V	—	—	75	150
h_{fe}	I_E: 10 mA; V_{CE}: 10 V	4	5·5	—	—
h_{fe}*	I_E: 35 mA; V_{CE}: 15 V	—		3·5	5·0
C_{ob}	V_{CB}: 5 V	2 pF	4 pF	2 pF	4 pF
$V_{BE(Sat)}$	I_C: 50 mA; I_B: 1·5 mA	0·75 V	1·0 V	0·75 V	1·0 V
$V_{CN(Sat)}$	I_C: 50 mA; I_B: 1·5 mA	—	1·0 V	—	1·0 V
$V_{CE(Sust)}$	I_C: 10 mA pulsed	25 V		35 V	
N (1 MHz)	I_C: 1 mA; V_{CE}: 6 V	—	3·5 dB	—	—

* At 100 MHz

Programmed Learning—A New Design for Training

Part 2—Past, Present and Future Uses in Regional Engineering Training

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U.D.C. 371.33: 658.386

Programmed learning, which was described in Part 1 of this article, has been used in the London Telecommunications Region Engineering Training School for some 3 years. In this part, the effect on training of the need for task analysis is emphasized, and the various media of presentation and some of the many teaching machines are described and their use reviewed. Experience in the Regional Engineering Training School is also described, and the benefits to be gained by large-scale adoption of programmed learning are discussed.

INTRODUCTION

In Part 1 an explanation of programmed learning was given, and examples of linear and branching programs were illustrated. In this Part the various media of presentation of programmed learning and some of the machines which have been used in the London Telecommunications Region (L.T.R.) are described. Such important factors as the rigid use of task analysis and the financial savings which have been gained, and could be gained, by the use of programmed learning will be discussed. Also included is a report of the experience of the last 3 years, and suggestions for the possible future uses of programmed learning in Regional Engineering Training Schools.

TASK ANALYSIS

The advent of programmed learning has meant an increased awareness of the need to relate training and job requirements—so much so that it is now a prerequisite of all program writing that a task analysis[1] should be carried out. This phase of the exercise is alone sufficient to result in considerable improvement in training.

The actual object of task analysis is to determine what a person does, how he does it, what he does it with, what he does it to, and the reasons why he does it. In this way it is possible to isolate the knowledge, skills and attitudes which are essential to job or subject mastery. The analysis helps to guard against the dangers of teaching too little or teaching irrelevant material, and reveals the discrepancies or assumptions in the existing literature or manuals which describe the task. It is unfortunate that this type of analysis is often tedious, time consuming, expensive and difficult to carry out, as this results in a tendency for it to be sacrificed on the grounds of expediency or economy.

In carrying out a task analysis[2] it is customary to describe all overt acts carried out by the technician or craftsman in terms of task elements. Each description of such an element needs to include[3] the following.

(*a*) An indication or cue which signals the beginning of an action, e.g. excessive feeler-gauge clearance.

(*b*) An action word, usually a verb and its associated qualifiers, e.g. adjust.

(*c*) A control or physical object which the technician or craftsman manipulates or acts upon, e.g. Allen key, tappet screw.

(*d*) An indication of response adequacy, which takes the form of another signal. This tells him when his action has been carried out correctly, e.g. a feeler gauge indicates the correct clearance.

Thus, a complete and reliable task description would be "When there is an excessive feeler-gauge clearance, adjust the tappet screw until the correct clearance is determined by using the feeler gauge."

THE MEDIA OF PRESENTATION

Programmed learning and teaching machines are often referred to in similar terms. There is a confused conception that when programmed learning is described then teaching machines are inferred. This is not so: a lesson can be prepared by programmed-learning methods and can be fitted to whichever media happen to be most suitable for the students under consideration.

If the information is to be given in very easy steps to a limited target population then a linear program will be prepared, and this will be presented on a simple teaching machine, on sheets of paper, in a loose-leaf binder, or in a bound text-book. If the information to be imparted were more difficult to understand, and alternative answers would benefit the students or widen the target population, then a branching program or a mixture of linear and branching programs would be written. This could be presented either in sheets or scrambled book form, or in one of a number of branching teaching machines.

Conventional lectures can be prepared using programmed-learning techniques, and then neither teaching machines nor books will be used. Very definite claims have been made for the great improvement shown by lecturers who have spent some time in a programmed-learning group and then returned to lecturing.

Programmed learning is, therefore, a method of preparing learning material, and the media through which it can be applied are sheets of paper, books, teaching machines, overhead projectors, audio tapes, closed-circuit television, or conventional lecture methods.

The programmer decides, by careful study of the target population, the content of the program and the terminal behaviour desired from the students, whether the program shall be linear, branching or a mixture of both, and if the medium will be sheets of paper, a book, a teaching machine or conventional lecturing.

† London Telecommunications Region.

TEACHING MACHINES

In recent years a large number of different types of teaching machine have been offered to training and education offices. At first there were very few programs associated with the machines, but, recently, more and more programs have been written for various levels of student learning.

A teaching machine is simply a mechanical or electrical device for the controlled presentation of programmed material. It may consist of a simple mechanical arrangement for picking up one sheet of paper after another and allowing the student to read only one section of a page at a time. The other extreme is an electronic device with access to a computer, which has a store of many branches or graded levels of learning, so that the student can be switched from level to level in keeping with his responses to the many questions which are set for him. The simple linear machine may cost only a few pounds, but the computer type is complex and the machine, together with its multi-stream program, could cost many thousands of pounds.

Some of the machines which have been used in the L.T.R. Engineering Training School are of interest, and the following paragraphs give a brief outline of the machines and their relative merits.

The Grundymaster

The Grundymaster (Fig. 5) is a simple linear teaching machine that is operated by a large knob, turned by the student when he is ready to take the next step. The program material is linear and printed on sheets of paper, but the machine allows only a small amount of the page of information to be presented to the student at one time. When he has written his answer in the space provided the student turns the knob and controls the page so that it only moves one frame at a time. His answer moves under the transparent

FIG. 5—The Grundymaster teaching machine

screen so that he can read it but not change it. The positioning of a black screen obscures the correct answer until the student turns to the next frame, when he can both check the first answer and read the second frame. Reference to Fig. 5 will illustrate the process. In a well constructed program, he will obtain 80–90 per cent correct answers; he is thus tested and rewarded at each step. If his answer is wrong he can re-read the frame to check the validity of the given answer. Should he not agree then he can consult the tutor. By the time the average student is presented with a program, the frames will have been validated many times by the programming team, and the time taken for the tutor to explain the answers will be very short.

International Tutor Machines, Ltd., who manufacture the Grundymaster, have prepared many programs for their machine. Some of these programs have been used to teach power apprentices how to use hand tools and machine tools; the level of learning is appropriate to young apprentices in industry.

Some difficulty has been experienced with the sequencing of the individual sheets of paper, but this problem is under investigation.

The Autotutor

The Autotutor machine (Fig. 6) uses 35 mm film, and the program is usually branching. By using a special code running along the edge of the film it is possible to move the film backward and forward as required. The image is back-projected on to a ground-glass screen, not unlike a television screen in appearance. The movement of the program is controlled by a row of buttons marked A to I and a return button marked R. It is possible to give five alternative answers for the student to choose, and any correction is catered for by the branching nature of the program when he has chosen an incorrect answer.

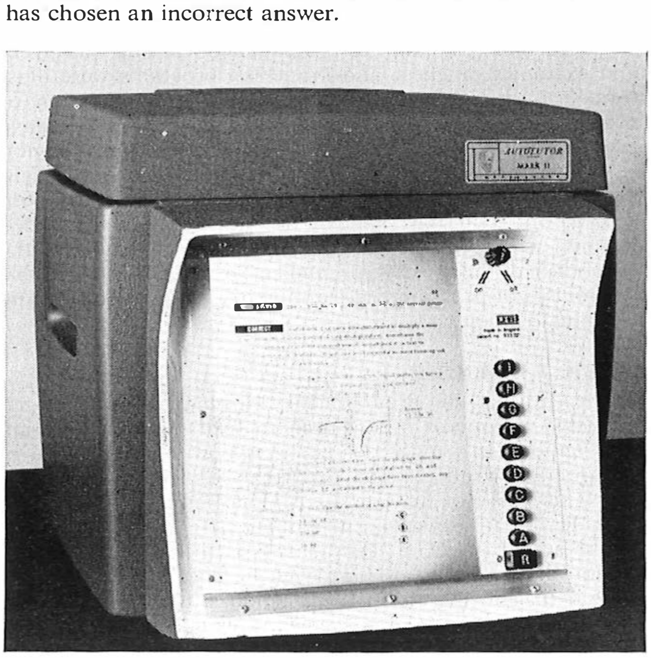

FIG. 6—The Autotutor

The machine, manufactured by U.S. Industries, Inc., gives very little trouble when subjected to the rigours of the classroom. The cost of preparing a program on film is high and subsequent amendments are costly. Unfortunately, the programs which have been prepared for this machine are not aimed at the L.T.R. target population, and so the machine has had a limited application in the Regional Engineering Training School.

The Canterbury

The Canterbury teaching machine (Fig. 7) makes use of the standard 8 in. × 5 in. filing card suspended by its shorter side so that the card takes up the more acceptable page shape of a text book. Slots are cut in the upper edge, and, by a simple but ingenious use of a spring-loaded grip and pairs of selection pins, it is possible to make a four-selection type machine. A handle on the lower left-hand side of the machine may be placed in one of four slots A, B, C or D. This enables the programmer to use any three of these four arrangements on any one card, and so he can use a question and three-answer branching program. Operation of the lever drops a predetermined number of cards if the choice is correct. If an incorrect choice has been made it is likely that only one card will drop, and the next card will correct the student and ask him further questions if necessary. This machine can also be used for linear or mixed technique programming.

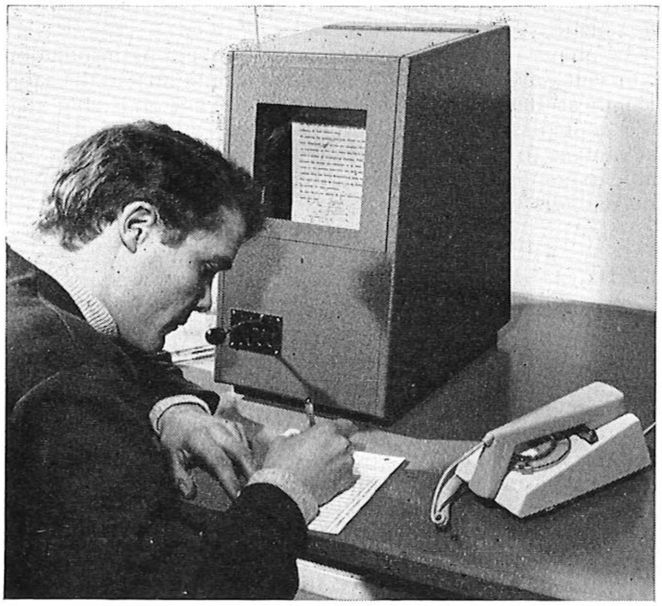

FIG. 7—The Canterbury teaching machine

The advantage of the Canterbury machine, manufactured by the Education Supply Association, lies in the ease with which the program can be corrected on validation, or changed, by simply inserting more cards, when additional information is required. Further advantages of the Canterbury machine are its relatively low cost, its portability and the fact that it does not require a mains power supply.

EXPERIENCE AT THE L.T.R. ENGINEERING TRAINING SCHOOL

In 1964 experiments were carried out at the L.T.R. Engineering Training School with the programs which were available on teaching machines which could readily be rented. The first experiments used the Autotutor machines with programs on mathematics, electronics and management studies. The students were very interested, but, although the results were similar to those obtained by conventional methods, the programs had not been written for the level of the student using the programs, and this caused difficulties.

Later in 1964 it was decided that a special program should be written to help in the solution of the difficult problem of training field staff upon the introduction of new subscribers' equipment. A small group of one programmer and one assistant was set up, and after some experimental work it was decided to write two programs covering, firstly, the facilities and installation details and, secondly, the maintenance of the Trimphone.

Because these programs were to be sent out into the Telephone Area Installation Offices it was decided that the information should be presented in such a manner that the student could have a teaching machine, note-book and the necessary equipment arranged around him on a desk or table. By this method it was possible to combine the three stages used in the Regional Engineering Training School: lecture, demonstration and practical work. These would take place almost simultaneously, thus maintaining the interest of the student and giving him stimulus by immediate reward as discussed in Part 1.

The first Trimphone program was analysed, written, validated, revised and finally tested in 9 weeks. This program covered the facilities and installation details. Today the same program could be written in shorter time, and would probably contain less frames.

The finished program was used with the Canterbury Teaching Machine in the North West Telephone Area of the L.T.R., where all the fitters and their supervisors were taught the facilities and installation aspects of the Trimphone. Each fitter spent approximately 1 hour in his local Installation Office working through the program and carrying out instructions on how he should remove the telephone base, learn about the contents, re-assemble and fit the telephone, etc.

A second program on the maintenance of the Trimphone was written, and this was given to all the subscribers' apparatus maintenance staff in the North West Telephone Area. The Appendix gives a summary of the results of these two programs. There is little doubt that the trial was well received in the North West Telephone Area, and this has also been so in the North Telephone Area of the L.T.R., and in the Northern Ireland, and Wales and Border Counties Directorates where the L.T.R. programs have been used to teach staff the facilities, fitting and maintenance of the Trimphone.

In recent months, a complete training course, the initial subscribers' apparatus installation course, has been written in programmed-learning form and is at present being validated. By the time this article has been printed many students in the L.T.R. will have received their instruction by this method. Originally planned to take 9 days, the course has been programmed so that the faster students become apparent in the first few days and arrangements can be made for them to return to their Telephone Areas on completing the course. For example, if a student takes only 7 days, there will be a saving of 2 days for productive work in the field; he can, moreover, be replaced immediately by another student, because the system allows for the students to progress at their own speed and move from stage to stage independently. Only at two or three points in the course will it be necessary to give conventional lectures, and these will be of a summarizing nature and can be given to students at slightly different stages of progress.

As previously mentioned under the section dealing with the Grundymaster teaching machines, the power apprentices are, at the present time, being taught hand tools and machine tools by programmed learning. The programs were written for apprentices in industry, but it has been found that L.T.R. Engineering Training School students have attained the required standard set by the original programmers, and also within the specified times.

FINANCIAL SAVINGS

Training is expensive irrespective of the form in which it is presented—not only in terms of school costs, but also in terms of lost work and the cost of products and materials used in the teaching process. Although there have been many recorded instances where the application of programmed learning has reduced training time and resulted in higher job proficiency, there are few which have been costed in terms of money saved. An exception was a study[4] which involved an American manufacturer of telephone relays, who employed 120 men to produce 6,000 relays every day at a manufacturing cost of $2 each; a further 120 men were employed to adjust the relays manually at an additional cost of $1 per relay.

It was decided to study the cost of training the relay adjusters, 40 of them being trained every year at a total cost of

$80,000. This amount accounted for the actual cost of training, of production lost and of the overheads involved. The existing training system consisted of 5 hours of lecture-demonstration followed by the adjustment of simple relays while "on the job." It took about 60 working days for an average trainee to attain 70 per cent of his department's production standard. At the end of a year he was expected to reach between 85 and 100 per cent. After the use of programmed learning, the trainees attained the 70 per cent standard in 40 days, and the cost of training was calculated to be $59,000, thus showing a saving of 33 per cent in time and 26 per cent in money.

Investigations were also made into the cost of supervising the trainees. Under the original system the supervisor sacrificed 10 per cent of his productivity, equivalent to $1,000 per year, to training. Total cost of supervision for all the trainees, at 40 per year, was $40,000 per year. Programmed learning reduced the supervisor's time to one half, and thereby saved $20,000 in supervisory time. The total estimated savings were $41,000 per year on what had been a current training cost of $120,000 per year—a reduction of approximately one third. It was estimated that the cost of the program, involving tape recordings, still pictures, cine films and five relay simulators, was all recovered by the end of 1 year.

Recently, a cost comparison was made between the teaching of the Trimphone-facilities program by programmed learning and by conventional methods. The terms of the comparison were that the student would receive training in the necessary information and skill by (*i*) the programmed-learning method, using a teaching machine in a Telephone Area office, or (*ii*) conventional presentation at the Regional Engineering Training School.

(*i*) In costing the programmed-learning method the time of one programmer and one assistant, together with a typist, was considered, and estimates were made for the cost of the machines, the blank program cards and the Trimphones. It was shown that the total costs were as follows.

			£
Total cost for	100 students	=	809
Total cost for	400 students	=	863
Total cost for	1,000 students	=	977
Total cost for	10,000 students	=	2,590

(*ii*) Costing of the conventional method included lecture-preparation time, presentation time together with demonstration time, certain overheads and the cost of the Trimphones, and gave the following figures.

			£
Total cost for	100 students	=	283
Total cost for	400 students	=	483
Total cost for	1,000 students	=	885
Total cost for	10,000 students	=	8,500

Above 1,200 students the conventional method was calculated to be more expensive than the programmed-learning method. This number of students will quickly be achieved in the L.T.R. alone, since the program will be required by all subscribers' apparatus installation and maintenance staff. Experience suggests that savings could be obtained with the initial subscribers' apparatus installation course where the numbers of students will be large, but the cost ratios would not be so marked.

FUTURE OF PROGRAMMED LEARNING IN THE REGIONAL ENGINEERING TRAINING SCHOOL

The use of programmed learning as a method of teaching has been accepted throughout the world, and many countries are pushing ahead with its application in education and also in industry. Experience at the L.T.R. Engineering Training School shows that, with large numbers, savings in instructors' time and students' time can be made. In an atmosphere of improved productivity, where the time given to training a man is more important than ever, a system which can make a recruit more productive in less time is of obvious merit. Programmed learning is objective: its aim is to improve training, reduce the training time taken by a student, and reduce the time taken by the tutor and his staff. All these things it can do, but it has to be applied with great care; in particular, it needs to be applied only after a most searching analysis into the tasks and skills which it is envisaged will be taught.

In preparing the initial subscribers' apparatus installation course it was decided that the course should remain the same length as that required by conventional methods, but that the contents should be more detailed, which would be of advantage to the slower student. Quicker students should be able to complete the course in two to three days less than the normal two weeks.

CONCLUSIONS

The benefits to be gained from the introduction of programmed learning on a large scale are numerous and have already been mentioned. With detailed analysis, some school courses may be reduced in length and made more interesting and far more efficient; productivity would moreover be improved. A complete analysis of all the Regional Engineering Training School courses would take many years, but a detailed examination of the more elementary and frequently held courses—the two apprentice courses, the initial subscriber's apparatus installation course (already completed), initial jointing course, and several of the early installation courses—would improve training and reduce the overall time spent in the schools.

ACKNOWLEDGEMENTS

Acknowledgements are due to the three manufacturers of the teaching machines briefly described, namely, International Tutor Machines, Ltd., U.S. Industries Inc. (Great Britain), Ltd., and Educational Supply Association.

References

1 Stainer, F. W. Task Analysis—A Case Study. *Programmed Learning Educational Technology*, Vol. 4, p. 52, Feb. 1967.

2 Davies, I. K. Analytical Synthetic Stages of Programme Writing. *Programmed Learning*, Vol. 2, Number 2, 1965.

3 Miller, R. V. The Newest Rates of the Industrial Psychologist. *Industrial Psychology*, ed. Gilmer, B. H., New York, 1961.

4 Hickey, A. E. Programmed Learning in Business Industry. *Applied Programmed Instruction*, ed. Margulies, S., and Eigen, L. D., New York, 1962.

APPENDIX

Trimphone Programs

Facilities Program

Final draft, with subject revision (February 1966).

Number of frames in program	=	107
Minimum student time	=	40 minutes
Maximum student time	=	100 minutes
Mean student time	=	71 minutes

Result of Criterion Test

100 per cent students obtained a mark of more than 85 per cent.

Mean mark	=	93 per cent
Standard deviation	=	4·8 per cent
Improvement against first draft	=	7 per cent

The final draft contains additional material to cater for the Mark II Trimphone. The 7 per cent improvement accompanied a reduction in the standard deviation.

Retention Test

Taken 3 weeks after the criterion test.

Mean mark	=	86 per cent
Standard deviation	=	10·0 per cent
Retentive loss (after 3 weeks)	=	7 per cent

Maintenance Program

Final draft (March 1966).

Number of frames in program	=	60
Minimum student time	=	50 minutes
Maximum student time	=	110 minutes
Mean student time	=	79 minutes

Result of Criterion Test

83 per cent of students obtained a mark of more than 90 per cent.

Mean mark	=	90·8 per cent
Standard deviation	=	10·4 per cent
Improvement against first draft	=	6·1 per cent

Again, an improvement in the final draft accompanied a reduction in the standard deviation.

Numbers of Students Involved

Validation tests:	approximately	143
Fitters trained in North West Area:	approximately	400
Other Areas (fitters and maintenance):	approximately	1,000

Cable, Drop-Wire, No. 4

U.D.C. 621.315.2

Experience with modern drop-wire methods of local overhead construction has led to the development of an improved type of drop-wire cable that has both a greater breaking strain and an insulation with increased resistance to abrasion.

Since 1954, when the first of the modern drop-wires was introduced, several problems concerned with their use have arisen. For example, Cable, Drop-Wire, No. 2 is relatively costly due to its complex insulation, which has a low abrasion resistance and tends to stretch and rupture near wedge-type terminating clamps under working conditions. The breaking strain of the drop-wire is 290 lb minimum—insufficient to enable the drop-wire to be erected with an adequate safety factor in span lengths greater than 60 yd.

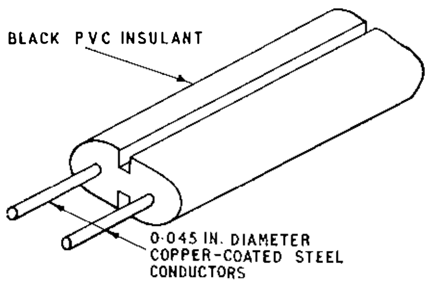

FIG. 1—Cable, Drop-Wire, No. 4

In comparison, Cable, Drop-Wire, No. 4 (see Fig. 1) has two copper-coated steel conductors, 0·045 in. diameter, each having a breaking strain of between 300–350 lb. A black PVC insulation of mean thickness 0·065 in. means that the overall size and weight of the drop-wire is such as to allow 75 yd spans to be erected at a tension of 50 lb. High-voltage electrical breakdown tests have confirmed that the PVC insulation is suitable for use up to 11 kV. Dropping tests, which involved releasing bare power conductors (which were under tension) and allowing them to fall freely over the drop-wire, were also held. Only a slight abrasion of the insulation occurred. Impact tests confirmed this result.

The drop-wire will be erected using the existing fittings used in erecting Cable, Drop-Wire, No. 2 with one exception. Fig. 2 shows the double-legged, helically-wound, terminating

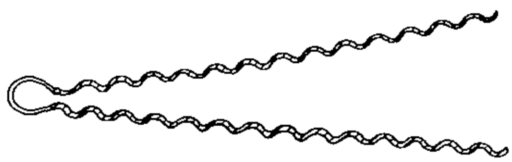

FIG. 2—Clamp, Drop-Wire, No. 4

clamp (Clamp, Drop-Wire, No. 4) that was designed to give easy application and adequate grip on the drop-wire in the shortest overall length, as shown in Fig. 3.

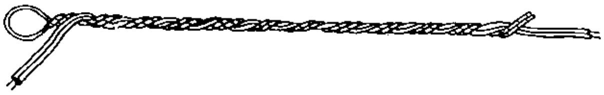

FIG. 3—Clamp, Drop-Wire, No. 4 fitted to Cable, Drop-Wire, No. 4

Considerable savings will be made now that Cable, Drop-Wire, No. 4 has been introduced to supersede Cable, Drop-Wire, No. 2 and Wire, Cadmium-Copper, 70 lb, PVC. While it will also supersede the use of Wire, Cadmium-Copper, 70 lb, H.V. at power crossings up to 11 kV, Wire, Cadmium-Copper, 70 lb, H.V. will still be needed at power crossings between 11–30 kV. The use of Cable, Drop-Wire, No. 3 will not be affected.

E. A. H

Transit Switching Centres Using BXB1121 Crossbar Equipment

Part 2—Circuit Principles and Equipment Practice

N. WALKER, M.B.E., B.SC.(ENG.), C.ENG., M.I.E.E., F. A. STALLWORTHY and R. F. McLUSKY, C.ENG., M.I.E.E.†

U.D.C. 621.395.344.6: 621.395.722

Part 1 of this article described the basic crossbar-type group selection unit used at transit switching centres and gave details of the trunking and facilities provided. A description of the general operation of the equipment was also included. Part 2 describes the circuit principles and the equipment practice used. Details are given of the method of code translation, internal signalling, route monitoring, link selection and route marking. The three types of electromechanical relay and the magnetic counter used are also described, and equipment installation aspects are briefly reviewed.

CIRCUIT PRINCIPLES

Code Translation

The circuit elements involved in the transfer of codes from the register to the translator, via the coupler, and from the translator to the marker, via the coupler and information paths, are shown in Fig. 9.

The m.f. receiver receives three digits as m.f. pulses, and passes them to the register in d.c. form to operate two of the relays 0R, 1R, 2R, 4R, 7R and 11R (not shown). Contacts of these relays form a check element to verify that only two relays are operated, and, if this condition is met, earth potential is applied for the duration of each pulse via the make contacts of two of the relays 0R–11R. The earth potential is extended for the first-digit pulse via break contacts of relays 3H, 2H and 1H to operate two of the code-storage relays 1A–1F in the register according to the 2-out-of-6 code; these relays store the first digit.

The operated relays 1A–1F prepare a locking circuit over their respective make contacts to a register-circuit holding earth potential. At the same time, they extend the operating earth potential to keep relay 1G short-circuited for the duration of the pulse. When the first-digit pulse ends, releasing the operated 0R–11R contacts, relay 1G is no longer short-circuited and operates in series with relays 1A–1F via the locking contacts. The two relays 1A–1F are also held. A contact of relay 1G operates relay 1H, which locks via a second winding to reduce holding current and also short-circuits relay 1G, which releases. The two relays 1A–1F remain held, along with relay 1H.

Change-over contacts of relay 1H connect the 0R–7R contacts to storage relays 2A–2E in the register. The 11R contact is disconnected, as the second and third digits are in 2-out-of-5 code and not 2-out-of-6.

The 2-out-of-5 code pulse for the second digit re-operates two of relays 0R–7R, and operates two of the storage relays 2A–2E in the register in a manner similar to that described for relays 1A–1F. At the end of the second-digit pulse, relays 2G and 2H operate. Change-over contacts of relay 2H connect the 0R–7R contacts to storage relays 3A–3E in the register. The 2-out-of-5 pulse for the third digit operates two of the storage relays 3A–3E in a manner similar to that described for relays 1A–1F. At the end of the third-digit pulse, relays 3G and 3H operate. Break contacts of relay 3H disconnect contacts 0R–7R, preventing further receiver operations affecting the 3-digit code now stored on two relays in each of the groups 1A–1F, 2A–2E and 3A–3E.

The coupler connects the locking earths of the operated register-storage relays directly through to a translator. These earth potentials cause two corresponding translator-storage relays to operate and lock in each of the groups 1A–1F, 2A–2E and 3A–3E.

Each of the three sets of digit-storage relays in the translator has contacts to form a 2-out-of-6 or 2-out-of-5 check element as required. If the check element verifies that only two relays are operated in each instance, then the 2-out-of-6 code (15 combinations) and the two 2-out-of-5 codes (10 combinations each) are expanded to 1,500 individual points, and one point corresponding to the stored code is earthed. This point will be strapped to one or more route relays, RG, which operate in readiness to give the translated code for the marker to identify the route. At a T.S.C. there may be more than one route suitable for a particular destination, and at this stage in the call a check is made to establish whether the first choice or an alternative route is free. The first available route is identified by causing earth potential to be connected to four contacts of the appropriate RG relay. These contacts earth one lead in each of four sets of 10 leads that are connected via a diode matrix to give four digits in 2-out-of-5 code. These digits are stored on relays in the coupler and are then passed to the markers, as required, over an information path. Normally, two of the digits, representing a 1-out-of-100 selection, will be given to the markers of the first-stage group selection units, whilst the other two digits, also representing a 1-out-of-100 selection, will be given to the markers of the second-stage group selection units.

Information Paths

Internal digital and information signals are transmitted between the registers, or couplers, and the markers during the establishment of calls. Groups of common connecting wires, referred to as information paths, are used for this purpose. One information path consists of 20 wires, and the number of paths provided is determined by the traffic requirements. Any free path can be seized, and on each seizure is held long enough for the transmission of the required forward

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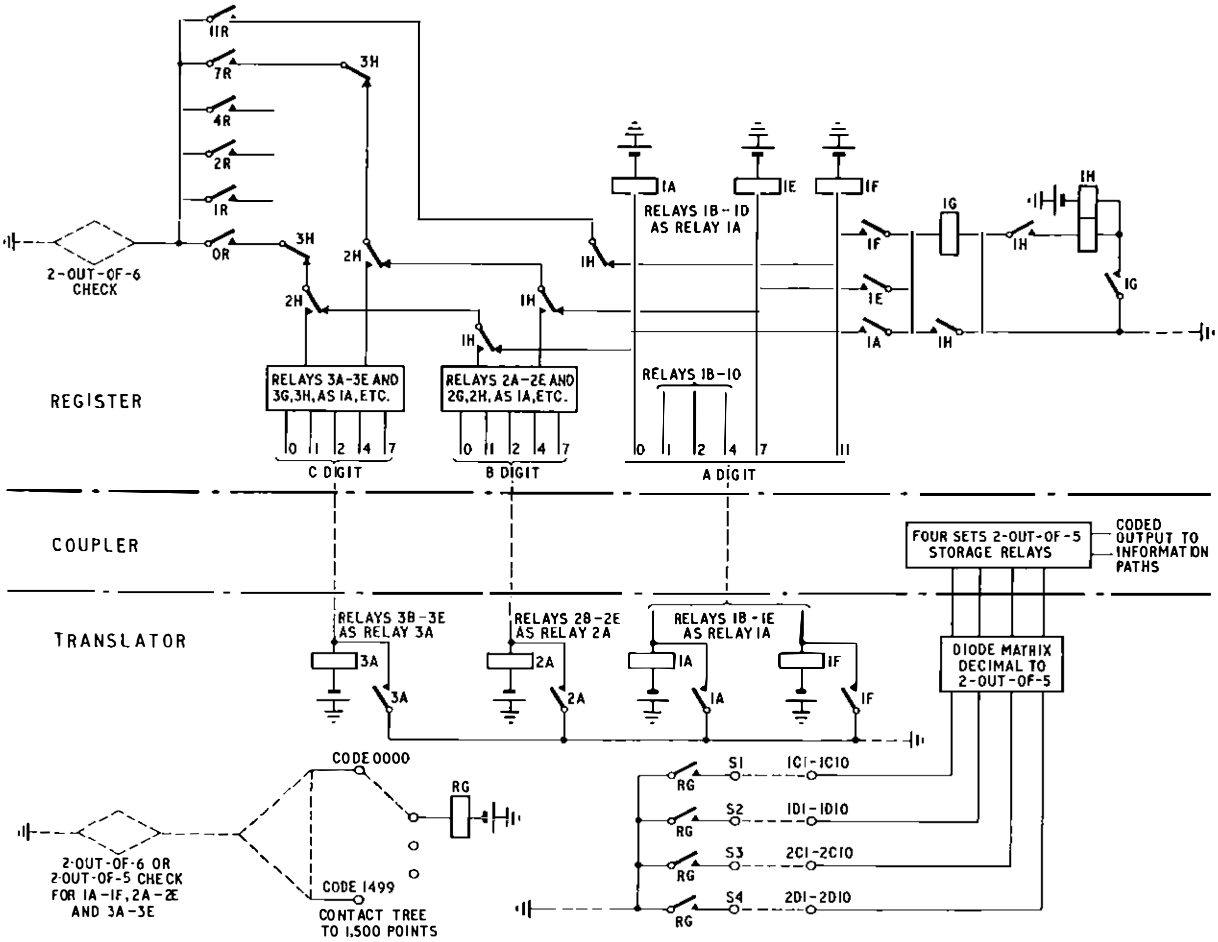


FIG. 9—Circuit elements used in transfer of codes to and from translator

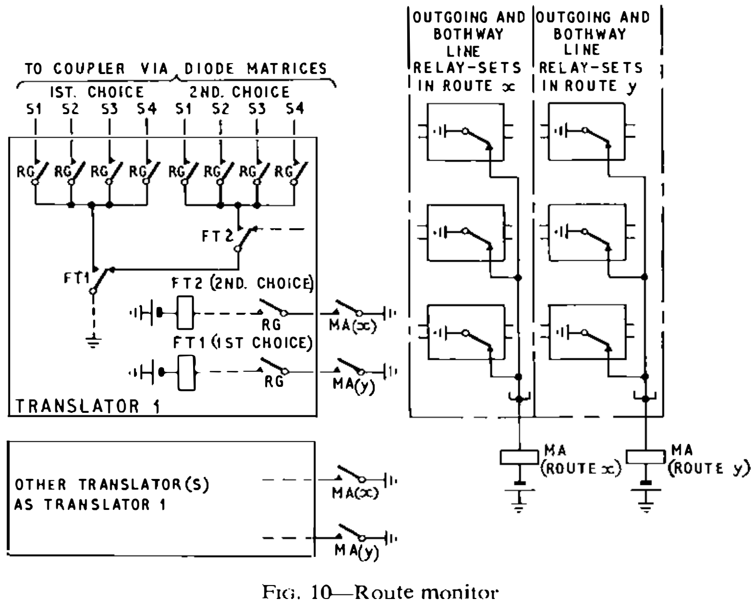


FIG. 10—Route monitor

or backward signals between the equipments concerned. The signals are in d.c. form, digital signals being passed as two conditions on five wires, while each information signal makes use of one or more wires, as required.

Route Monitoring

Fig. 10 shows how the route monitor determines whether a route contains any free circuits, and how it makes this information continuously available to all translators at the T.S.C. One MA relay is associated with each outgoing route, and it is energized so long as any circuit in the route is free. When all circuits are busy (in or out of service), the MA relay is released and its contacts remove earth potential from a lead to each translator.

When a translation is required for a code appropriate to, say, route y a relay RG operates in the translator, and, if the contact of relay MA(y) is operated, a relay FT1 operates and the translation routing information for route y is given to the coupler by causing earth potential to be connected via four contacts of the RG relay.

If, for a given code, route y is the first choice and route x the alternative choice and both routes have free circuits, then two FT relays will operate. However, the first-choice translation only is given to the coupler, as a contact of relay FT1 (first choice) controls the earth connexion to the appropriate four contacts of an RG relay. In the event of route y being busy and route x being free, relay MA(y) is released and relay MA(x) is operated, and, when the RG relays operate, relay FT2 (second choice) only operates and the translation for the second-choice route x is substituted. If both route y and route x are busy when the RG relays operate, the two FT relays concerned remain released, causing the translation for congestion announcement to be substituted by the translator.

Link Selection

The circuit shown in Fig. 11 is simplified to indicate the fundamental selection of a free link between the primary section to which the incoming-line relay-set is connected and the secondary section having a free outlet in the required group of circuits. The coupler will have already signalled the primary section to seize a marker, thus operating relay CL (not shown) in the primary section concerned. On seizure, the marker will seize an information path and signal the identity of the path to the coupler. The coupler will then be connected to the information path and pass the code of the required route to the marker. All free outgoing-line relay-sets have their m-wires marked with earth potential. On receipt of the code, contacts of the appropriate marking relays will extend earth potential from the free circuits in the route concerned to the m-wires of the secondary outlets on which they appear. At the same time, relay DF (not shown) in the marker operates. One DF contact operates relay CQ in the associated primary section, whilst another prepares to operate relays TF in all secondary sections.

Those secondary sections which have access to a free line relay-set (i.e. one having an earthed m-wire) will have their TA relays operated, and a TA contact in series with the TF relay allows the TF relay to operate in these sections. If these sections have a free link to the primary section with the operated relay CQ, the respective selector magnet TV will be normal. A TF contact in each of the wires p and r between the secondary and primary sections allows relay TM to operate. The operation of relay TM signifies a free link. Relay TM earths the TN and TO relays to establish if the secondary section has priority (see description of Fig. 13). If it has priority, relays TN and TO operate. Relay TN identifies the secondary section as the one to complete the selection, and

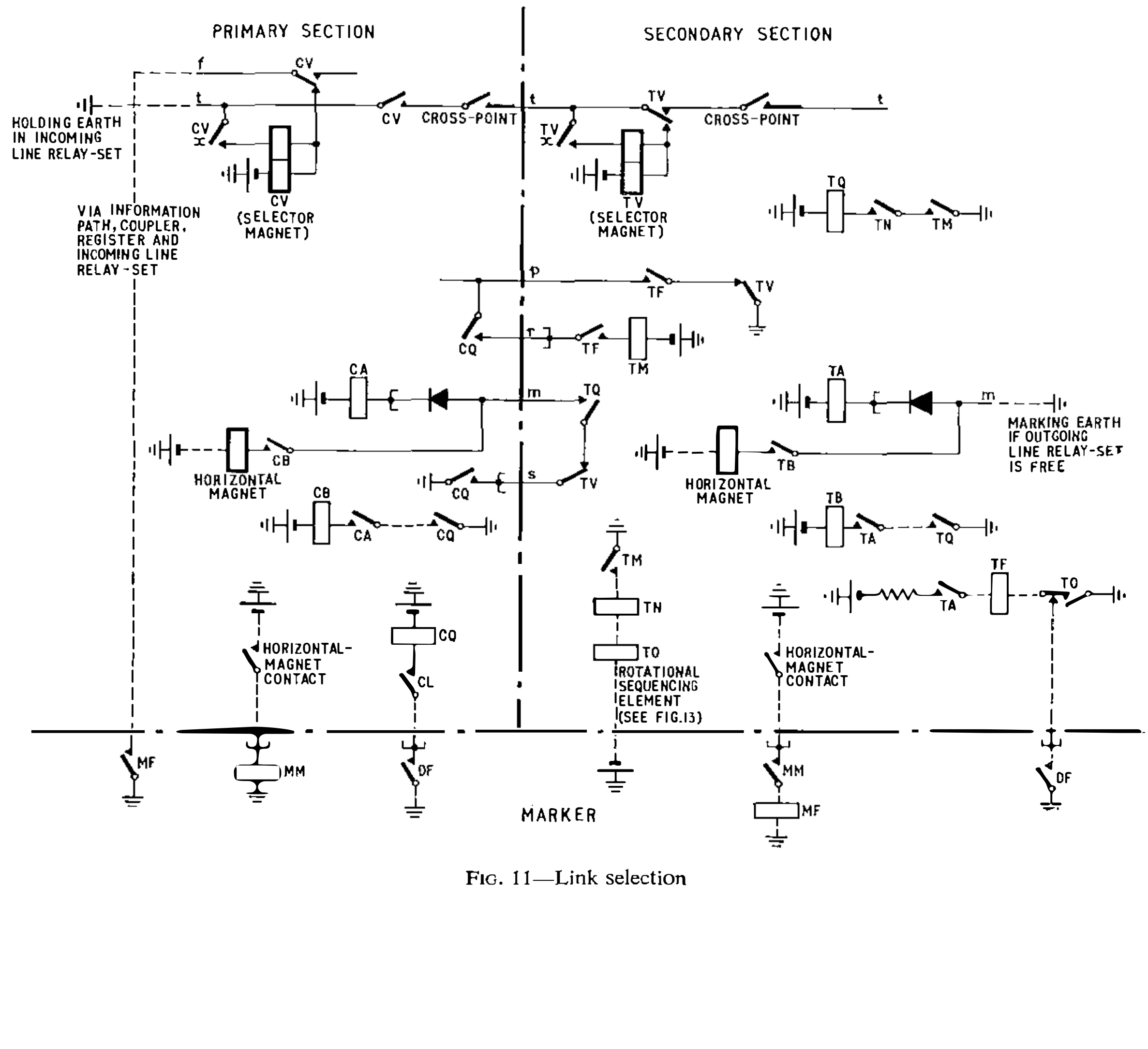


FIG. 11—Link selection

contacts of relays TM and TN operate relay TQ. Relay TQ operates relay TB. A TB contact connects the m-wire of the marked outlet to its associated secondary horizontal magnet, which operates. The operation of this magnet completes selection of the outlet.

If two or more free circuits in the required route arc available from the same secondary section, a priority arrangement, affecting the operation of the horizontal magnets in the section, establishes the order of choice.

A contact of relay TQ also connects together leads m and s to the primary section, operating relay CA. Relay CA operates relay CB, a contact of which connects the primary horizontal magnet to the m-wire from the secondary section. The operation of this horizontal magnet selects the specific primary outlet associated with the link to the secondary section. The operation of a contact associated with the horizontal magnet in the primary section connects --50 volts to operate relay MM in the marker. Likewise, a contact of the horizontal magnet in the secondary section connects −50 volts via an MM contact to operate relay MF in the marker. Relay MF indicates that both horizontal bars are operated.

At this stage an information path is seized, and a contact of relay MF causes a signal to be relayed via the information path, coupler, register and incoming-line relay-set to the f-wire of the primary section, operating the magnet (CV) of the primary selector associated with the incoming-line relay-set. Magnet CV operates and locks on its x contact to the t-wire holding earth, and disconnects itself from the f-wire. The cross-point associated with the operated selector and horizontal bar extends all leads (only the t-wire is shown) to the secondary section. The extension of the t-wire carrying the holding earth operates the magnet (TV) of the secondary selector associated with the switched primary outlet. Magnet TV operates and locks on its x contact to the t-wire holding earth. The cross-point associated with the operated secondary selector and horizontal bar extends all leads to the outgoing-line relay-set. The operation of break contacts on the TV magnet releases relay CA and the primary horizontal magnet. The extension of the leads to the outgoing-line relay-set causes it to remove the m-wire earth to release relay TA and the secondary horizontal magnet. Other relays now release, leaving a switched-through connexion with the selector magnets of both sections held by the earth on the incoming-line relay-set t-wire.

Route Marking

The required outgoing route is identified by two digits of the translation obtained from the translator and stored in the coupler. When the marker has seized an information path and signalled the path's identity to the coupler, the coupler passes the appropriate 2-digit code to the marker via this information path, in a 2-out-of-5 coded form. The marker checks each digit for only two conditions out of five, and signals the digits to the code tags of the marking relays as earth potential on one of 10 wires in each of the two groups of digit wires shown in Fig. 12. The circuit uses ten MW relays each with 10 contacts to give a unique marking on one of 100 code tags. A cross-connexion field is used for strapping code tags to their appropriate marking relays, SK, and provision is made for the outgoing circuits to be given priority in marking over the bothway circuits in the same route.

Assuming that the code of the required route is 90, then earth potential on the "tens" digit lead No. 9 will cause relay 9MW to operate. Contacts of this relay connect the 10 code tags 90–99 to the "units" digit leads, and earth potential on the "units" digit lead 0 is extended only to the code tag 90. The typical strapping shown in Fig. 12 is for the marking of route 90, assumed to have mixed unidirectional and bothway circuits. The SK relay contacts (not shown) arc used to mark the outlets of the secondary sections corresponding to the outgoing and bothway circuits in the route, one contact being required for each outlet in each portion of the route. One or more SK relays, each having up to 10 contacts, are required for each portion of the route. When the code tag 90 is earthed only the SK relay(s) of the outgoing portion operate. These are associated with the tag designated A. If any of the outgoing circuits are free their m-wires will be marked with earth potential and one of them may be selected as described under "Link Selection." If, after a delay of approximately 100 ms, no free outgoing circuit is available, relay SJ operates to extend earth potential from code tag 90 to the tag designated B, so operating the SK relay(s) of the bothway portion, which permits the m-wires of any free circuits in this portion to be marked and made available for selection.

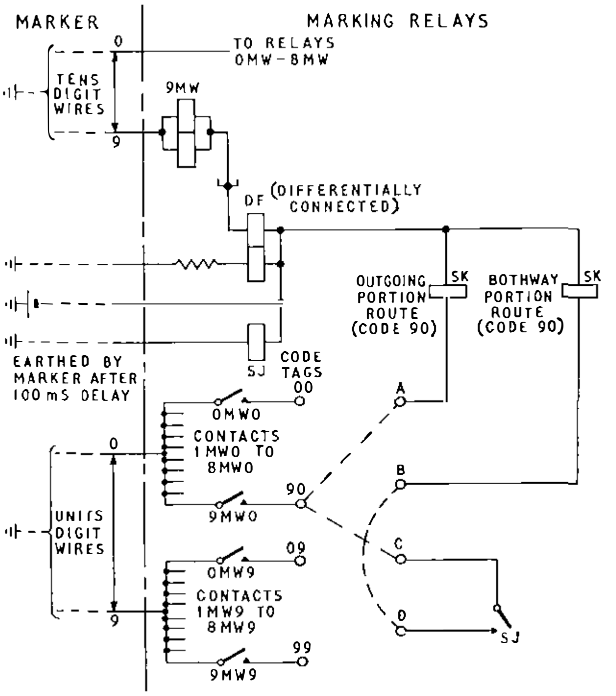


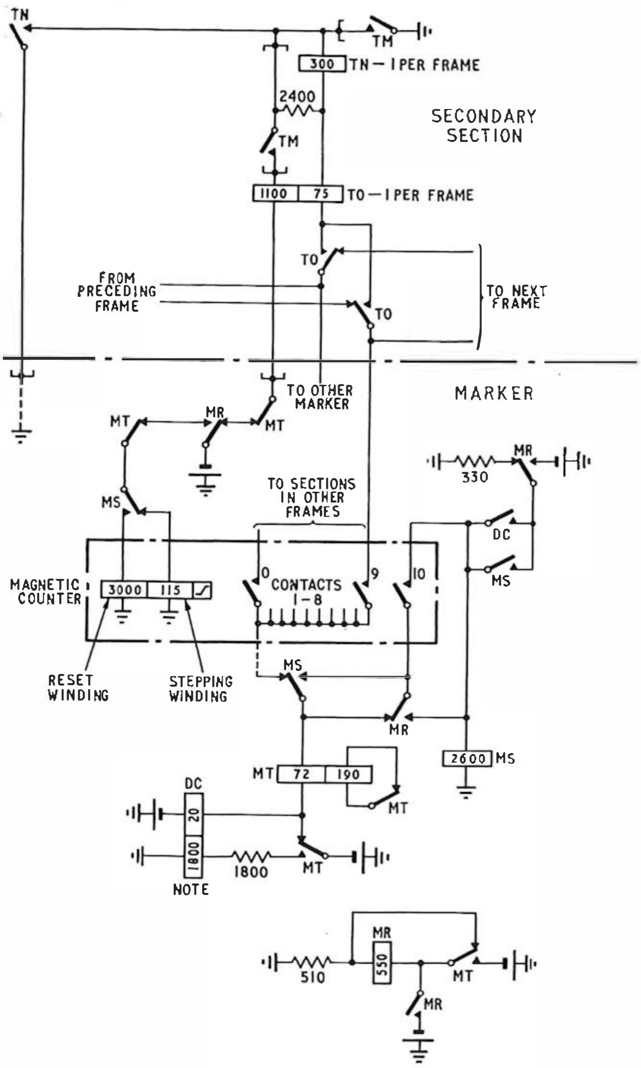
FIG. 12—Route marking

The double-winding MW relays provide a safeguard against a faulty winding causing marking failures. Provided both windings of an MW relay are in circuit, relay DF, which is differentially connected, remains balanced and unoperated. If, however, one winding of an MW relay is open-circuit, relay DF is unbalanced and operates to draw attention to a faulty MW relay while the circuit continues to function correctly.

Rotational Selection of Secondary Sections

In order to give even traffic loading within a group selection unit, and to ensure that the same equipment is not used on successive calls, it is necessary to arrange that any particular secondary section does not have continual priority of selection. A rotational sequencing arrangement in each marker ensures that priority of selection is given to each secondary frame in turn. As each secondary frame accommodates two secondary sections rotational sequencing affects secondary sections in pairs, but means arc provided to ensure that priority of selection is given to one section of each pair. Each group selection unit is served by two markers whose rotational sequences arc opposite to each other.

Fig. 13 shows the circuit elements involved. Priority of



Note: Relay DC is differentially connected.

FIG. 13—Circuit elements used in rotational selection of secondary sections

selection is controlled by a magnetic counter in the marker, which pre-allots the secondary frame. Assume that contact 9 is closed and that one of the two secondary-section TM relays has operated, thus indicating that the secondary section concerned is capable of completing the connexion. Contacts of relay TM operate relay TO to −50 volts via MT and MR contacts. A contact of relay TO operates relay TN to −50 volts via contact 9 of the magnetic counter, and also holds relay TO. Relay TN, operating, permits completion of selection to proceed as described under "Link Selection." Relay MT in the marker operates slowly. A break contact unit of relay MT releases any TO relays that may have operated in secondary frames other than the one allotted by the magnetic counter. Relay MT also operates relay MR, which locks to its own contact. A further contact of relay MR prepares for stepping the magnetic counter after secondary-section action is completed. On completion of this action relay TM releases and disconnects the holding earth of relays TN, TO and MT. The release of relay MT causes the slow release of relay MR by means of a short-circuit. It also connects −50 volts to the stepping winding of the magnetic counter during the slow release of relay MR. The magnetic counter advances one step, and the next secondary frame is given priority. The release of MR relay re-applies −50 volts to the secondary sections for subsequent seizures.

When the magnetic counter advances beyond contact 9 it has to operate contact 10 prior to operating contact 0, which allots the next frame in the sequence. By the interaction of relays MS, MT and MR the reset winding of the counter is pulsed after the release of relay MT and during the slow release of relay MR, and the magnetic counter is reset to 0.

A check against two contacts of the magnetic counter being closed at the same time is made following the operation of relay MT by the differentially-connected relay DC. Under fault conditions relay DC operates and causes relay MS to operate following the operation of relay MR. A contact of relay MS disconnects the −50-volt feed to the contacts of the magnetic counter, thus preventing further switching.

COMPONENTS

Standard Relays

The electromechanical relays used in the system are of two types. Fig. 14 shows a round-coiled relay having a twin-armed armature operating two spring-sets, and Fig. 15 shows a pair of oval-coiled relays having single armatures each operating one spring-set. The pair of oval-coiled relays can be mounted in the same space as one round-coiled relay.

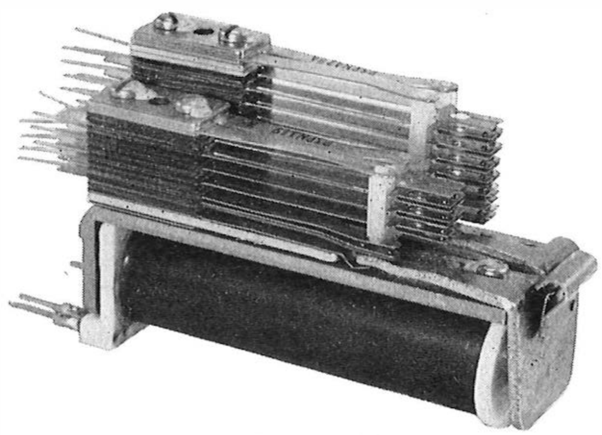


FIG. 14—Round-coiled relay

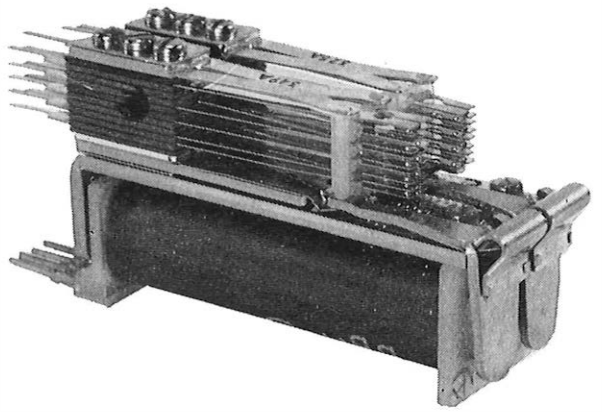


FIG. 15—A pair of oval-coiled relays

A round-coiled relay may embody two equal spring-sets having up to 26 springs each, to give a total contact arrangement such as 26 make units on a relay. One oval-coiled relay may embody up to 33 springs in a single spring-set, to give maximum contact arrangements such as 15 make-units and 1 change-over unit, or 16 make-units. However, it is normal practice to limit, where possible, the round-coiled relay to 15 springs for each spring-set, because above this value only a limited number of coil types can operate the load, and the relatively fast speed of operation cannot be maintained. It is normal practice to limit the relay spring-set of the oval-coiled relay to 26 springs; above this figure a special armature is needed.

The fixed and moving springs of a spring-set are held in two notched nylon combs and do not require individual tension adjustment. Tensioning against the armature is achieved by a special mechanical spring, at the top of each spring-set, bearing on the moving comb, which rests on the armature.

The standard contact material is an alloy of 90 per cent silver 10 per cent gold, electrically welded to the contact springs. The contacts are of the twin-domed type, and the contact surface is maintained by a slight "wiping" action in operation. Spring-set and coil terminals are arranged to take wire-wrapped connexions, although it is also possible to arrange a standard relay as a plug-in type by using an adaptor.

Quintuple Relay Unit

The quintuple relay unit is a special assembly of five small relays each having a single make-contact, mounted as one unit; it is illustrated in Fig. 16. Two of these quintuple relay units can be mounted together in the space of one standard round-coiled relay. These relay units are used mainly to register digits in a 2-out-of-5 coded form.

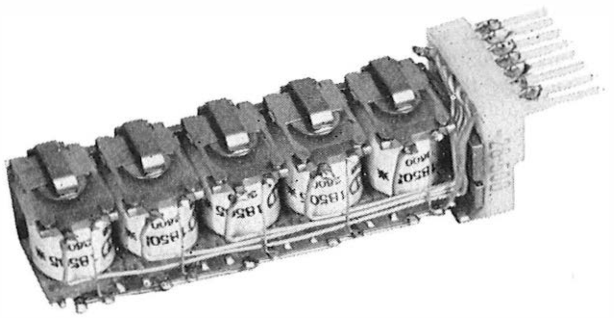


FIG. 16—Quintuple relay unit

Magnetic Counter

The magnetic counter is a stepping relay (Fig. 17) and occupies the space of two standard round-coiled relays. It comprises a double-winding coil on a single core, and is designed to operate 10 armatures in sequence. These, in turn, each operate a single make-contact. When pulses are fed to the stepping winding of the counter the armatures operate in sequence, one for each pulse. As each armature operates it prepares the succeeding one for operation, operates its own make contact and releases the preceding contact, all preceding armatures remaining held by residual magnetism. For example, after receiving four pulses, armatures 1 to 4 are held in the operated position, the fifth armature is ready to receive the next pulse and only the fourth contact unit is closed. To release the counter, one pulse to the reset winding is required, and this restores all the armatures to their initial positions.

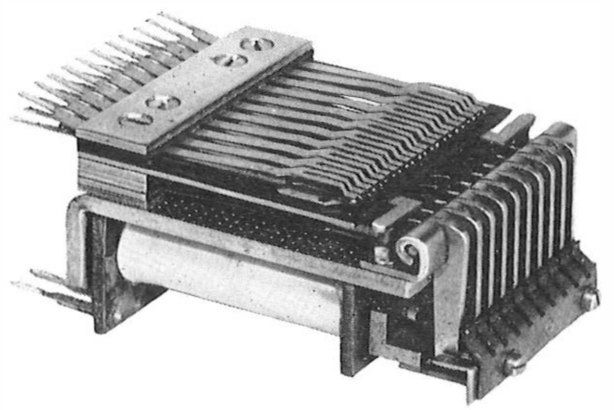


FIG. 17—Magnetic counter

Miscellaneous Components

The majority of the small components such as resistors and capacitors are carried on special mountings, which can be either clipped on top of a relay spring-set, as in Fig. 18, or are suitable for mounting in place of a relay spring-set, as shown in Fig. 19. Varistors, quenches and the smaller resistors can be fitted directly to the terminals of coil windings and other apparatus. Larger components, such as capacitors, are mounted directly on a relay yoke in place of either the coil, as shown in Fig. 20, or the spring-sets. For wiring purposes, all such component mountings present exactly the same appearance as the terminals of relay coils and spring-sets, and are suitable for wrapped-wire connexions.

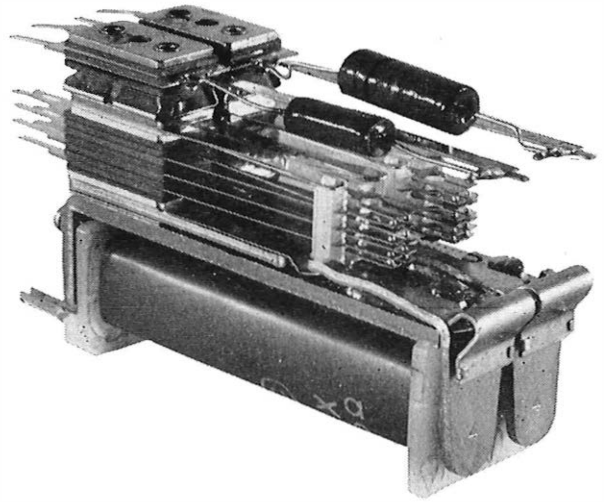


FIG. 18—Components mounted on relay spring-set

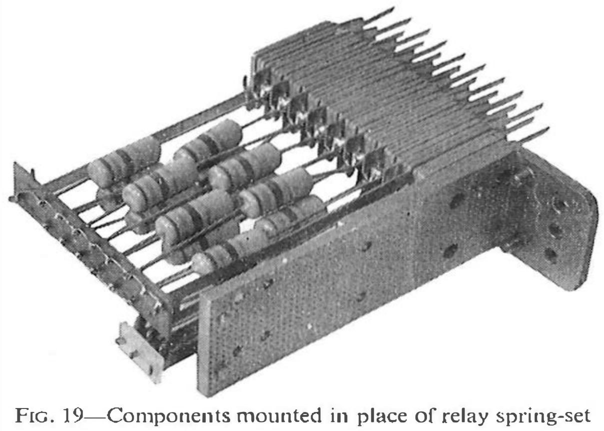


FIG. 19—Components mounted in place of relay spring-set

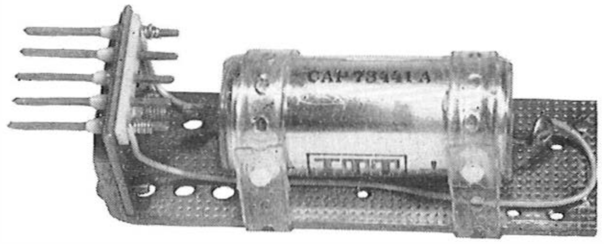


FIG. 20—Component mounted in place of relay coil

EQUIPMENT PRACTICE

The basic unit for mounting apparatus such as a multi-selector and relays is a frame. There are two widths of frame: 1,340 mm (4·396 ft) or 1,050 mm (3·445 ft) between mounting holes. Fig. 2 illustrates one of the larger frames. The standard height of a frame is 390 mm (about 15 inches), but half-height frames are also available.

According to the kind of equipment involved, a frame can mount one complete circuit, part of a large circuit, or several smaller circuits. A primary section is an example of one circuit on a frame, a translator an example of one circuit occupying several frames, and a line relay-set an example of one circuit occupying one part of a frame.

Within a frame, relays are mounted on vertical bars which, as convenient, can be provided singly, or grouped together in twos, threes or fours to make a sub-assembly; such a sub-assembly comprising one marker is shown in Fig. 21.

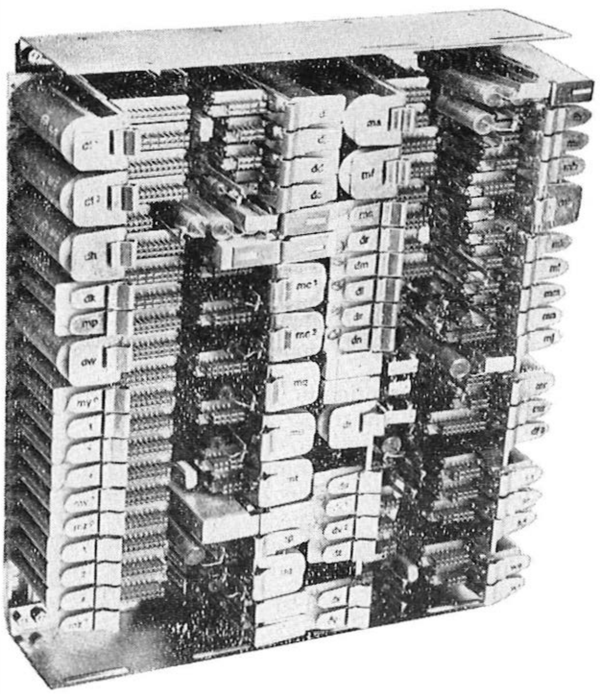


FIG. 21—Sub-assembly comprising one marker

It is often convenient if there are several circuits in a frame to arrange the sub-assembly size to mount one circuit. Frames are also suitable for accommodating I.D.F.-type connexion strips for use as a local cross-connexion field. Each frame (except for the I.D.F. frames) carries at one or both ends terminal blocks to which all connexions to and from the circuits on the frame are made. The rear face of each terminal block carries internal frame cabling that is wired in the factory. The front face is for external connexions, via exchange cabling to other frames or cross-connexion fields and I.D.F.s, which are cabled during installation. The system uses wrapped connexions instead of soldered joints, both for factory wiring and cabling during installation. This applies to relays (except where British Post Office 3,000-type relays are used) as well as to terminal blocks.

The frames are mounted, at the installation site, on uprights by a clamping arrangement to form single-sided racks. Six standard frames plus one half-height I.D.F. frame form the normal complement of a rack. The frames are grouped on the racks according to their functions, e.g. register racks, primary-section racks, etc. Between every adjacent pair of racks there is a cabling chute by which the cables gain access to terminate on the frames. If frames on the same or adjacent racks are cabled together the inter-frame cable forms are prepared in the factory.

Each frame is fitted with front and rear covers. The front cover has, at each end, a small hinged portion that opens to allow access to the terminals on which the exchange cabling terminates, without uncovering the full frame. The covers are designed to hang one on top of another for parking when removed for maintenance purposes. At the bottom of the rack a special power frame is fitted which carries the fuse mounting and the auxiliary alarm or supervisory relays; a plug-in type of alarm fuse is used. In the centre of each rack there is usually a small supervisory panel which carries, for example, the busy lamps for all circuits on the rack, and a fuse-alarm lamp. It also carries a battery jack. Apparatus and wiring aisles are laid out to standard widths between covers, but, as the depth of the rack is only 8 inches, more suites can be accommodated in a given area than with step-by-step equipment.

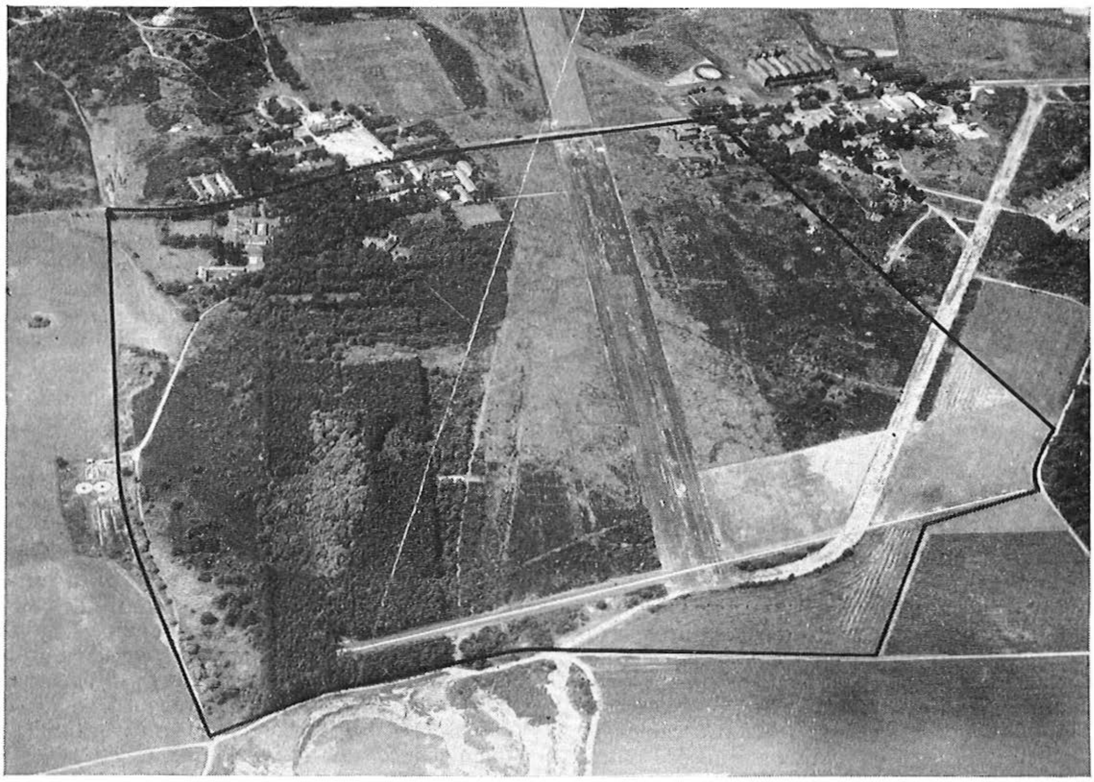
Power is distributed by bus-bars to the end of each suite. A power cable is then run from the bus-bar, down the end panel of the suite, and along the bottom of the suite to the various power frames at the bottom of each rack. Each suite is normally fused by one or two 60-ampere fuses mounted at the top of the suite end-panel.

The physical design allows the installer to build all the uprights on site, fit the overhead mesh and run cables, prior to mounting the individual frames of switching equipment. With this arrangement the majority of the heavy work on an installation can be carried out before the assembled frame units are brought on to the installation floor for mounting.

ACKNOWLEDGEMENT

The authors wish to acknowledge the assistance given by their colleagues in preparing this article. The photographs of the equipment are reproduced by permission of Standard Telephones and Cables, Ltd.

Site for the New Post Office Research Station



This aerial photograph, taken looking west, shows the 100-acre site (outlined by black line) for the new Post Office Research Station at Martlesham Heath, Suffolk, to the east of Ipswich. The new buildings will be in the top left-hand corner of the area outlined. As described below, work has commenced at the site on the construction and installation of an experimental circular waveguide, the performance of which will be studied to assess its long-distance transmission characteristics.

Long-Distance Transmission by Circular Waveguide

Long-distance millimetric-wave transmission in circular waveguide using the low-loss H_{01} propagation mode is a possible means of providing trunk routes of extremely high traffic capacity. The successful development of a circular-waveguide system would permit the transmission of signals throughout a very wide frequency spectrum, extending from about 35 GHz to 100 GHz, with an attenuation of only a few decibels per kilometre, independent of atmospheric conditions. This frequency band is large enough to accommodate at least a hundred broad-band channels, each of which could carry television, multi-channel telephony or data.

The practical possibilities of this form of transmission are being investigated by the British Post Office Research Department, and, as part of the investigation, an experimental 1-mile run of circular waveguide is to be installed on the new Research Station site at Martlesham. A field site for the first one-third of a mile has been prepared and can be seen towards the bottom of the above aerial photograph, running in a straight line from a field laboratory among the trees on the left to the boundary fence on the right. The waveguide is in the course of construction and installation by University College London under a Post Office research contract.

The performance of the experimental waveguide will be determined by the Research Department using specially developed measurement techniques, and the information obtained will be used, together with the results of other Research Department experimental work, to assess the realizable transmission characteristics of a fully-engineered circular-waveguide system.

D. W. M.

Local-Line Plant: Rationalization of the Cable-Pair Appropriation Records

D. O. ESSEEN AND H. D. HEWSTONE†

U.D.C. 621.395.743:621.315.213.14:651.5

This article briefly outlines the content and cost of the local-line network, and the methods of recording the termination, interconnexion and appropriation of cable pairs on main-cable, branch-cable and distribution-point cards which have been practised until recently. It describes recently introduced procedures that use new types of combined cabinet-and-pillar cards and new distribution-point cards in conjunction with photocopiers to expedite and cheapen the preparation of the record and simplify its use. It also describes the Buromatic Fleet Photocopier, which is being introduced into external-planning offices and some installation-group routing-and-record offices to provide the necessary photocopying facilities.

INTRODUCTION

The local-line network represents capital assets in the form of external plant with a gross book value of about £500,000,000. This includes about 10,000,000 cable pairs from exchange main distribution frames (M.D.F.s) through to 1,200,000 distribution points (D.P.s), and 28,000 cabinets and 45,000 pillars, which provide flexibility. The termination and interconnexion of the cable pairs between M.D.F.s, cabinets, pillars and D.P.s is recorded on some 2,500,000 cable-pair allocation cards held and used in routing-and-record offices for the provision of service, plant-exhaustion information, control statistics, and, in telephone exchanges, for maintenance purposes. During 1966 the network was increased by some 750,000 cable pairs, 77,000 D.P.s, 440 pillars and 2,500 cabinets. The compilation of about 800,000 cable-pair allocation cards was necessary to record this increase and any consequent rearrangements of existing plant. The cost of this effort in planning offices and routing-and-record offices is estimated to be nearly £500,000, and it is expected that a similar annual effort will be necessary for many years to record new plant provided to satisfy the anticipated demand for telephones.

The format of the main-cable, branch-cable and D.P. cards* introduced in 1949 has caused some difficulty in cable-pair allocation and other uses. Many marginally-improved methods were considered, but no alternative which gave sufficient advantage in facility of use to justify changing what had become an extensive and established record was available until a comprehensive study, which included the effort involved in the procedures for creating the records, was undertaken. This revealed that photocopying facilities could be used to make savings substantial enough to justify a major change in records and procedures.

PROCEDURES

The provision of new plant and records commences in the Telephone Area external-planning group with the preparation of a development scheme. The proposed layout of the new cable pairs on the cabinets, pillars and D.P.s is designed from the new scheme plan, using, in addition, information copied from the existing records. The layout is used to prepare works-instruction records, which list the present and proposed terminations and cross-connexions in a form suitable for use by the construction staff who are to execute the work. After completion of the field work, these works-instruction records, amended if necessary to accord with the actual work done, are sent to the routing and records officer who, under the old procedure, transferred and rearranged appropriate parts of this information into a different form on three sets of cable-pair allocation cards, i.e. main-cable, branch-cable and D.P. cards. He also prepared a further set of D.P. cards for maintenance use at telephone exchanges. The above information-transfer processes normally required the same basic record information to be manually transcribed five times between forms and cards of differing formats and for various purposes.

The two new cable-pair allocation cards, the cabinet-and-pillar card and the D.P. card, have a format which is suitable for all purposes, and allows the permanent record card to be produced in the planning stage as part of the normal course of designing and preparing works-instruction records. A photocopier is then used to create a translucency of the card, and, from this translucency, dyeline prints are made for use as works-instruction records by the construction staff. A photocopy of the D.P. card is also provided for maintenance use. The new cards and procedures, in conjunction with the use of photocopiers, will normally reduce the stages of manual transcription from five to one, thus reducing costs and improving accuracy. The flow chart in Fig. 1 compares old and new procedures in the planning group, the works group and the installation group routing-and-record offices, and shows clearly the stages of hand-copying that are eliminated.

RECORDS

Fig. 2 shows a typical subscriber's line between the telephone-exchange M.D.F. and the subscriber's premises, and Fig. 3 shows elements of the old forms and cards used to record details of that connexion. The old forms (A154, A961) are marked to indicate the works instruction issued when subscriber 5432 was diverted from D.P. No. 28 to new D.P. No. 209 on new pillar No. 4, which has been installed to provide distribution relief in conjunction with cabinet relief, in turn provided by a new augmenting main cable. The old cards (A2549, A2550, A2555 (*a*)) show how this was recorded, after completion, on the cable-pair allocation cards. A single diversion only has been shown, to illustrate the principle. In practice, there would usually be many changes on each D.P., and all new main-cable pairs would be cross-connected through to D.P.s.

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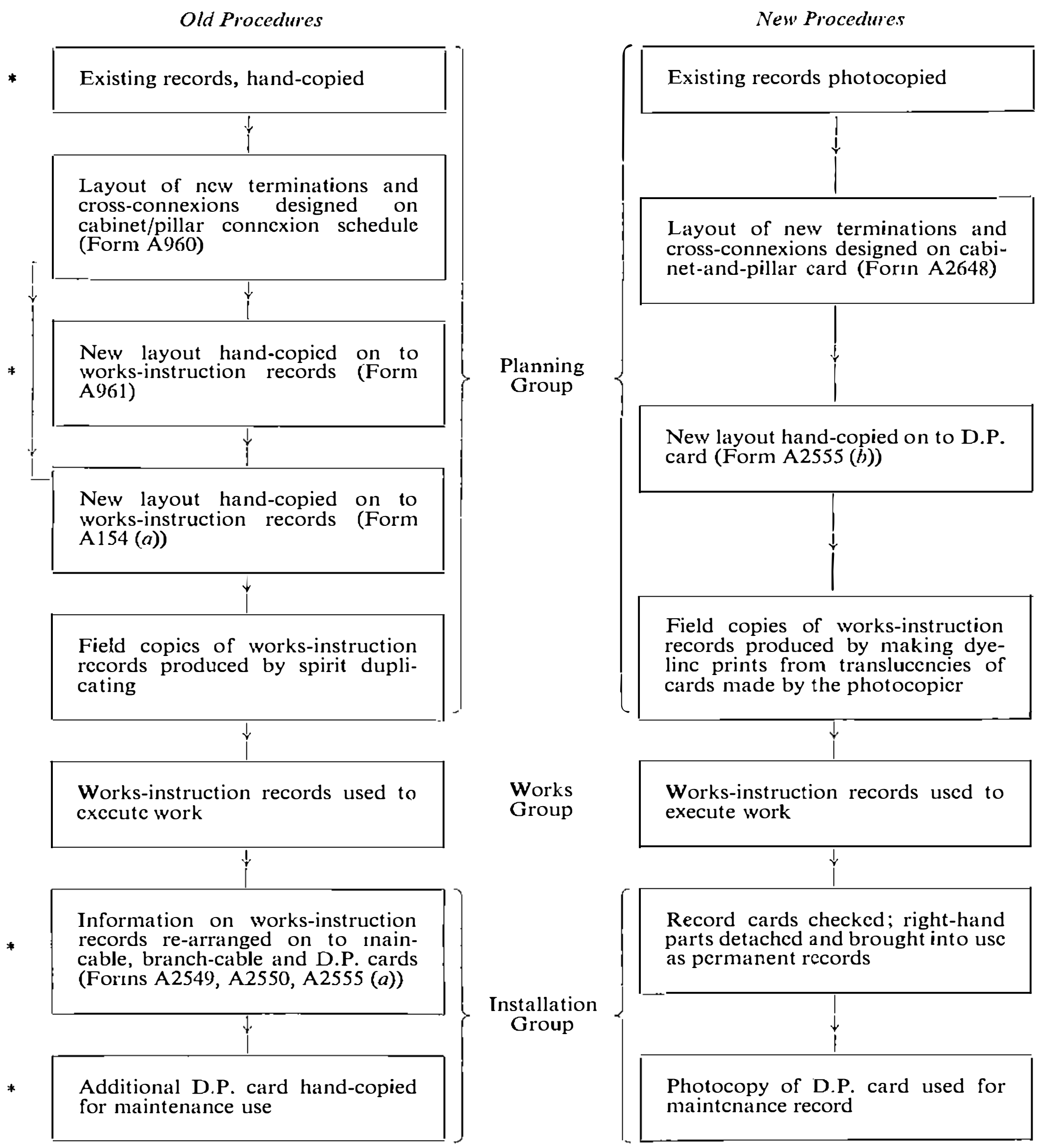
† Exchange-Area Planning and Economics Division, Operational Programming Department, Telecommunications Headquarters.

* MORRIS, A., and DOLAN, W. H. Local-Line Plant: Pair-Appropriation Records. *P.O.E.E.J.*, Vol. 43, p. 69, July 1950.



* Hand-copying stages eliminated by new procedures.

FIG. 1—Flow charts of old and new procedures

Fig. 4 shows elements of the new cards marked to show the same plant changes, and a comparison with Fig. 3 makes the advantages of the new cards clear. The cards have been designed to be used for

(*i*) cable-pair allocation by routing officers,
(*ii*) cabinet, pillar and D.P. termination and cross-connexion design by planning officers,
(*iii*) development-scheme works-instruction records prepared by planning officers and photocopied for the use of works staff, and
(*iv*) plant-exhaustion information.

They are two-part cards which, as a whole, can express all the information required for works-instruction records. The right-hand parts can be detached and form the permanent cable-pair allocation cards. The whole or parts of one or both cards are used by the planning officer, according to the nature and requirements of the work.

ADVANTAGES

The advantages that will result from the new records and procedures are as follows.

(*a*) There is a potential annual saving of about £165,000, which represents 33 per cent of that part of the planning office and routing-and-record office effort devoted to the preparation of cable-pair records.

(*b*) The reduction in the amount of hand-copying will reduce the number of copying errors, giving some improvement in the accuracy of the records.

(*c*) The use of a format that is more rational with respect to the physical arrangement of plant in the field and as depicted on plans and diagrams, and which is suitable for all cable-pair record purposes, must facilitate work in both planning offices and routing-and-record offices.

(*d*) The count of spare pairs for exhaustion-of-plant returns is quicker and cheaper.

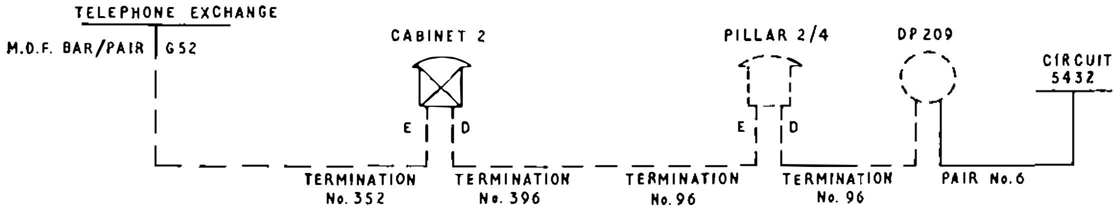
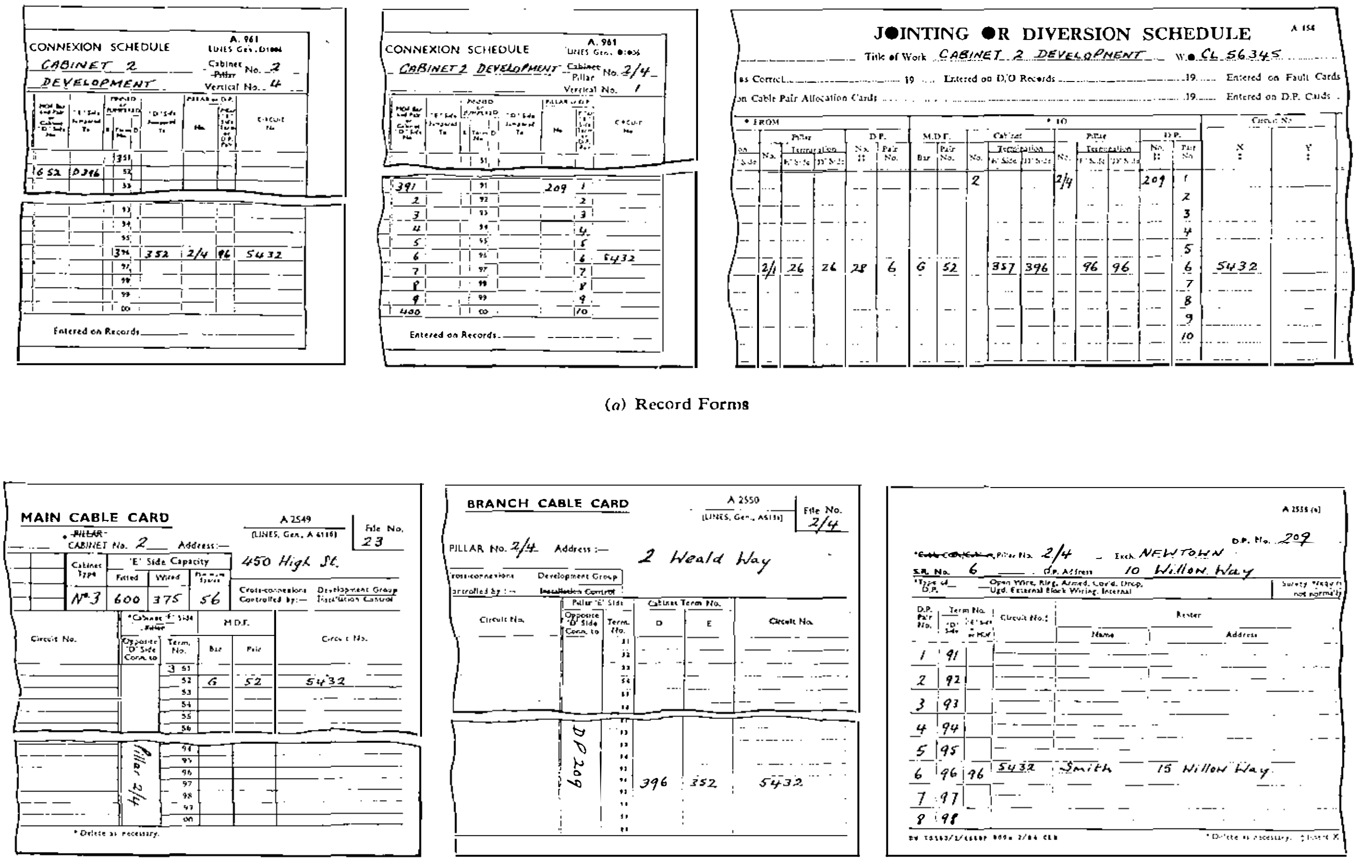


FIG. 2—Typical subscriber's line from exchange M.D.F. to subscriber's premises



(*a*) Record Forms

(*b*) Record Cards

FIG. 3—The old-type cable-pair allocation records

THE PHOTOCOPIER

The two principal photocopying requirements of the new procedures are for (*a*) a single positive copy from existing record cards in routing-and-record offices, and (*b*) up to six copies of all new record cards prepared in planning offices (a translucency from which dyeline prints can be reproduced is most economic for this purpose).

The choice of a photocopier was quickly narrowed down to one of the reflex type and, finally, to the Buromatic Fleet Photocopier. By the use of one type of translucent autopositive paper, this photocopier can produce either a positive or a reverse copy direct from the original without the need for an intermediate negative.

The Buromatic Fleet Photocopier consists basically of two sections, namely, the light-box, to expose the sensitized paper, and the processor, to develop and stabilize the copy. The two sections are connected electrically but can be used independently.

FUTURE DEVELOPMENTS

An article on local-cable-pair appropriation records would be incomplete without brief reference to further developments in this field now being formulated and evaluated. It seems likely to prove economic and expedient at some time in the future to use computers to store and process at least part of these records as part of a fully-integrated automatic data-processing system for Telephone Area operation. The new card A2648 has been evaluated to ensure that it is satisfactory for use as a primary-data collection document from which punched cards can be prepared as input media to a computer. It will, therefore, facilitate this next step if it comes to fruition.

There is an immediate need for an improved standard method of quickly finding the appropriate D.P. record from the address of a potential subscriber when application for service is made. Hitherto, the main official method of doing this has been by using the Ordnance Map record. The forecast of high telephone penetration is leading to the position in

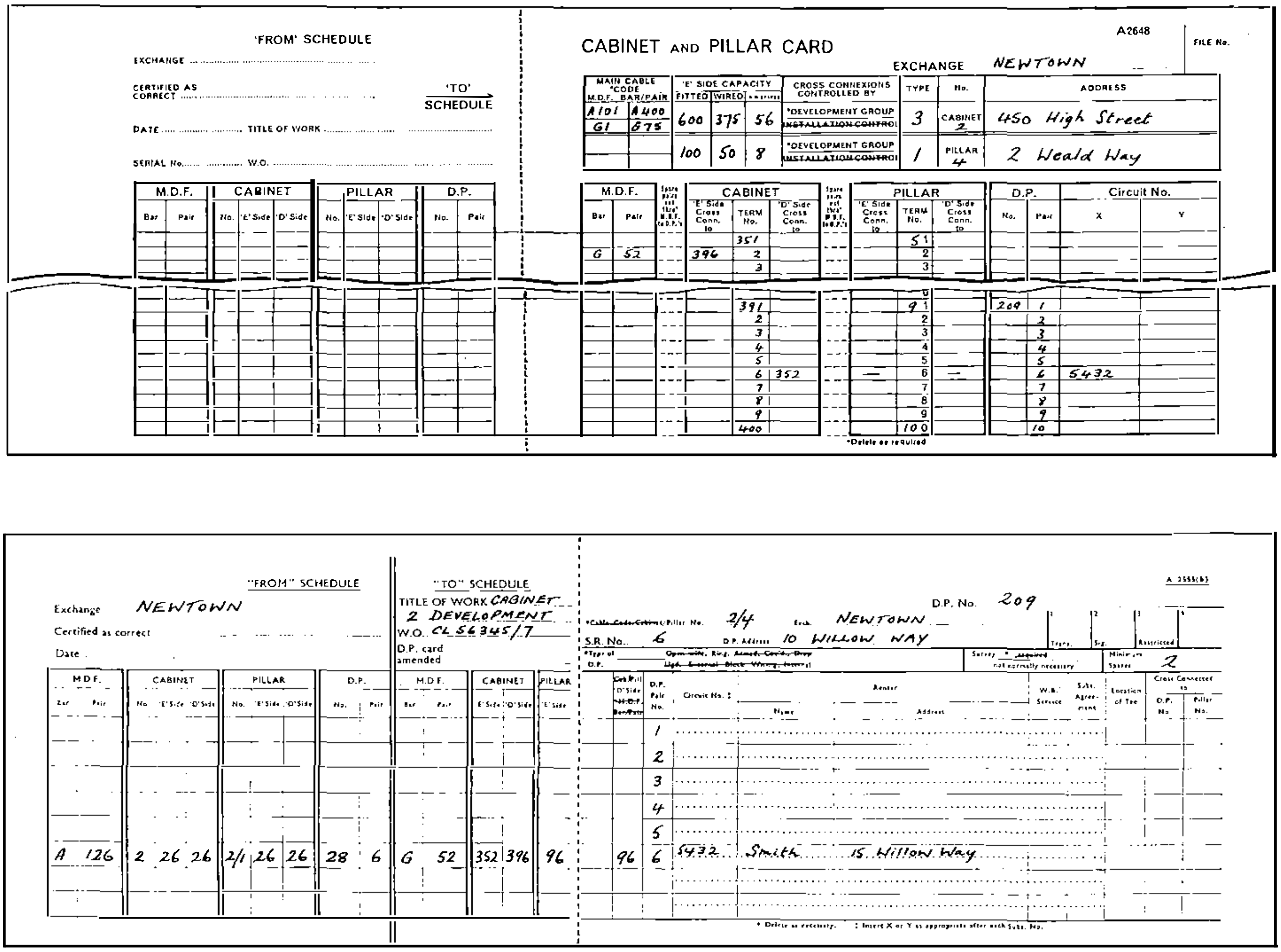


FIG. 4—The new combined cable-pair allocation and works-instruction record cards

which a D.P. pair will exist for most tenancies. The D.P. record will then have space for a record of most tenancies, and many will normally be recorded in D.P. pair order. It is a logical next step to devise a D.P. record which allows all the addresses to be written in road numerical order so that access to the plant record can be made directly from a given address. An address/D.P. plant record of this type is at present under trial, and it is possible that the D.P. card A2555 (*b*) will be superseded in due course by this new record, which retains the procedural advantages of the latter whilst providing quick address/D.P. "look-up" facilities in a form rationalized to make easy information transfer to a computer should this prove desirable. There may well be an interim period during which a more simple address/D.P. look-up, which can be brought into use more quickly and cheaply, will be introduced.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the contribution of Regional and Telephone Area staffs in all Telecommunications Regions to the formulation and field-trial of the new methods, particularly to those in the North Eastern Telecommunications Region, who were responsible for much innovation and trial.

Maintenance of the Subscriber Trunk-Dialling Network

B. F. YEO, C.G.I.A., C.ENG., M.I.E.E., and J. H. GEE†

U.D.C. 621.395.635.4–7

The extension of subscriber trunk-dialling facilities to all subscribers will not be achieved until 1970, *but for several years a rapidly increasing number of subscribers have had direct experience of the performance of the trunk network. This means that the service has become less and less susceptible to the shielding effect of the operator who, with the manually-controlled service, could make repeated attempts to establish an initially unsuccessful call. New maintenance concepts have, therefore, become necessary to raise maintenance standards so that the new service will provide a performance no less satisfactory than the manually-controlled system. This article discusses the problems that have arisen and the techniques that are and will be used to overcome them.*

INTRODUCTION

Although the program for the extension of subscriber trunk-dialling (S.T.D.) facilities is not due to be completed until 1970, already most trunk calls are subscriber-dialled. For several years, however, more and more subscribers have become directly exposed to the standard of performance given by the trunk network without the shielding effect of an operator, which was previously obtained under the manually-controlled service. This emerging situation has forced the maintenance engineer away from the old concept, where local and trunk exchanges tended to be treated in isolation, to the view that the whole system should be dealt with as a large, integrated, line, signalling and switching network.

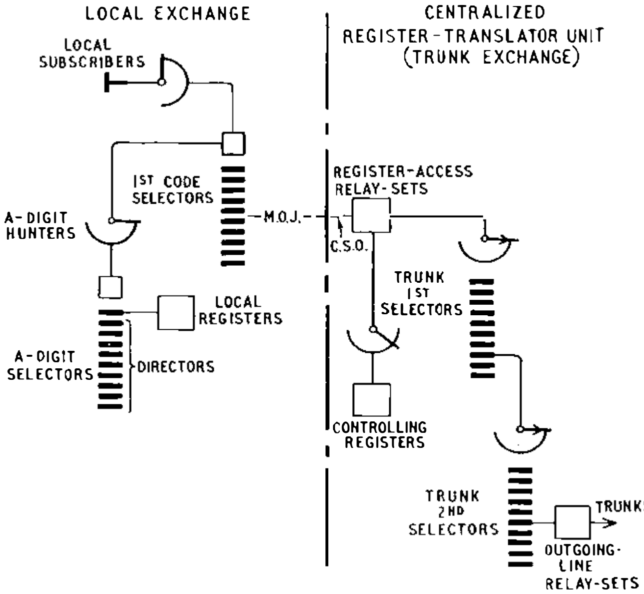
This article discusses the problems that arise and the approach which has been made in these circumstances, and suggests how new techniques may be exploited in the future to improve the S.T.D. service.

A national trunk-dialling system places even greater emphasis than before on the need for reliable long-distance lines. The apportionment of failures between line plant on the one hand and exchange equipment on the other is, at present, difficult to assess quantitively. However, experience suggests that, as far as trunk circuits are concerned, the number of faults attributable to line plant tends to be greater than that due to exchange equipment. Nevertheless, when considering all the equipment involved in making an S.T.D. call, the overall performance as seen by the caller is more often adversely affected by exchange-equipment failures than it is by line-plant defects. This article, in consequence, is concerned mainly with network maintenance as seen from the switching and signalling point of view. This is not to say that the performance of line links is necessarily satisfactory or could not be improved, but the widespread use of automatic gain-control on h.f. groups, coupled with arrangements now being introduced for the automatic busying of trunk circuits, will have the result of further buffering the caller against the effects of line-link variations and breakdowns. Strenuous efforts are also being made to reduce the incidence of line faults and interruptions due to working-party activities—particularly on multiple-path routes—by a series of "plant-improvement plans."

† Mr. Yeo and Mr. Gee are, respectively, in the Exchange Equipment Design and Installation Standards Branch, Telecommunications Development Department, and the Systems Performance and Maintenance Branch, Service and Sales Department, Telecommunications Headquarters.

Trunking and Definitions

Typical arrangements for the routing of S.T.D. calls outgoing from director and non-director areas are shown in Fig. 1 and 2, respectively. Corresponding arrangements for

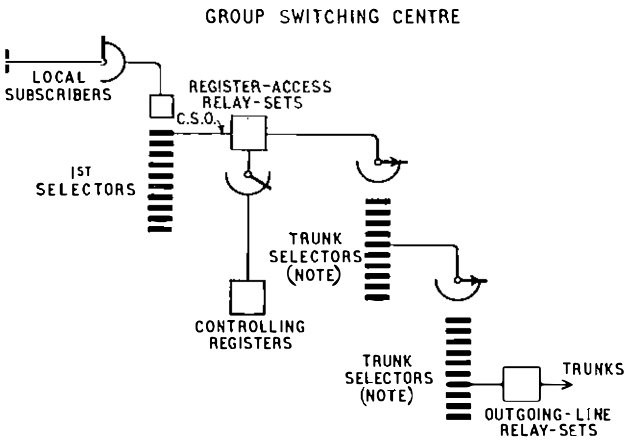


C.S.O.—Centralized service-observation measuring point
M.O.J.—Metering-over-junction relay-set

FIG. 1—Quality-of-service measuring arrangements for outgoing S.T.D. calls in a director area

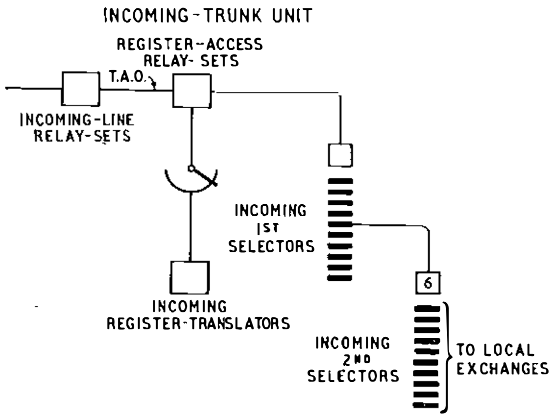
S.T.D. calls incoming to director and non-director areas are shown in Fig. 3 and 4. At this point it is worth defining some of the terms commonly used in connexion with S.T.D., as follows.

Trunk Circuit: A long-distance connexion between one exchange and another, used to carry public telephone traffic. It comprises the terminal signalling relay-sets plus the line. The latter may be routed wholly in audio-frequency cables, or may consist of a circuit in a single carrier group or in an h.f. system, or be made up of various combinations of these three main categories. Often, as far as the present division of maintenance responsibilities is concerned, a trunk circuit is taken to include equipment, at the incoming end, which is permanently and individually attached to that circuit, e.g. the incoming first-selector.



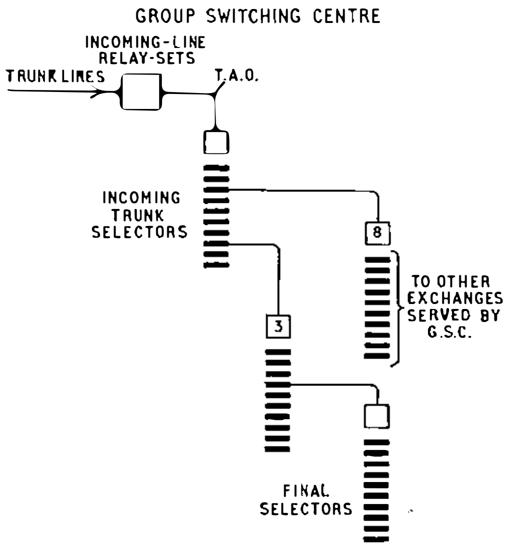
C.S.O.—Centralized service-observation measuring point
Note: Could be 2-motion selector

FIG. 2—Quality-of-service measuring arrangements for outgoing S.T.D. calls in a non-director area



T.A.O.—Trunk automatic observation measuring point

FIG. 3—Quality-of-service measuring point for incoming S.T.D. calls in a director area



T.A.●.—Trunk automatic observation measuring point

FIG. 4—Quality-●f-service measuring point for incoming S.T.D. calls in a non-director area

Trunk Exchange: An exchange for switching traffic to or from the trunk network, and to which subscribers are not directly connected. An example of such an exchange is the incoming register-tranlator unit to be found in director areas for distributing incoming trunk traffic to local director exchanges.

Group Switching Centre: The exchange at which subscribers in a charging group or dependent charging group are connected to the trunk network. It is here that the controlling register is situated. In smaller group switching centres (G.S.C.s) the trunk switching equipment is often accommodated with the local exchange equipment, so that subscribers obtain access directly to the controlling register-translators.

Local Exchange: An exchange to which subscribers are directly connected and whose main function is to connect those subscribers together. The subscribers may also be connected, via junction circuits, to similar exchanges in a linked-numbering area. All local exchanges are directly connected to their respective G.S.C.s.

SERVICE MEASUREMENT AND FAULTING TECHNIQUES

The principal method of measuring service is, at the present time, centralized service-observation. This is used to measure local service—by observing the progress of local calls—at local exchanges, and to measure S.T.D. service by observing the progress of trunk calls as seen at the point where they enter the S.T.D. network, i.e. at the input side of the controlling register-access relay-set. The S.T.D. measuring points are indicated "C.S.O." on Fig. 1 and 2. Such observations relate to outgoing service, and are a measure of the performance of the outgoing trunk-switching equipment at the originating centre plus that of the line and signalling equipment, of the incoming trunk-switching equipment at the distant end, and of the local network at the distant end. Other observations, known as trunk automatic observations, are taken at the incoming sections of trunk units and G.S.C.s, and are a measure of the service given by that part of the unit plus that given by the local network served by the unit. These observation points are indicated "T.A.O." in Fig. 3 and 4.

The live traffic thus observed is monitored by specially trained operators. Calls to be observed are presented on a random basis and the operator sees, in effect, a sample of the service given by the network. The setting-up sequence is recorded in detail for each observed call, and the results are subse●uently analysed at a central point by computer. About 1,000 outgoing calls are observed each month at all main trunk units and about 500 at nearly every G.S.C. The summarized results are made available nationally, and are also analysed in more detail and made available each month to local traffic and engineering staffs. Failures due to plant (expressed as "percentage calls ineffective due to plant defects") are broken down into the following components: no tone, number-unobtainable tone, wrong numbers, and miscellaneous. The number-unobtainable tone may be further divided, for local benefit, to indicate the stage of the call at which tone is received. The degree of congestion is also shown and is divided as far as possible at present into "local" and "distant" categories. The existing standard busy tone does not distinguish between plant busy and subscriber busy, but it is sometimes useful to know the point at which the tone is received. A new form of busy tone—equipment-engaged tone—is being introduced, and this will yield additional information to help in pin-pointing the places in the network where congestion is occurring.

Centralized service-observation measurements are supplemented by trunk-line dialling tests; these are at present carried out by operators but are soon to be performed by automatic equipment. These tests are a means of assessing the performance of trunk routes between main switching centres. Various other checks are, or will be, carried out by automatic monitors and call-sending and display devices, which either exist or are in the course of development. The monitoring devices are used by engineering staff, as required, to provide measurement of service and to indicate where in the system the equipment is not working satisfactorily; the call-senders are used to investigate the performance of a particular trunk route, or individual trunk circuit, by automatically transmitting a series of test calls to a special test number at the distant exchange. The sending equipment notes the receipt of the correct supervisory tone or other appropriate signal from the test number. Most test-call sending equipments may be used in two ways: first, to measure performance by noting the number of failures out of the total of test calls transmitted, and, second, to assist in locating faults by holding the connexion when the correct signal is not received, thus allowing the equipment set-up to be traced through to determine the point of failure.

The trunk and junction routiner is another device for automatically checking the performance of trunk routes, circuit by circuit. The routiner also makes use of a special test number at the distant centre, not only to check correct routing but to enable a test tone to be received by, and transmitted from, the test number relay-set to measure the transmission performance of the trunk circuit under test.

Another approach which has proved of value in showing-up areas of difficulty in the network is that known as the reference-centre procedure. In principle, this is merely a system of plotting, in grid formation, reports and indications of difficulties encountered. Thus, assistance operators and local maintenance controls pass details of subscribers' reports to the reference centre, where they are plotted, as appropriate, in terms of point of origin against destination. Fig. 5 shows

I/C EXCHANGE NAME	O/G TRUNK ROUTE AND ROUTING DIGITS																			
	LONDON FARADAY N.D.					BIRMINGHAM NEWHALL					MANCHESTER GUARDIAN					TUNBRIDGE WELLS				
	21					45					73					831				
BRISTOL CENTRAL	II			II	I		I				I	I					I			
NORTH			I						III			II					I			
EASTERN																				
SOUTH	I											I								
WEST																				
FILTON	I							I												
BEDMINSTER								I												
DAY OF WEEK	MON	TUES	WED	THUR	FRI	MON	TUES	WED	THUR	FRI	MON	TUES	WED	THUR	FRI	MON	TUES	WED	THUR	FRI
DAILY TOTAL	4		1	2	1		1	1	3		1	5					2			
WEEKLY TOTAL	8					5					6					2				
NUMBER OF CIRCUITS PER ROUTE	220					100					70					40				
% FAULTS	3·6					5					8·6					5				

I/C—Incoming O/G—Outgoing

FIG. 5—Layout of typical form used for plotting fault incidence

the layout of a typical form used for plotting purposes. Reports are also received from trunk maintenance control centres. In the course of a few hours it is often possible to detect a pattern which directs attention to a part of the network where trouble is being experienced and where detailed investigation is called for.

The hold-and-trace technique, previously mentioned, is a time-consuming method, often requiring the co-operation of staff at a distant switching centre. Furthermore, the practice of holding common equipment and high-revenue-earning trunk circuits as the sole means of network maintenance is to be deprecated. Holding and tracing, therefore, should be regarded as supplementary to the regular preventive-maintenance procedure, only to be applied when it is not possible to identify a particular source of trouble by other means.

Distant-end co-operation may not be necessary, when, for example, the performance of a particular trunk circuit or route is being checked, because test calls can be sent to a test number. However, the need to avoid wasteful allocation of selector levels means that the test-number relay-set is usually trunked from 3rd-selector or subsequent levels. This results in the success of the test call being dependent, in part, on the performance of the distant-end switching train, a feature that can sometimes confuse the issue when it is the trunk circuit itself which is being investigated. To overcome this drawback a new form of test-number relay-set has been proposed. This has the capacity to store several digits, the value of which can be predetermined. Once the relay-set has been seized, the test-call sender at the outgoing end of the circuit transmits the predetermined digits. If these are correctly received, the answering relay-set returns an acknowledgement signal which the sender recognizes. After a suitable interval, to allow the sender and test-number relay-set stores to reset, the sender repeats its program; this time the initial routing digits are suitably absorbed in the answering relay-set. The connexion is maintained throughout the sequence and the process continues until the sender is manually disconnected from the trunk-circuit relay-set.

The facility of transmitting Strowger pulses at speeds and ratios other than nominal enables the sender, if required, to check the pulsing performance of the trunk circuit. Moreover, after reaching the answering relay-set, the correct operation of the distant-end switching train to subsequent digits is no longer a factor. The degree to which a new test-number relay-set design, as proposed, may be arranged to combine the functions of more than one type (to minimize the total number of test-numbers or levels required) has yet to be determined.

GENERAL APPROACH

The idea of an integrated switching network is, of course, not new in principle. The director system, for example, operates in this way, and, moreover, depends on a controlling register-translator at every exchange to facilitate the use of a common numbering scheme for the area served and to provide the means of steering the calls to their objective exchanges. The S.T.D. system is similar, but is complicated by more complex charging and routing arrangements and by having to function over a long-distance network incorporating more elaborate signalling and transmission systems. The long-distance aspect, in particular, tends to magnify the problems of co-operation which often arise between two exchanges. It is, nevertheless, important that these problems be recognized and overcome if fault tracing and clearing are to be expedited. It must be appreciated not only that the outgoing S.T.D. service, as seen from a G.S.C. or trunk exchange, is dependent in part on the performance of distant local networks, but that the incoming service of that G.S.C. and of the local area which it serves are influencing some other centre's performance.

The behaviour of the S.T.D. network as one large linked-numbering area, normally working without the intervention of an operator, raises more acutely the question of what overall performance should be expected. In 1964–65 the call-failure rate due to plant defects, expressed as a percentage, was twice as bad as corresponding figures from the U.S.A., West Germany and Switzerland—to name only a few other Administrations. Although the systems in use and the methods of measurement are not the same in all respects, it is evident that the United Kingdom service could be better. This state of affairs has been recognized in the priority now being given to the improvement of service; the intensification of effort which this facilitates is beginning to show encouraging results.

With any system it is probably true to say that improvement in service beyond a certain point involves an increasingly disproportionate cost—whether in terms of manual effort, tester and routiner provision, or initial equipment costs. With this in mind, it is likely that the best overall average S.T.D. service which can be achieved in the United Kingdom under present circumstances is a call-failure rate (due to plant defects) of between 2 and 3 per cent. There can be as many as 16 stages of equipment involved in setting-up an S.T.D. call from one director area to another; this demands from each item in the chain a standard of performance which is considerably higher than that (until recently) considered acceptable for local service.

The general approach to maintenance is to subject the equipment to routine-testing and preventive work in an endeavour to anticipate service failures, supplemented by the qualitative system-diagnosis method of the reference centre and coupled with special investigations into specific areas of weakness, making use of the auxiliary devices and techniques, e.g. monitors and senders, under hold-and-trace conditions. Thus, with an S.T.D. network based as it is on Strowger-type electromechanical switching equipment, judiciously-applied preventive maintenance is necessary to keep the system generally under control and in good condition. The higher standards now demanded lead, in turn, to the more intensive provision and utilization of automatic routine-testing devices, coupled with the liberal use of available and projected call-sampling equipment. The supervising maintenance engineer also has an interest in the adequacy of equipment provision and in the efficiency of gradings used in the installations under his control, since congestion, in some circumstances, tends to increases the number of calls ineffective due to plant defects. Above all, he needs to exercise a continuing management function, keeping all aspects of service and plant performance under constant surveillance, so that maintenance effort may be effectively deployed to anticipate trouble rather than to deal with it after it has appeared.

EQUIPMENT PERFORMANCE

The service given by any system is determined primarily by the reliability of its individual components. This is particularly so with the existing S.T.D. network, based on step-by-step equipment and having no repeat-attempt feature to shield the caller from first-attempt failures. All equipment has an inherent liability to failure at some time, although careful design can reduce this considerably; it is, therefore, an important aspect of the maintenance engineer's job to identify weaknesses in items of equipment, to minimize failures due to these causes by suitable maintenance techniques, and, finally, to anticipate the remainder by periodic overhauls and inspections. Because of the influence of many factors such as environment, age, frequency of operation, and variations in routine maintenance work, it has always been difficult to determine the inherent reliability of production equipment working under live-traffic conditions. An attempt is now being made to remedy this situation and obtain more accurate information about equipment performance by carrying out a series of controlled experiments in the field.

An example of an investigation currently in hand is that into the behaviour of a particular signalling system. The relay-sets associated with a selected number of trunk circuits were first overhauled and tested. The correct functioning of each relay-set plus line plus distant-end relay-set was then verified by passing a series of test calls over the circuits. The experiment is continuing as follows. Normal routine-testing of the relay-sets is carried out and any faults which arise therefrom, or are brought to notice by other means, are carefully noted and investigated. At regular intervals a further series of test calls is passed over the circuits to check the overall performance, and each relay-set is inspected and its adjustments checked. Results so far obtained suggest that the individual relays will remain in adjustment for a considerable period (after correct initial treatment) and that, after an initial settling-down period following the disturbance due to overhaul, the signalling system is capable of giving a very good performance; in fact, given proper treatment before being put into service, the inherent reliability of the system is likely to prove appreciably better than earlier experience had suggested.

MAINTENANCE EXPERIENCE

The detailed work involved in investigating particular difficulties calls for a high degree of perseverance. Since the work is generally a matter of the diagnosis and clearance of faults of an intermittent nature, it is best carried out by a nominated individual or team. Every encouragement needs to be given to the staff concerned with this type of work to maintain the effort despite the fact that the immediate results might well be discouraging.

Test-call sending and live-traffic monitoring have already been mentioned. The temptation to follow-up these programs by hold-and-trace exercises from the originating unit should be resisted, except in those instances where the general level of performance is already good, so that poor results are exceptional and their causes are consequently fairly easily identifiable.

Investigations have shown that a high proportion of faults are such as can be found by normal routine-testing procedures. A common cause of trouble, not always obvious, is the inconsistent behaviour of timed relays not in correct adjustment. Selector circuits, and many of the British Post Office signalling circuits, rely for their proper performance on the correct contact-sequencing and timing of many relays. Although most circuits are tolerant over a large range of deviation from nominal of the battery-supply voltage, pulsing speeds, and make-to-break ratios when treated separately, multiple connexions such as occur in the trunk network can experience failures under certain circumstances when limits are allowed to drift.

With the increased use of routiners, failures from this sort of trouble should be greatly reduced, provided that circuits failing a routine-test cycle (on the timing test) are subsequently dealt with properly. Many investigations have confirmed that when the timing of a relay is adjusted so that it lies within the maximum (or minimum) limit and the mean value of the timing range (depending on whether an operate or release lag is required), it will stay well within the routiner reject limits for a long period. This has a double reward: circuits so adjusted are far more tolerant of each other when connected in tandem, and it helps to boost morale and gives greater confidence in the routiner. This results from the maintenance engineer being freed from the frustration of finding on re-test that equipment shown up as faulty by the routiner performs satisfactorily because, during the intervening interval, marginal temperature changes have caused the relay timing to move within the pass limit of the routiner test.

THE FUTURE

The trunk transit network, soon to be commissioned, is expected to give an improved performance (on those calls which require multi-link connexions) by virtue of the repeat-attempt and self-checking features inherent in the signalling and switching system designs. The bulk of S.T.D. traffic will, however, continue to be carried by the existing Strowger-type network for many years to come.

In the near future, the progressive introduction of electronic and crossbar exchanges will give a continuing improvement in the performance of local switching networks; this, in turn, will have a beneficial effect on S.T.D. service. In the more distant future the wider application of common-control and electronic switching techniques, making possible faster switching and signalling systems, will facilitate the extension of the repeat-attempt feature so that the caller will be increasingly sheltered from the effects of network failures. Ultimately, the possibility of call-routing and control over an integrated, computer-based, network, with automatic re-routing and in-built safeguards against network failures, holds out even greater prospect of an S.T.D. service which operates at maximum efficiency and which is effectively free from failure as far as the user is concerned.

Arrangements will also be made for calls to be sampled and monitored automatically during set-up so that failures may be recorded in detail and fed into a computer for subsequent analysis. From this, a great deal of useful information will be derived: traffic data, routes and destinations giving poor performance, stages within the originating centre where failures are occurring, and, of course, a continuous measure of S.T.D. service.

The development of storage and data-processing systems for the various operational needs of Telephone Areas and Regions will facilitate the collection and analysis of information derived from automatic testing equipment such as the trunk and junction routiner. This will enable trunk-switching centres, trunk maintenance controls, and management at all levels, to be served rapidly with up-to-date and detailed results, thus allowing a closer and more effective control to be exercised on network performance.

CONCLUSIONS

The advent of S.T.D. has resulted in the emergence of a national integrated network in which switching, signalling and transmission functions are inescapably interrelated. This situation, coupled with renewed emphasis on giving service to the subscriber, means that maintenance can no longer be conducted solely by dealing with trunk exchanges, local exchanges, etc., in isolation, but must be organized and managed on a national basis, with particular reference to the need for co-operation between the various centres. Strowger-type equipment will carry the bulk of S.T.D. traffic for many years to come, and must be made to give a higher standard of performance than it does at present, if the overall service objectives are to be realized. Regular analysis of performance figures and the determined follow-up and rectification of weaknesses thus indicated will usefully supplement routine maintenance work.

Experience has shown that many of the faults found in the course of special investigations are straightforward and capable of detection by normal methods if these are systematically applied. It is hoped, in the future, to utilize electronic and computer techniques to shield the subscriber from some of the network failures at present encountered, and, at the same time, to provide useful traffic and maintenance information to assist management in directing effort to the best advantage.

Books Received

"Propagation of Short Radio Waves." Edited by D. E. Kerr. Constable and Company, Ltd. xvii+728 pp. 307 ill. 24s.

"Electronic Time Measurements." Edited by B. Chance, R. I. Hulsizer, E. F. MacNichol, Jr., and F. C. Williams. Constable and Company, Ltd. xviii+538 pp. 383 ill. 24s.

"Threshold Signals." Edited by J. L. Lawson and G. E. Uhlenbeck. Constable and Company, Ltd. xii+388 pp. 172 ill. 18s.

The above three books were originally published by McGraw-Hill Book Co., Inc., in the Massachusetts Institute of Technology Radiation Laboratories Series as Volume 13 (1951), Volume 20 (1949) and Volume 24 (1950), respectively. By the co-operation of McGraw-Hill with Dover Publications, Inc., the books, unabridged and unaltered, have now been reproduced in Dover paperback editions on a paper which, the publishers claim, gives minimum show-through and will not discolour or become brittle with age; the pages are sewn in signatures, and the books may be opened flat without fear of pages dropping out.

Although most volumes in the Radiation Laboratory Series are devoted to specific radar subjects, "Propagation of Short Radio Waves" deals with the phenomena associated with the propagation of such waves between terminal points, whether they be the radar antenna serving a dual purpose or the antennas of a communications system. The authors sought to present a summary of the state of knowledge in the microwave-propagation field at the close of the war, a subject they admitted to be a rapidly changing one.

The object of "Electronic Time Measurements" is to present the method of approach to the problems of radio time and distance measurement by manual and automatic means, and to describe practical circuits employed for these purposes in the 1940s. The book also includes techniques of pulse data transmission and pulse-amplitude cancellation methods.

The authors of "Threshold Signals" wished to write a more or less complete critical account of the experiments and theoretical ideas pertaining to the problem of the detectability of a signal in noise. It soon became clear, however, that the subject was too large for this, and they therefore limited themselves to describing the work done at the Radiation Laboratory during the war, with sufficient introductory material to make the account intelligible.

"Transmission Lines, Antennas and Wave Guides." R. W. P. King, A.B., Ph.D., H. R. Mimno, E.E., Ph.D., and A. H. Wing, E.E., Ph.D. Constable and Company, Ltd. xvii+347 pp. 218 ill. 16s.

The Dover Publications paperback edition of "Transmission Lines, Antennas and Wave Guides" is a corrected and up-dated version of the work first published by McGraw-Hill Book Company, Inc., in 1945.

This book provides an introduction to the basic principles of transmission lines, antennas, waveguides and radio-wave propagation in the ionosphere. In accordance with its objective, the presentation avoids complicated mathematics but is, nevertheless, consistent with the more advanced mathematical theory. It seeks to give an insight into the fundamentals of radio transmission and radiation for practical engineers, radio astronomers, radio amateurs and college students.

The first chapter, by Dr. Wing, deals with non-resonant and dissipationless lines, transmission-line constants, impedance matching, circle diagrams and general equations from the conventional electric-circuit point of view. The last chapter, Chapter 4, is by Dr. Mimno and discusses ground-wave and sky-wave propagation. The middle two chapters were prepared by Dr. King: the first, on antennas, begins with a qualitative introduction to electromagnetic theory, and continues on to the driven antenna and the receiving antenna as circuit elements, coupled antenna and transmission lines, electromagnetic field of antennas and arrays, and closed circuits as antennas; the second is devoted to ultra-high-frequency circuits, covering classification of circuits and transmission, non-resonant and resonant circuits.

The Effects of the Earth's Magnetism on Submarine Cables

G. A. AXE, C.ENG., M.I.E.E.†

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In this article two sources of extraneous voltages that affect submarine cables are considered: voltages which are induced in water moving in the earth's magnetic field, which may, in favourable conditions, produce a current of the order of tens of milliamps in a cable's centre conductor if it is earthed at both ends, and voltages induced in cables when there are violent changes in the earth's magnetic field, which, for some cables, can be of the order of 1,000 *volts and can interfere with the power supply to submerged repeaters if allowance for the effect has not been made.*

INTRODUCTION

The magnetic phenomena which affect submarine cables are of two types: those that are due to the movement of conducting material in the earth's magnetic field, and those due to changes in the magnitude and direction of the earth's magnetic field. In nearly all instances they result from natural causes, the notable exception being the disturbance of the earth's magnetic field due to nuclear explosions at high altitudes.

In the heyday of d.c. telegraphy the effects of magnetic phenomena were of widespread interest and of consequence, since the voltages produced were of the same order as those used for signalling. Of recent years the influence of such phenomena on the power-feeding arrangements for submerged repeaters has been noticeable, although rarely of any great significance. More attention will need to be paid to these effects, however, with transistor repeaters, as the power-feeding voltages are generally lower.

Land cables are sometimes similarly affected, but the effects are more noticeable and of more consequence on submarine cables owing to their freedom from other interference and their generally greater lengths.

EFFECT OF MOVEMENT OF WATER

When a large body of water is moving, and, therefore, cutting the earth's magnetic field, it would be expected that an e.m.f. would be induced in it and that a current would flow through the water and return through the sea bed; this was pointed out by Michael Faraday very soon after his discovery of electromagnetic induction in 1832,[1] but his attempts to verify it experimentally in the Thames near Waterloo Bridge were unsuccessful.

When the water is moving through a channel spanned by a cable earthed at both ends a current will flow through the cable. If the movement of water is due to the tides, the current will change direction with the tides; in fact, it will be an alternating current, usually with a frequency of two cycles/day. It should be particularly noted that the current is due to an e.m.f. induced in the water—no e.m.f. is induced in the cable. This is an example of the generation of electricity by the movement of a conducting fluid in a magnetic field, magneto-hydrodynamic generation (m.h.d.), a subject of current research in an attempt to convert heat energy to electrical energy without the use of rotating machinery.

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The effect has been noticed on many occasions during cable testing,[2,3] probably the first being in 1851 on the first successful Anglo-French cable, and was dealt with quantitatively in a paper by M. S. Longuet-Higgins in 1949.[4] In the idealized case there considered—a long straight shallow channel of semi-elliptical cross-section—it was shown that the potential difference in volts (e) between the two sides of the channel is given by

$$e = \frac{vZL \times 10^{-8}}{1 + (R_1L/R_2 2D)},$$

where v = velocity of the water (cm/s),
L = width of the channel, i.e. the distance between the earth electrodes (cm),
D = depth of the channel (cm),
Z = vertical component of the earth's magnetic field (gauss),
R_1 = specific resistivity of the water (ohm.cm), and
R_2 = specific resistivity of the water-channel bed (ohm.cm).

It will be noted that the potential difference is independent of the direction of the cable, since only the vertical component of the earth's magnetic field will produce any e.m.f. between points in a horizontal plane, and it is not directly proportional to the distance between the earth electrodes except when the term $R_1L/R_2 2D$ is very small. Potential differences due to this effect, which have been measured between earth electrodes (in most instances the cable outer conductors) on either side of various stretches of water, are given in Table 1.

TABLE 1
Voltages due to Water Movement at Spring Tides

Route	Distance Between Earth Electrodes (Nautical Miles)	Maximum Potential Difference (Volts)	Approximate Rate of Flow (Knots)
St. Margarets Bay–Sangatte	20	0·89	2·45
Aldeburgh–Domburg	81	0·74	1·60
Port Kail–Donaghadee	22	0·93	2·70
Nevin–Howth	62	1·05	2·15
Portsmouth–Ryde	4·5	0·3	1·75
Gairloch–Stornoway	37	2·2	1·0

Another feature which the theoretical treatment indicates is that the return currents extend down into the sea bed and inland from the shore lines to distances comparable with the width of the channel. These currents may, therefore, affect inland cables near the coast.

Since the communications engineer is usually only concerned with this phenomenon to the extent of reassuring himself that it may be neglected, it will be of interest to consider the maximum voltage that is likely to appear between earth electrodes and the maximum current which would then flow in a cable.

For a given length of cable, the voltage will increase as the expression R_1L/R_22D gets smaller; the highest voltages will, therefore, be found across narrow deep channels with beds of high resistivity. For example, if the channel considered is 10 nautical miles wide, 50 fathoms deep, and with a bed consisting of igneous rock whose resistivity may be of the order of 10^5 ohm.cm, then, taking the resistivity of sea water as 25 ohm.cm, the expression R_1L/R_22D has a value of 1/40. Under these circumstances the potential difference between the ends of a cable due to a 2-knot tide would be 0·85 volts and, since the conductor resistance of typical concentric submarine cable (0·62 in. diameter dielectric) is of the order of 2 ohms/nautical mile, the maximum current that could flow in such a cable would be about 40 mA.

The magnitude of these effects is insufficient to affect either the design or operation of submerged-repeater systems, but it does cause difficulties during d.c. cable-fault location, and is known to have had one other interesting and unfortunate effect. After a series of reports of the poor insertion-loss/frequency characteristic of a music circuit to Northern Ireland (an audio circuit on a coaxial submarine cable) it was found that the low-frequency loss varied with the state of the tide. This proved to be due to saturation of the audio-frequency transformers by the current flowing through the centre conductor of the cable at the time of maximum flow of water. The maximum current measured was about 20 mA. The difficulty was simply overcome by fitting a large series capacitance in the circuit at one end. Fig. 1 gives a typical arrangement of audio-frequency equipment associated with an unrepeatered submarine-cable carrier system, and shows the d.c. path through which current due to differences in earth potential can flow, together with arrangements for blocking the current or measuring it as required.

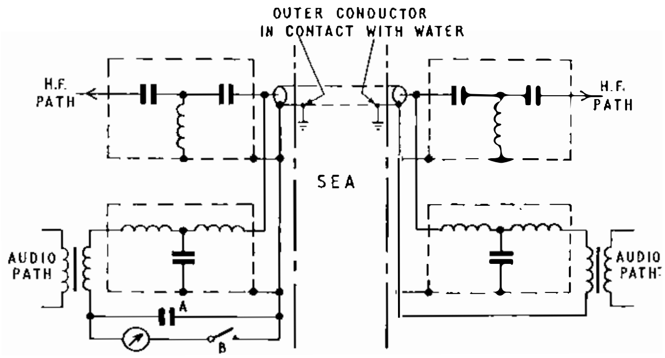
A typical recording of the current flowing in a cable centre conductor, showing the effects due to the tidal flow, is given in Fig. 2.

It is of interest to note that the electric currents flowing in some parts of the sea due to the movements of water are sufficient to cause local variations in the total magnetic field which could be significant for some purposes;[5] this also is an effect that was anticipated by Michael Faraday.[6]

Measurement of the Rate of Flow of Water

The phenomenon discussed above has been used as a means of continuously measuring the mean rate of flow of sea water.

Following the disastrous floods of 1952 on the south-east coast and in the Thames estuary, the National Institute of Oceanography intensified their study of the effect of wind on



A—Blocking capacitor
B—Switch to connect current-measuring device

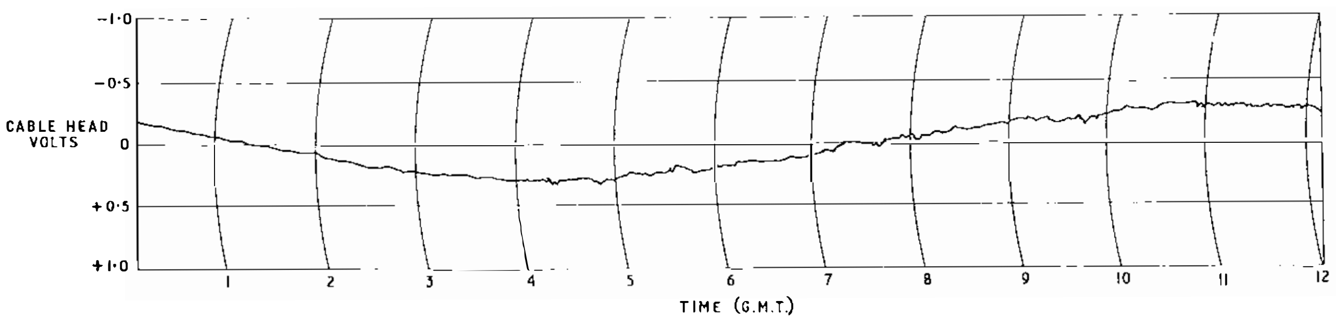
FIG. 1—Arrangement of audio-frequency equipment associated with unrepeatered submarine-cable carrier system

tidal flow, and for this purpose they were given facilities for recording induced voltages, due to the movement of water, first on a cable from St. Margarets to Sangatte and, later, on other cables across the North Sea and the Irish Sea.[7] It is of interest to note that although photographic recording equipment was used initially, experience showed that the standard British Post Office recording milliammeter (Decibelmeter No. 14) would give quite satisfactory results.

CHANGES IN THE EARTH'S MAGNETIC FIELD

When changes occur in the direction or magnitude of the earth's magnetic field, e.m.f.s will be induced in all conductors which it cuts, including all cables and the material of the earth's surface, e.g. the sea.

Although for many purposes the earth's magnetic field is considered to be constant or to change only very slowly and regularly with time, there are almost continuous variations in its magnitude or direction, the largest of which may have important effects on submarine cables.



The scale shows the approximate p.d. required between the ends of the cable to produce the current

Except during the first few hours there are also superimposed the effects of minor magnetic disturbances which occur very frequently

FIG. 2—Recording of current flowing in Port Kail–Donaghadee submarine-cable centre conductor, showing one cycle of the effect of tidal flow

Direct-current telegraph circuits, both in land and submarine cables, and d.c. signalling on telephone circuits[8] are occasionally affected by magnetic disturbances, but on submerged-repeater systems the signal path is not affected provided that the equipment supplying power to the submerger repeaters can adequately compensate for the additional voltages which appear.

It is of paramount importance that transoceanic systems should not be rendered unworkable by great magnetic storms, since it is during such storms that h.f. radio links and telegraph cables are likely to be unworkable.

Although there has been a great increase in the study of magnetic variations of recent years, particularly in the polar regions, in the upper atmosphere and in outer space, their pattern is still neither fully known nor understood. However, those features which affect submerged-repeater systems are described below, and the allowances that should be made in system designs so that their performances are unaffected are suggested.

MAGNETIC STORMS

The most intense disturbances in the earth's field are called magnetic storms. These are world-wide phenomena, affecting both hemispheres and spreading within a few minutes over the whole earth. The degree of disturbance which is classified as a storm varies with geomagnetic latitude (latitude with respect to the earth's magnetic poles), but in southern England a change greater than $1 \cdot 5 \times 10^{-3}$ gauss is classed as a storm (about $\frac{1}{2}$ per cent change), while a change greater than 3×10^{-3} gauss (1 per cent change) is a great storm. The records of the Greenwich and Abinger (now Hartland) magnetic observatories over a period of 80 years show 697 small storms and 112 great storms. Of the great storms, not all are severe enough to affect submerged-repeater systems. It will be seen, therefore, that the collection of data on their effects takes a considerable time. It is now 11 years since the effects on submerged-repeater systems were first noticed, and since then there have only been major disturbances on three occasions totalling about 30 minutes.

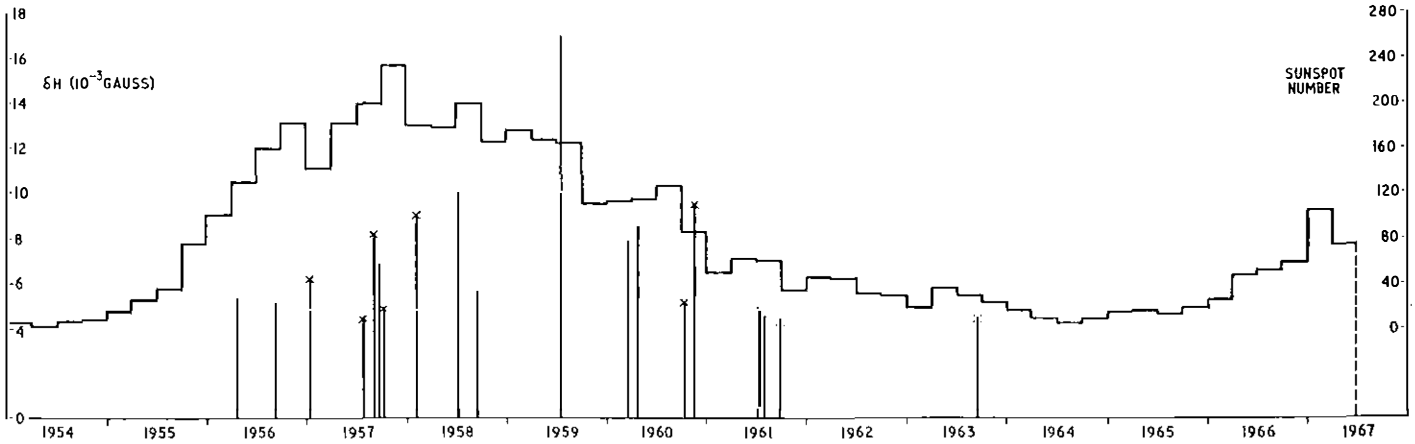
In general, the greatest disturbances follow the emission of a flare from a large sun-spot near the centre of the sun's disk. When such a spot emits a flare, a considerable increase in the intensity of certain types of solar radiation may be recorded almost immediately on the earth, and 1 to 4 days later there may be a severe magnetic storm. It is considered that such flares emit streams of charged particles travelling at between 1,000 and 300 miles/second, and that any parts of such streams which come within the earth's influence are guided along the lines of the earth's magnetic field towards the magnetic polar regions. Here they cause changes in the intense electric-current systems which normally flow in the ionosphere about 50 miles above the earth's surface, thereby changing the earth's field and inducing currents of thousands of amperes in the earth's crust. The arrival of these particles in the ionosphere also affects its power to reflect and refract radio waves, and produces the luminous electric discharge known as the aurora (aurora borealis or northern lights in the northern hemisphere, aurora australis in the southern hemisphere).

Most magnetic storms have the following pattern. A sudden change in the intensity of the earth's field occurs within a few seconds over the whole earth, followed by a few hours of minor disturbance. Several hours after the sudden commencement the most violent phase of the storm occurs, during which the intensity of the field may change rapidly both above and below its normal value; this intense phase may last several hours. Neither the detailed variations nor the periods of maximum disturbance are simultaneous over the whole earth. The intense phase is followed by a long period of moderate disturbances, during which the earth's field gradually restores to normal; this may last several days.

The main features of the distribution of the great storms are as follows.

(*i*) Their frequency of occurrence follows the 11-year sun-spot cycle to a large extent, although the greatest storms do not necessarily occur in the sun-spot maxima years. Fig. 3 gives the mean daily sun-spot numbers for the years 1954–1967 and the dates and comparative magnitude of magnetic storms of outstanding intensity.

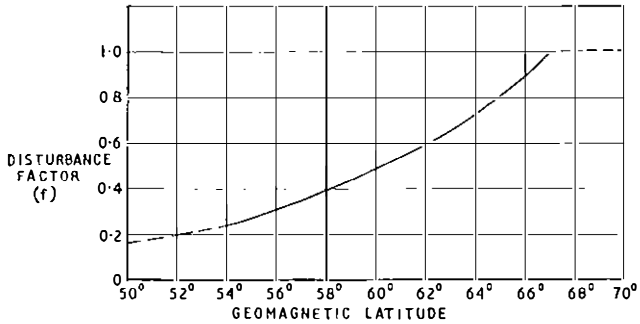
(*ii*) Their change in magnitude with geomagnetic latitude is similar to that for other magnetic disturbances, being greatest at about 67° North and South geomagnetic latitude and falling off very rapidly toward the equator and less rapidly towards the pole, in the manner shown in Fig. 4. The



The right-hand scale and horizontal lines give the 3-monthly average of daily Zürich sun-spot numbers.

The left-hand scale and vertical lines show the dates and magnitudes of magnetic storms during which the change in horizontal intensity of the earth's magnetic field (δH) as measured at Abinger (Surrey) or Hartland (Devon) exceeded 4×10^{-3} gauss. Storms whose effects on submarine cables are recorded in Table 2 are marked thus: ×

FIG. 3—Sun-spot numbers and outstanding magnetic storms, 1954–1967



Note: North of latitude 67° *f* is thought to decrease, but, as the law is unknown, it should be taken as 1·0

FIG. 4—Relationship of intensity of magnetic disturbance and geomagnetic latitude

frequency of observation of the aurora is also closely related to geomagnetic latitude, the regions around 67° North and South geomagnetic latitude being known as the auroral zones.

(*iii*) The change in magnitude with longitude is related to the time of day. During a great storm the most violent disturbances occur in the midnight to early morning part of the auroral zone.

(*iv*) There is some evidence that the current system which causes the disturbances moves from west to east at a velocity of about 100 km/s.[9]

(*v*) The component of the field that suffers the greatest change is the horizontal component along the magnetic meridian.

Effects on Land and Submarine Cables

The main effect on cables is due to the very large induced currents flowing in the earth's outer layers, a proportion of which will flow in any cables that are in any way earthed at both ends, since there will be a potential difference between the two earthing points. It may be that in some instances the voltages induced directly into the loop formed by the cable and the earth-return path will also be appreciable, e.g. when the cable route and earthing points are such that the loop has a large area, but direct measurements of voltages occurring due to minor magnetic disturbances indicate that they are usually small (less that $\frac{1}{10}$ of those due to the first effect).

Both land and submarine cables are affected. In Sweden, lying in or near the auroral zone, the effect on land cables is considerable, being adjudged a potential fire hazard.[10] On short submarine telephone cables without repeaters the effects are not important, being mostly of the same order of magnitude as those due to tidal effects. Fig. 2 shows, in addition to the tidal effect, the effect of a minor disturbance of a magnitude which occurs very frequently, while Fig. 5 shows a major disturbance on the same cable.

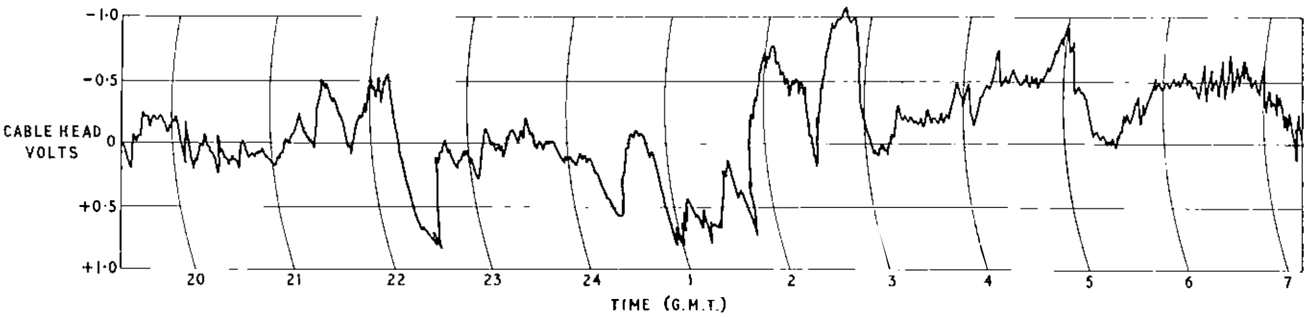
Effects on Submerged-Repeater Systems

Submerged repeaters are energized by direct current supplied from the terminal stations along the centre conductor of the coaxial cable. The complete loop circuit consists of the power equipment at one terminal, the cable centre conductor with the repeaters in series with it, the equipment at the other terminal (which may include power equipment if the system is double-end fed), a connexion to earth, and a return path through the earth and sea to an earth connexion at the first station. Power equipment for submerged repeaters always has an approximately constant-current output characteristic so that, provided the capabilities of the equipment are not exceeded, any extraneous voltages which appear in the power loop will cause changes in the output voltage of the equipment. These additional voltages have to be allowed for in determining the maximum output voltage required from the power equipment, and the speed of regulation has to be sufficient to counteract the changes in the extraneous voltages. In many instances both the voltage and current outputs of the power equipment are continuously recorded, so giving, inadvertently, a record of the effects of magnetic storms. Provided the current remains constant, the change in output voltage is equal and opposite in polarity to the extraneous voltage.

The voltages which appear in this power loop during magnetic storms are, again, mainly the result of the differences in potential between the two earthing points due to the magnetic-storm currents flowing in the earth's crust, but it may be that, under certain conditions, significant voltages are induced into the loop directly.

Fig. 6 shows the changes in power-feeding voltage at Oban on the Oban–Clarenville No. 2 cable during the magnetic storm of 11 February 1958. It will be seen that the magnetic-storm voltages change quite slowly, taking times of the order of a minute to build up to their maximum value and maintaining a given polarity for several minutes at a time. There are also components of higher frequency, of the order of 1 Hz, but these are of smaller amplitude.

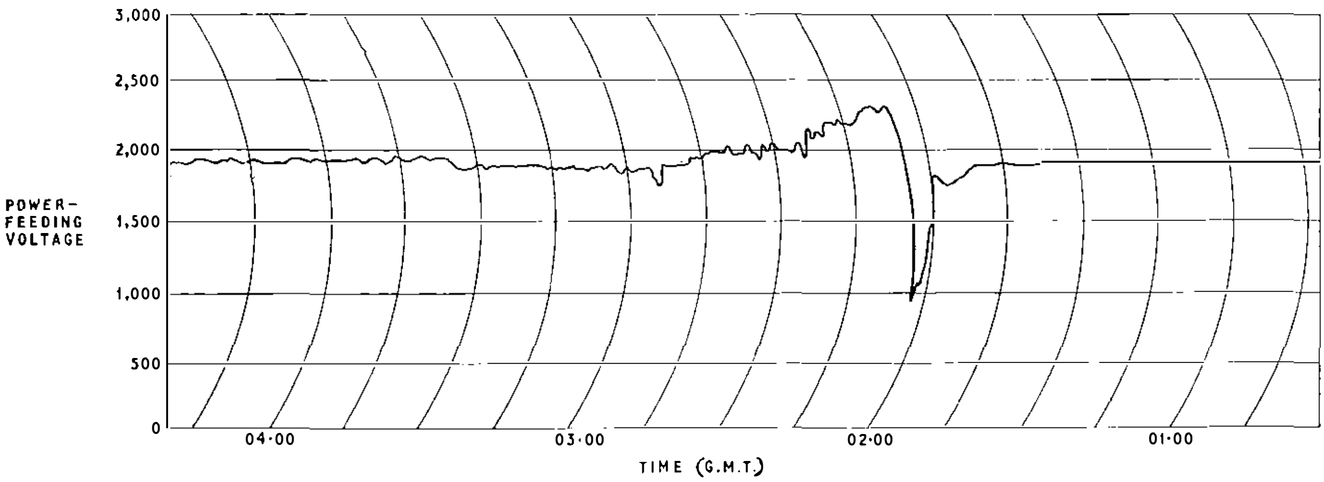
The first occasion on which a submerged-repeater power-feeding circuit was noticeably disturbed was on 21 January



Shows the effect of a larger magnetic disturbance (9 October 1962) completely obscuring the tidal effect shown in Fig. 2. Since there is no entry for 9 October 1962 in Table 2, the disturbance was not severe enough to affect submerged-repeater systems

The scale shows the approximate p.d. required between the ends of the cable to produce the current

FIG. 5—Recording of current flowing in a Port Kail–Donaghadee submarine cable



The recording shows the effect of the great storm of 11 February 1958, the most violent phase being after 0200 (G.M.T.). The voltage due to the storm is shown on the chart, about 1,000 volts maximum, plus a similar though greater change in the output of the Clarenville equipment, making a total of 2,700 volts, as shown in Table 2

FIG. 6—Output voltage of the power-feeding equipment at Oban on the Oban–Clarenville No. 2 cable

1957. Details of this and subsequent disturbances are given in Table 2. The table is thought to be complete in respect of systems terminating in the United Kingdom, but there may be significant omissions as regards other systems.

TABLE 2
Magnetic-Storm Voltages Recorded on Submerged Repeater Systems

Date	Time (G.M.T.)	Cable Affected	Maximum Voltage Recorded (Volts)
21.1.57	22.00	Aberdeen–Bergen	over 100
		Clarenville–Sydney Mines	450
		Oban–Clarenville	200
30.6.57	23.00	Aberdeen–Bergen	50
3.8.57		Aberdeen–Bergen	over 100
4.9.57		Aberdeen–Bergen	over 100
23.9.57		Aberdeen–Bergen	over 100
11.2.58	02.00	Aberdeen–Bergen	130
		Clarenville–Sydney Mines	145
		Oban–Clarenville	2,700
6.10.60		Middlesbrough–Goteborg	over 100
12.11.60		Middlesbrough–Goteborg	over 100
13.11.60	10.00	Aberdeen–Bergen	over 100
		Clarenville–Sydney Mines	500
		Middlesbrough–Goteborg	600
		Oban–Clarenville	550
16.11.60		Middlesbrough–Goteborg	over 100
1.10.61		Middlesbrough–Goteborg	over 100
23.9.63		Middlesbrough–Goteborg	over 100
3.9.66		Middlesbrough–Goteborg	over 100
4.9.66		Middlesbrough–Goteborg	over 100
25.5.67		Middlesbrough–Goteborg	over 100

In the past, lacking any more precise information, a maximum induced voltage of 1 volt/nautical mile has been allowed for in determining the maximum power-feeding voltage required. It is believed, however, that this is in some instances excessive and in others barely adequate. Of recent years, being near a sun-spot minimum period, there have been no major storms and, therefore, no opportunity of collecting more data, but during the sun-spot maximum period around 1969 there will, no doubt, be several major storms and many more cables than ever before to be affected.

It is considered that there is at present insufficient data to enable the maximum voltage likely to appear on any cable to be estimated, but, nevertheless, it is useful to summarize present thoughts on the matter in the expectation that when more data become available a method of estimation may be evolved and a better knowledge of the factors determining this voltage obtained.

The voltage between the two earthing points caused by the currents already flowing in the earth has been considered by A. Karsberg,[10] and for land cables it is concluded that the maximum voltage is proportional to:

(*a*) the distance between the two earthing points,

(*b*) the resistivity of the earth between the two earthing points,

(*c*) an intensity factor determined by the geomagnetic latitude and obtained from the curve in Fig. 4, and

(*d*) the cosine of the angle between the line joining the two earthing points and the direction of current flow, which is most likely to be along the geomagnetic latitude.

For short submarine cables it would appear that these factors also apply. Factors (*a*), (*c*) and (*d*) are clearly relevant, although it has not been possible to show direct proportionality. The effect of depth of water on (*b*) is not known.

For long submarine cables it is doubtful whether the same considerations apply, since, as the worst disturbances are not simultaneous over the whole earth, it would not be expected that the whole area between the earthing points would carry maximum currents simultaneously. Furthermore, over long distances the fact that the currents are flowing in or on a sphere rather than a plane may be relevant. If the worst disturbances are at any one time localized to areas about 1,000 miles across, the worst affected 1,000 miles of cable should perhaps be considered and the rest neglected.

Any voltage which may be induced directly into the loop formed by the cable and the earth-return path will be proportional to the rate of change of the earth's field and to the area of the loop normal to the change in field, and will be influenced by the screening effect of water and earth. Attempts to compare the voltages induced into a loop of cable with those appearing between the ends of cables during minor magnetic disturbances have shown the former to be of no great significance. Nevertheless, it is felt that the extremely high voltages measured on the Sydney Mines–Clarenville cables may be influenced by the fact that there is a long land section of 55 miles and that the earthing point in Newfoundland is in the Atlantic although the cable crosses the island before entering the water in the Gulf of St. Lawrence.

From a consideration of the above factors it is thought that all cables in the world may tentatively be divided into three categories.

(*i*) Those on which voltages in excess of 1 volt/nautical mile might be expected very occasionally.

(*ii*) Those on which appreciable voltages might be expected, but never in excess of 1 volt/nautical mile.

(*iii*) Those on which the magnetic-storm voltages are not likely to be appreciably greater than those allowed for in the power-feeding equipment for other reasons, e.g. temperature changes, repair allowances, current changes.

In category (*i*) are those cables in latitudes higher than 55° geomagnetic which run more or less parallel to the geomagnetic latitude. Included are all cables crossing the North Atlantic and the North Sea, north of the TAT–2 and United Kingdom–Denmark cables, respectively, except the Gairloch–Torshavn (SCOTICE) cable which is almost at right angles to the magnetic latitude.

In category (*ii*) are the remainder of the cables crossing the North Atlantic, the U.S.A.–Bermuda cable, and the Gairloch–Torshavn cable.

All other cables are in category (*iii*), though the Sydney–Auckland cable might be included in category (*ii*). All projected cables around South America, and in the South Atlantic and the Indian Ocean, would also fall in category (*iii*).

Fig. 7 is a map of the world showing geomagnetic latitudes 80°, 67°, 55° and 45°, and the geomagnetic equator.

A Use for Magnetic Variations

As with voltages due to tidal flow, it is interesting to note that currents in cables caused by changes in the earth's field have also been used for measurements not connected with communications.

The Geology Department of the University of Liverpool has been given facilities at certain repeater stations for making simultaneous measurements of magnetic disturbances and the currents which they produce, as a means of determining the resistivity of the rock at different depths below the sea bed. The natural disturbances cause currents having components over a range of frequencies, all sub-audio, different components penetrating to different depths in the sea bed and, therefore, encountering different resistivities.

MAN-MADE DISTURBANCE OF THE EARTH'S MAGNETIC FIELD

In 1962, when the U.S.A. were planning to detonate nuclear bombs at high altitudes, it was anticipated that there would be some world-wide effect on the earth's magnetic field, and some authorities were predicting changes of a magnitude which would have caused voltages sufficient to endanger the repeaters in many submarine cables.[11] If it had been considered necessary it would have been possible to disconnect the power-feeding circuits of all systems to prevent excessive currents passing through the repeaters. This was not done, but particular attention was paid to the continuous recordings of power-feeding voltages.

The only detonation detected was that at approximately 09.00 G.M.T. on 10 July 1962 when an atom bomb, with a power of the order of one megaton, was exploded at a height of about 200 miles. The disturbance was just detectable on the power-feeding voltage and current recorder charts on the

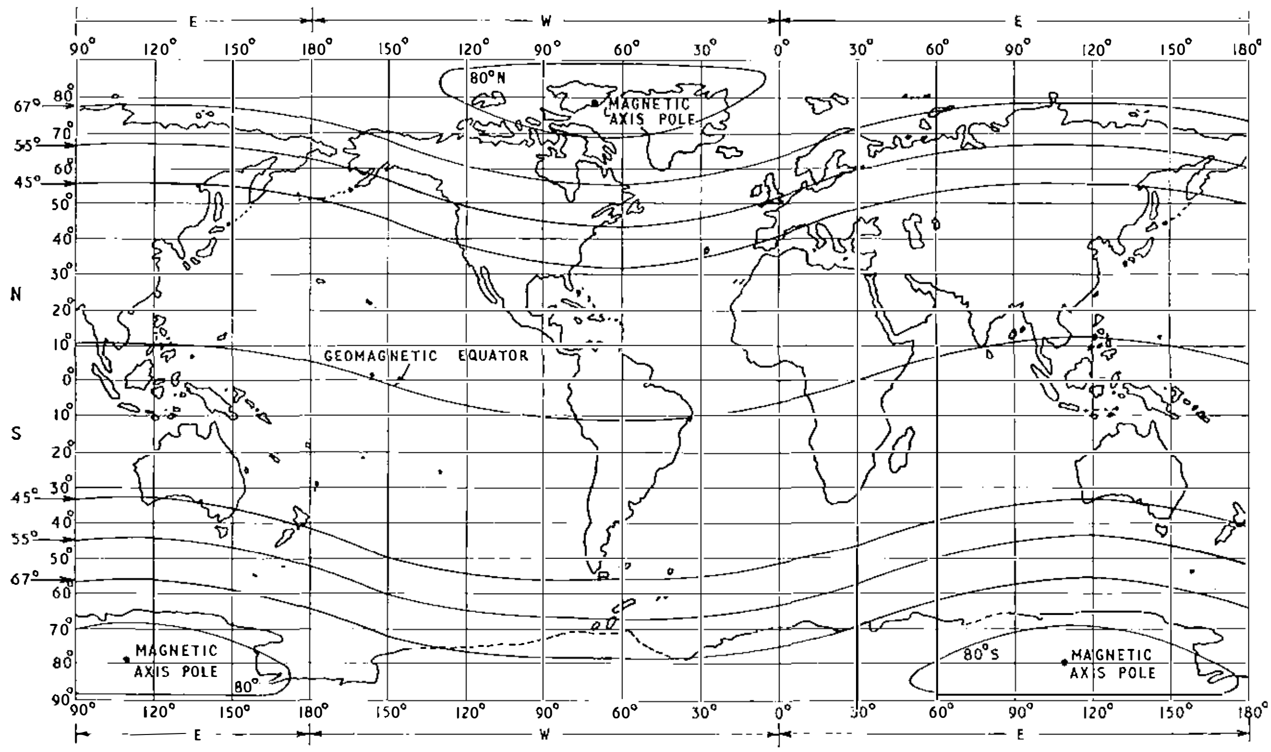
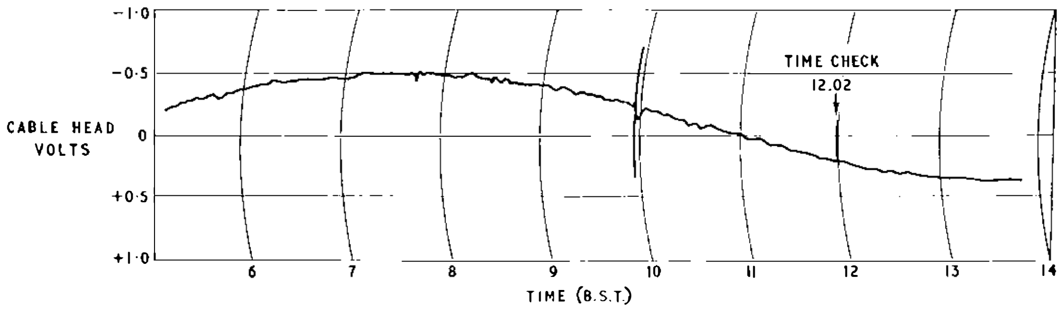
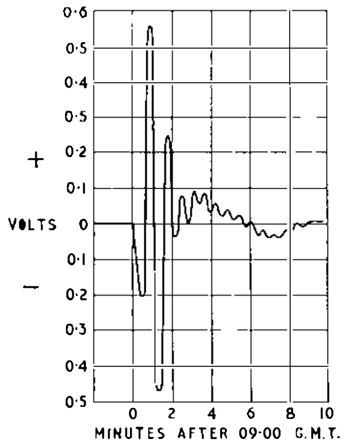


FIG. 7—Geomagnetic equator and geomagnetic latitudes 45°, 55°, 67° and 80°



(*a*) Chart Trace of Effect on Circuit set up to Measure Effects of Tidal Flow



(*b*) Sketch of Detail of Chart Trace

FIG. 8—Effect of atom-bomb detonation on centre-conductor voltage of Donaghadee–Kail No. 3 cable

Australia–New Zealand, United Kingdom–Sweden and Bournemouth–Jersey systems.

On a circuit originally set up on the Donaghadee–Port Kail No. 3 cable for the measurement of voltage due to water flow, the disturbance was clearly recorded, the chart being reproduced in Fig. 8 (*a*). The voltage appearing in the loop was approximately 0·55 volts, first in one direction and then the other. The cable is 22 nautical miles long and the disturbance voltage was, therefore, 0·25 volts/nautical mile: such voltages are frequently produced by natural disturbances. In Fig. 8(*b*) an attempt has been made to sketch the detail of the occurrence from careful examination of the recorder-chart trace.

Magnetic observatories throughout the world recorded this disturbance, which had a magnitude of about 2×10^{-4} gauss and a rate of change exceeding 10^{-5} gauss/second.

References

1 FARADAY, M. *Philosophical Transactions of the Royal Society*, p. 175, 1832.
2 CHERRY, D. W., and STOVOLD, A. T. *Nature*, Vol. 157, p. 766, June 1946.
3 *Journal of the Society of Telegraph Engineers*, Vol. 10, 1881.
4 LONGUET-HIGGINS, M. S. *Monthly Notices of the Royal Astronomical Society*, Geophysical Supplement, Vol 5, Mar. 1949.
5 HILL, M. N., and MASON, C. S. *Nature*, Vol. 195, p. 365, July 1962.
6 FARADAY, M. Experimental Researches in Electricity, Vol. 2.
7 BOWDEN, K. F. *Philosophical Transactions of the Royal Society*, Vol. 248, p. 517, Feb. 1956.
8 Magnetic Storm Affects Signalling. *P.O.E.E.J.*, Vol. 39, p. 77, April 1946.
9 LAWRIE, J. A., and PRICE, A. T. *Nature*, Vol. 197, p. 581, Feb. 1963.
10 KARSBERG, A. The Influence of Earth Magnetic Currents on Telecommunication Lines. *Tele* (English Edition) No. 1, 1959.
11 HOYLE, F. The Space Bomb. *New Scientist*, Vol. 14, p. 268, May 1962.

Books Received

"Radar System Engineering." Edited by L. N. Ridenour. Constable and Company, Ltd. xviii + 748 pp. 446 ill. 24s.

"Radar Aids to Navigation." Edited by J. S. Hall. Constable and Company, Ltd. xiii + 389 pp. 192 ill. 22s.

The above two books were originally published by McGraw-Hill Book Co., Inc., in the Massachusetts Institute of Technology Radiation Laboratory Series as Volume 1 (1947) and Volume 2 (1947), respectively. By the co-operation of McGraw-Hill with Dover Publications, Inc., the books, unabridged and unaltered, have now been reproduced in Dover paperback editions on a paper which, the publishers claim, gives minimum show-through and will not discolour or become brittle with age; the pages are sewn in signatures, and the books may be opened flat without fear of pages dropping out.

When "Radar System Engineering" was published in 1947 it was intended to serve as a general treatise and reference book on the design of radar systems. As the editor points out in his preface, thousands of times as much work had gone into pulse radar as into any other kind, and the overwhelming majority of this work had been concerned with microwave pulse radar; thus, the book deals primarily with microwave pulse radar. Eight chapters provide an introduction to radar and the problems of system design. Then follow six chapters dealing with design considerations of the major components of a radar set. Chapter 15 gives two fairly detailed examples of actual system design, and the closing two chapters deal with, respectively, moving-target indication and the transmission of radar displays to a remote indicator by radio.

The preface to "Radar Aids to Navigation" indicates that the book is intended primarily to describe the advantages and limitations of radar equipment when applied to problems of navigation and pilotage, whether the equipment is airborne, shipborne or ground-based; radar beacons as aids to navigation are also discussed. It should be pointed out that the editor, when writing the preface in 1946, says that, in this book, the emphasis is placed more on what can now be done with radar than on what should be possible in the future.

Installation Plans for Pulse-Code-Modulation Systems up to December 1969

U.D.C. 621.376.56(083.9)

The plans for the introduction of p.c.m. systems into the British Post Office telephone network up to December 1969 are described in this article. The information is mainly in the form of detailed maps, distribution histograms and tables.

Earlier issues[1, 2] of this Journal have described the 24-circuit pulse-code-modulation (p.c.m.) system; by December 1969, 920 of these systems will have been installed in the British Post Office telephone network and will be carrying traffic. Fig. 1 shows the systems which will terminate in Central London, the numbers indicating the number of systems on each route. Fig. 2 and 3 show the systems to be provided in England and Wales, and in Scotland and Northern Ireland, respectively. Table 1 lists the planned provision for each Region; it should be noted that the numbers marked with asterisks include five inter-Regional systems.

The picture presented is not yet sufficiently advanced to show the true pattern that will develop in the next 5–10 years, and it will be seen that in some of the more densely populated areas of the country relatively few p.c.m. systems have, as yet, been planned. More than half the systems shown are between group switching centres (G.S.C.s), underlined in Fig. 1, 2 and 3,

[1] Development of Pulse-Code-Modulation Systems. *P.O.E.E.J.*, Vol. 59, p. 10, Apr. 1966.

[2] JEYNES, E. Planning and Works Aspects of 24-Circuit Pulse-Code-Modulation Systems. *P.O.E.E.J.*, Vol. 60, p. 33, Apr. 1967.

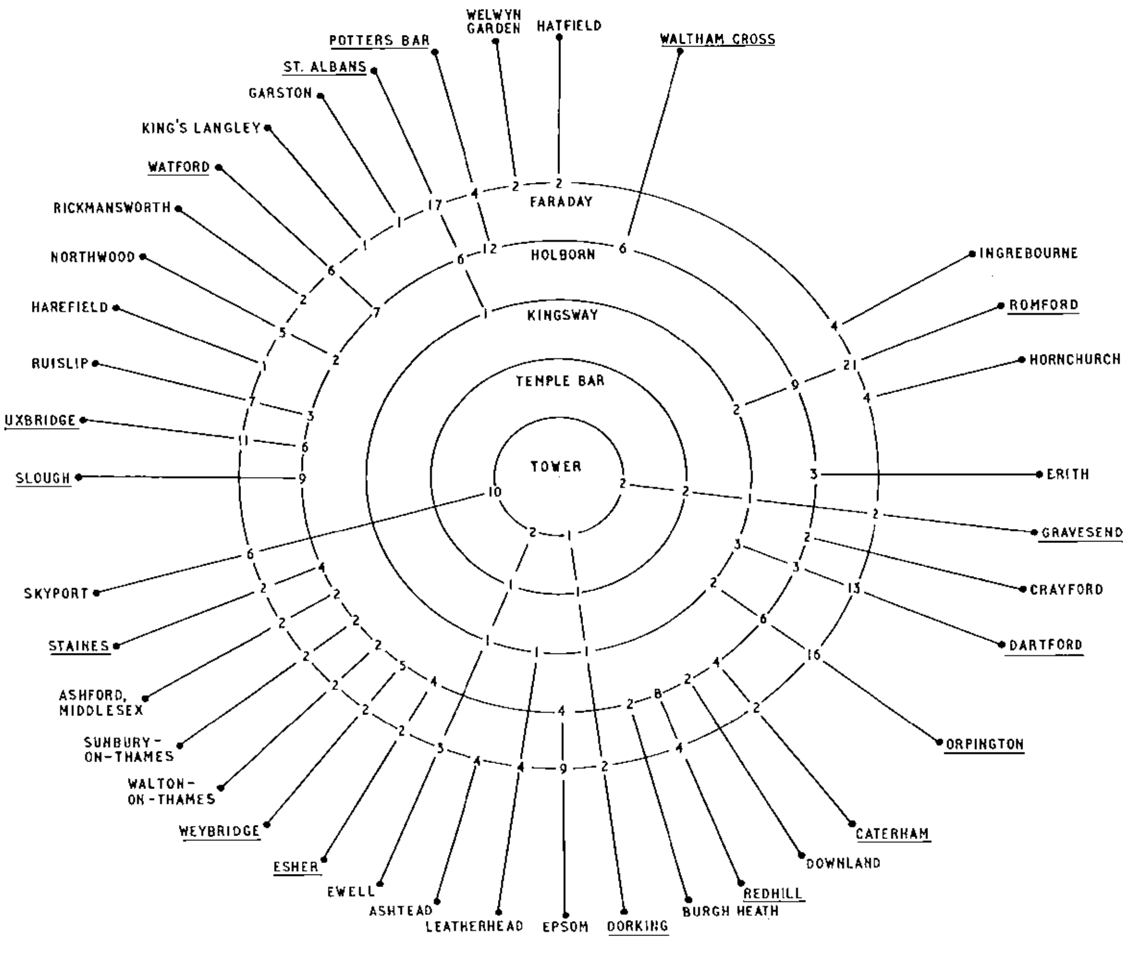


FIG. 1—24-circuit p.c.m. systems terminating in Central London

Fig. 2—24-circuit p.c.m. systems to be provided in England and Wales

FIG. 3—24-circuit p.c.m. systems to be provided in Scotland and Northern Ireland

TABLE 1

Summary of P.C.M. Systems Planned by Regions

Installation method	Contract	Direct labour	Direct labour	Direct labour	Totals
Ready-for-service date	June 1968	December 1968	June 1969	December 1969	
Eastern Region	—	4	11	31	46
London Telecommunications Region ..	72	157	—	80	309
Midland Region	10	—	8	33	51
North Eastern Region	4	77	13	39	133
Northern Ireland	—	14	13	17	44
North Western Region	6	29*	32	—	67*
Scotland	3	43	59	39	144
South Eastern Region	—	—	67	—	67
South Western Region	4	—	13	18	35
Wales and Border Counties	2	18*	9	—	29*
Totals	101	337	225	257	920

TABLE 2

Types of Exchanges Served by Planned P.C.M. Systems

Exchange type	G.S.C.	D.	N.D.	S.A.X.	U.A.X.14	U.A.X.13	TXE2	Totals
Number of exchanges	141	3	65	4	8	9	1	231
Number of p.c.m. systems from G.S.C.s to exchange shown..	583	29	258	4	28	13	3	918
Number of p.c.m. systems from N.D. to N.D. exchanges ..	—	—	2	—	—	—	—	2

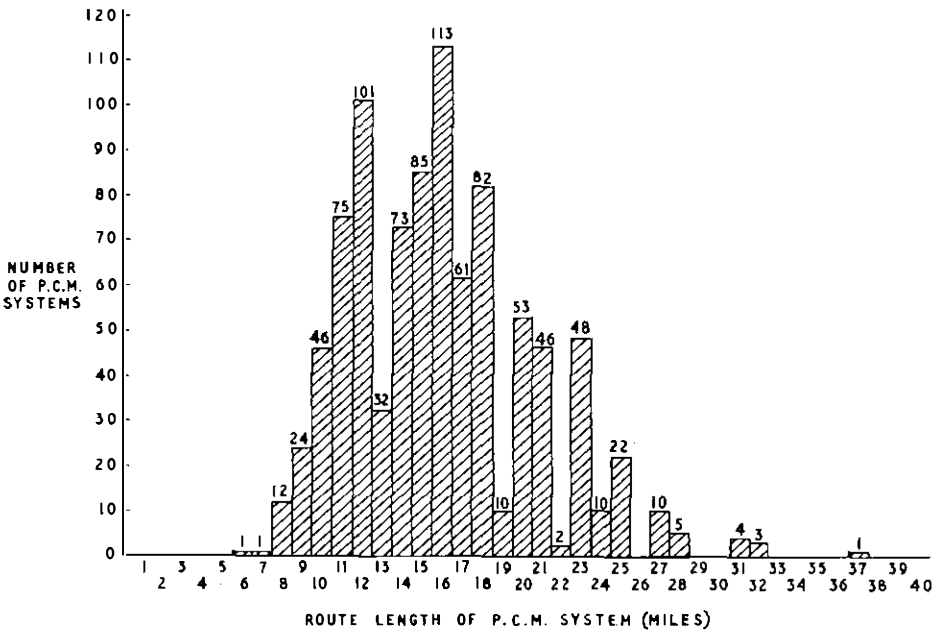


FIG. 4—Distribution of planned p.c.m. systems in terms of route lengths of the systems

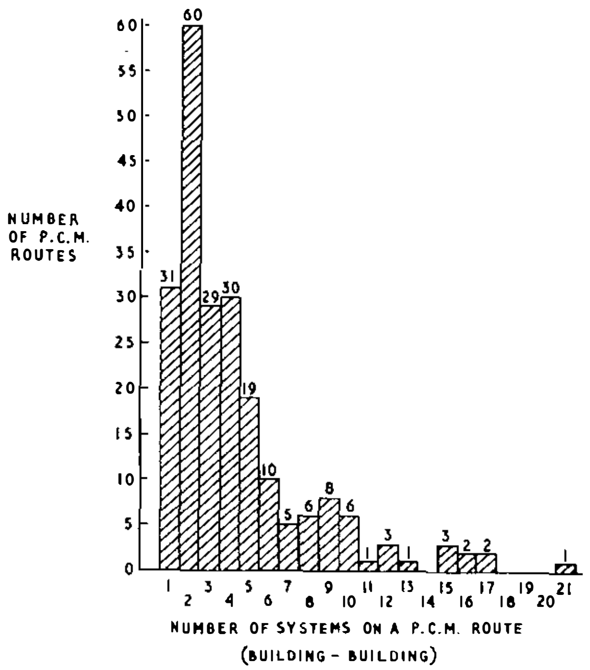


FIG. 5—Distribution of planned routes with respect to the number of p.c.m. systems per route

but future planning is expected to show that a higher proportion of local exchanges will be concerned; Table 2 gives details of the various types of exchanges served by these systems.

At present, the use of p.c.m. is considered to be more economic than the use of audio cables (10 lb/mile P.C.Q.T.) at distances above about 9–14 miles, depending on growth rates; however, these distances are expected to be reduced in the future. The distribution of the planned p.c.m. systems in terms of route length is shown in Fig. 4, and Fig. 5 shows the distribution of routes with respect to the number of p.c.m. systems per route. The average length of systems by December 1969 will be 16 miles. It will be seen that the number of systems on a route is small, and the maximum number of digital-link sections* planned so far in any one cable is only 40—for the size of cable used, this is well within the maximum number permitted by the present planning rules.

M. D. C. and J. F. G.

* A digital-link section consists of transmit and receive line terminals linked by a unidirectional transmission path.

Television Links to the Channel Islands for the Independent Television Authority

N. A. ELKINS, C.ENG., M.I.E.E.†

U.D.C. 621.397.743(423.4)

The distance of the Channel Islands from the English coast precludes the use of the usual methods of providing television links, and, because of the relatively small population served, the provision of a suitable submarine cable would be uneconomic. The islands are too close to the French coast to permit a tropospheric-scatter propagation link to be used, and the only practicable system is to relay signals radiated by broadcasting transmitters in England.

INTRODUCTION

The Channel Islands are situated some 16 miles from the coast of France and 60 miles from the south coast of England at the nearest points. They have a total population of about 100,000.

The Independent Television Authority (I.T.A.) operates a television transmitting station at Fremont Point on the island of Jersey, and a separate program contractor, Channel Television, has been appointed by the I.T.A. for the Channel Islands. The islands form the smallest of the I.T.A. areas, and have, for example, well under 1 per cent of the population of the Authority's London area. A unidirectional television link with the mainland is necessary in order to allow the program company access to the main Independent Television network, but, because only a small population is served, it is desirable that the cost of the link should be small.

Main inland television links are usually provided by means of line-of-sight microwave radio-relay systems. Links of this type can be provided economically and will give a good performance where the maximum spacing between stations does not exceed some 40 miles. The shortest distance to the Channel Islands is considerably greater than this, however, and extremely high aerials would be needed to give a line-of-sight path. The cost of the aerial-supporting structures alone would be sufficient to make a microwave link uneconomic in these circumstances. Other factors, including the high incidence of fading expected on long oversea paths, combine with the high cost to make a microwave link unacceptable.

Another possible means for the transmission of television signals over a 60-mile sea-path would be a suitable submarine cable, but again the cost would be prohibitively high in relation to the size of the population served. A radio link using tropospheric-scatter propagation would also be expensive, and, because the islands are close to the coast of France, it would not be possible to prevent an excessive proportion of the transmitted energy from reaching French territory, where it would be liable to cause interference.

The remaining possibility is the reception in the Channel Islands of television signals radiated by broadcasting transmitters in England, and this solution has been adopted. A receiving station has been set up on Alderney, the most northerly island of the group, and the nearest to the English coast, from where the signals are relayed to Jersey by means of a microwave radio-link. Fig. 1 shows a diagram of the complete system.

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CHARACTERISTICS OF CHOSEN LINKS

Transmitters

Three I.T.A. transmitters offer some possibility of reliable reception on Alderney: they are at Chillerton Down on the Isle of Wight, Stockland Hill near Axminster, Devon, and Caradon Hill near Launceston, Cornwall. Particulars of these transmitters are given in Table 1.

TABLE 1
I.T.A. Transmitters

Transmitter	Stockland Hill	Caradon Hill	Chillerton Down
Channel	9	12	11
Effective radiated power of vision transmitters in the direction of the Channel Islands (in kW)	20	20	2·7
Distance from Alderney (in miles)	88	119	77
Mean aerial height above sea level (in feet)	1,475	1,936	1,250
Polarization	Vertical	Vertical	Vertical
Program contractor	Westward Television	Westward Television	Southern Independent Television

All three transmitters are subject to a limitation of the effective radiated power (e.r.p.) in the direction of the Channel Islands, in order to reduce interference with French services. The e.r.p. of the Stockland Hill transmitter is 20 kW over a narrow angle in the direction of Alderney, specifically to provide an increased field strength in Alderney for the Channel Islands link. It was originally intended that the e.r.p. in this direction should be 50 kW, but this was reduced to 20 kW in order to avoid interference with transmissions from a French station at Bourges.

Received Signals

The measured median value of the field strength at the Alderney receiving site of the signal from Stockland Hill is +51 dB relative to 1 μV/m, and for 98 per cent of time the field strength lies in the range +12 dB to −5 dB relative to the median value. The measured median value of the field strength from the Chillerton Down transmitter is +49 dB relative to 1 μV/m, and for 98 per cent of time this signal lies in the range +16 dB to −8 dB relative to the median value. Thus, the signal from Chillerton Down has a somewhat lower median level than that from Stockland Hill, and is also subject to a greater fading range.

For 1 per cent of time the received-signal level is below the lower limit quoted, and for a smaller proportion of time the level is low enough for the noise level to be obtrusive, or even so severe as to render the signal unusable. During the remaining 1 per cent of time abnormally-high signal levels are received. High signal levels are not normally a cause of unsatisfactory signals, but occasionally they are accompanied by multi-path propagation, the effects of which may, in severe cases, render a signal unusable. A picture marred by multipath propagation may show several images, possibly of similar brightness, laterally displaced from one another.

The median field strength of the signal from the Caradon Hill transmitter is considerably lower than that from the other transmitters, and the received signal is unusable for most of the time. However, when the conditions of propagation are such that extremely high-level signals, marred by multi-path propagation, are received from Stockland Hill, it sometimes happens that an acceptable signal is provided by the Caradon Hill transmitter.

Interference

Because the level of the signals received at Alderney is rather low the link is more than usually susceptible to the effects of interference. Two types of interfering signal are most common: "ignition-type" interference, caused mainly by petrol-engine ignition systems, and co-channel interference from other television transmitters.

Considerable ignition-type interference was experienced when the receivers on Alderney were first put into operation, since about 200 of the 400 motor vehicles on the island were unsuppressed. These, together with some 50 other engines, including 23 on various types of boat, were fitted with suppressors, and interference due to this cause ceased almost completely. Occasional outbreaks still occur, but these are usually caused by the engines of boats visiting the island.

Interference of an impulsive kind also arises occasionally from an 11 kV overhead power-distribution line which passes in front of the receiving aerials at a distance of about 200 yards. The line is exposed on the seaward side, and salt deposits accumulate on the insulators so that under certain weather conditions flashovers occur. The deposits can be removed by washing, but in some types of weather they can return in a few hours.

Co-channel interference may be caused by any of a large number of television transmitters in France, the United Kingdom and Eire, especially when radio-propagation conditions favour the long-distance transmission of v.h.f. signals. The map (Fig. 2) shows the locations of the wanted stations and of some of the potential sources of interference. Particulars of the stations shown on the map are given in Table 2. The "protection ratio" referred to in this table is the separation required between the levels of the wanted and unwanted signals in order that the picture may be of acceptable quality.

The transmitter at Fremont Point, Jersey, is potentially the most important source of interference affecting the signals received on Channel 9 from Stockland Hill. In order to reduce the level of the interference, the e.r.p. of the Fremont Point transmitter in the direction of Alderney has been reduced to the lowest practicable figure. Unfortunately, this has placed the island outside the service area of the trans-

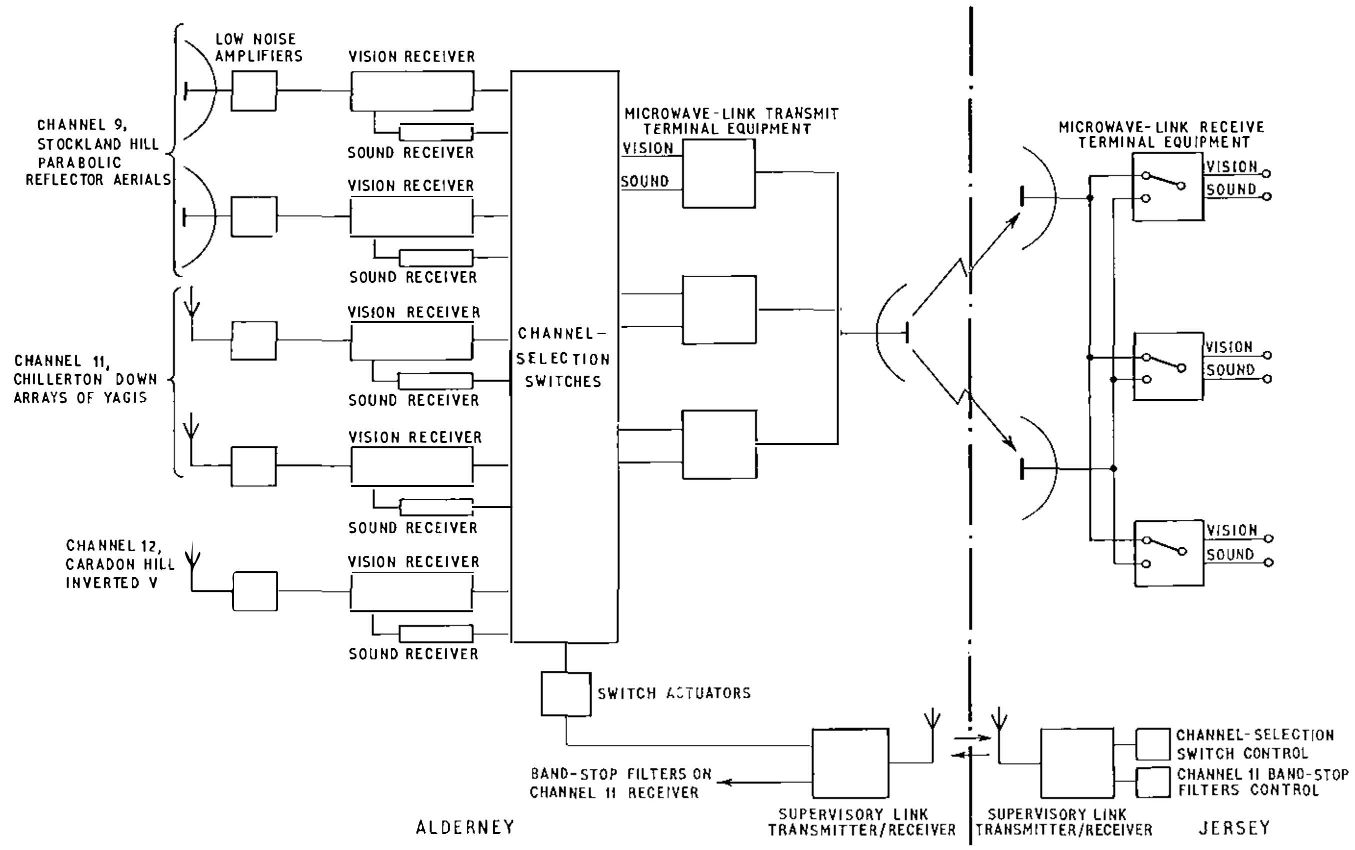
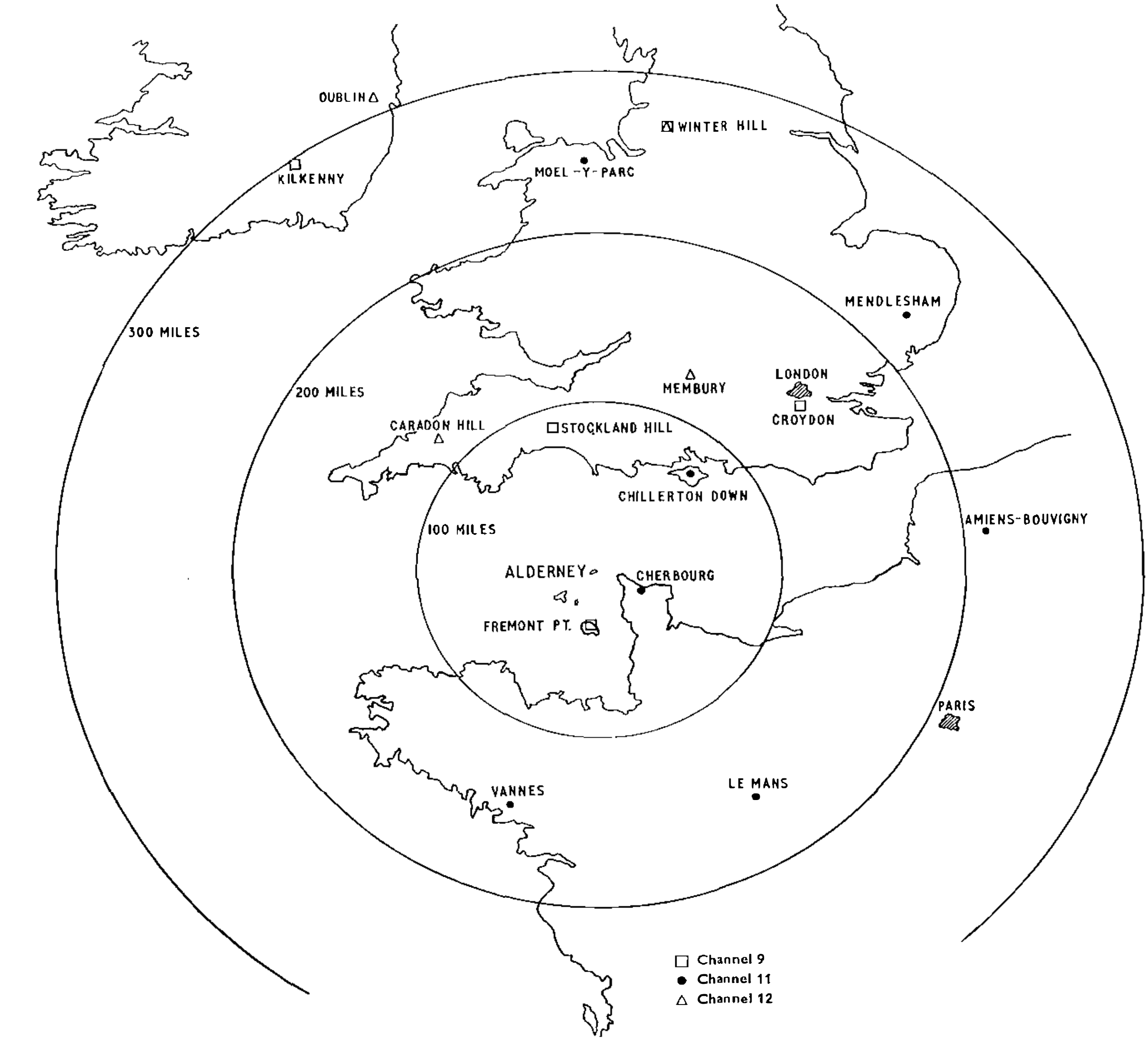


FIG. 1—Television links to the Channel Islands

mitter, and has left it without a reliable source of television signals. In spite of the reduction of e.r.p., however, the field produced in Alderney is still large enough to produce an objectionable amount of interference, but this has been reduced to a completely acceptable level by the use of aerials giving considerable rejection in the direction of the unwanted carrier frequency of Channel F11 lies within the bandwidth of the British Channel 11 at a frequency corresponding to a modulating frequency of 1·3 MHz. Easily-noticed interference patterns may be produced by signals of this frequency, so that, as Table 2 shows, a high protection ratio is required. Interference with the British Channel 11 from the French



The stations shown transmit on, or co-channel with, the channels indicated by the key symbols

FIG. 2—Locations of wanted stations and potential interference sources

signal. In addition, these aerials are sited on the north-facing slope of a hill, below the crest, in order to take advantage of the screening provided by the hill.

The other potential sources of co-channel interference with the Stockland Hill signal are effective only infrequently, when conditions favouring long-distance propagation exist over the path concerned. Identification of the source of co-channel interference of a transitory kind is seldom possible, but there have been a few occasions when the test card of the Winter Hill transmitter has been clearly seen at Alderney.

Most of the co-channel interference that is experienced on the signal from Chillerton Down arises from French stations operating on the French Channels F11 and F12. The vision Channel F12 arises from the upper part of the vision sideband, where the energy level is normally low, and possibly also from the sound carrier, the frequency of which lies just outside the pass-band of a Channel 11 vision receiver. Only a relatively-low protection ratio is required in this case.

Most of the interference experienced from the French Channel F11 is believed to originate from the transmitter at Amiens. The receiving aerials for the signal from Chillerton Down are adjusted to have minimum gain in the direction of Amiens, but it is also necessary to introduce a band-stop filter into one of the receivers in order to provide additional suppression at the unwanted carrier frequency on occasions when the level of the interfering signal is abnormally high.

The waveform response of the receiver is considerably degraded by the introduction of the filter, but the effect on picture quality is considered to be less objectionable than that of the interfering signal.

TABLE 2

Principal Sources of Co-Channel Interference

Station	E.R.P. in in Direction of Alderney (kW)	Distance from Alderney (miles)	Polarization	Protection Ratio Required (dB)
Stations Affecting Channel 9				
Fremont Point . .	0·1	32	Horizontal	35
Croydon . .	50	150	Vertical	35
Winter Hill . .	100	265	Vertical	35
Kilkenny . .	50	293	Vertical	22
Stations Affecting Channel 11				
Cherbourg . .	4	27	Horizontal	12
Vannes	10	146	Horizontal	12
Le Mans . .	50	160	Vertical	22
Amiens-Bouvigny	100	214	Vertical	39
Mendlesham . .	40	228	Horizontal	25
Moel-y-Parc . .	25	244	Vertical	35
Stations Affecting Channel 12				
Membury . .	0·5	128	Horizontal	25
Winter Hill . .	2·5	265	Vertical	35
Dublin	50	305	Horizontal	15

The chief source of co-channel interference from Channel F12 is the transmitter at Cherbourg, the field strength of which is considerably greater than that of any of the wanted signals. Interference from this source is also controlled by appropriate shaping of the aerial response.

The remaining French stations shown on the map are situated to the rear of the Channel 11 aerials, and the interference from these sources is adequately suppressed by a screen behind the aerials.

In spite of the very low signal level received from Caradon Hill, no case of co-channel interference with this signal has so far been recorded.

LINK EQUIPMENT

Five independent receivers and aerial systems are provided, giving duplicate facilities on the two main signal-sources of Stockland Hill and Chillerton Down, and a single receiver for the Caradon Hill signal. Three independent unidirectional microwave channels are provided between Alderney and Jersey, and the interconnexions between the five receiver outputs and the inputs to the three microwave channels are made by means of remotely-controlled coaxial switches.

Aerials

Each of the two aerials used on Channel 9 consists of a parabolic reflector, 30 ft in diameter, with a 4-element yagi array as the source. The aerials are sited on the slope of a hill, and one is placed 40ft above the other in order that the benefits of height deversity may be obtained. A photograph of one of the aerials is shown in Fig. 3. The gain of these aerials is 20 dB relative to a half-wave dipole, and the front-to-back ratio, i.e. the ratio of the gains of the aerial in the two directions of the major axis, is 27 dB. The upper aerial is at a height of 260 ft above mean sea-level.

Each of the two aerials used for reception of Channel 11 signals consists of an array of eight yagi aerials, each yagi comprising eight elements. The spacing of the yagis is arranged to give minimum response at angles of 73° and 45° from the axis, and the array is backed by a screen which shields the aerial from signals arriving from the rear. Each array has a gain of 18 dB relative to a half-wave dipole. The gain in the directions 45° and 73° from the axis is 38 dB less than the maximum gain, while in directions to the rear of the aerial the gain is at least 50 dB less than the maximum. A photograph of one of the aerials is shown in Fig. 4.

An inverted-V aerial is used for the reception of Channel 12 signals. It is made up of 12 parallel wires, and has a gain of 20 dB relative to a half-wave dipole. This type of aerial was chosen in order to relieve the tower of the additional loading which would have been imposed by a further array of yagi aerials.

Low-Noise Amplifiers

In every instance the aerial feeders are long enough to introduce appreciable loss of signal. To prevent the deterioration of noise performance, which would otherwise occur due to the feeder loss, a low-noise amplifier having more than sufficient gain to offset the loss is fitted close to the aerial terminals. Because the cable connecting the aerial to the amplifier is short the input circuit of the amplifier may be adjusted to give optimum noise performance, with little regard to any mistermination that may result, since the short-delay echoes so generated have a negligible effect on the waveform performance. The output impedance, on the other hand, must be matched to the feeder-cable impedance in order to suppress reflections which would otherwise give rise to long-delayed echoes. The amplifiers have a gain of 20 dB and an effective noise factor of 3 to 4 dB. Each amplifier makes use of two low-noise transistors, for which the d.c. power is fed along the coaxial cable carrying the radio-frequency signals.

The extremes of temperature to which equipment mounted on masts is subject are reduced by enclosing each amplifier in a thermally-insulated container having a thermal time-constant that is long enough to show an appreciable reduction in the diurnal temperature variation of the amplifier. As the

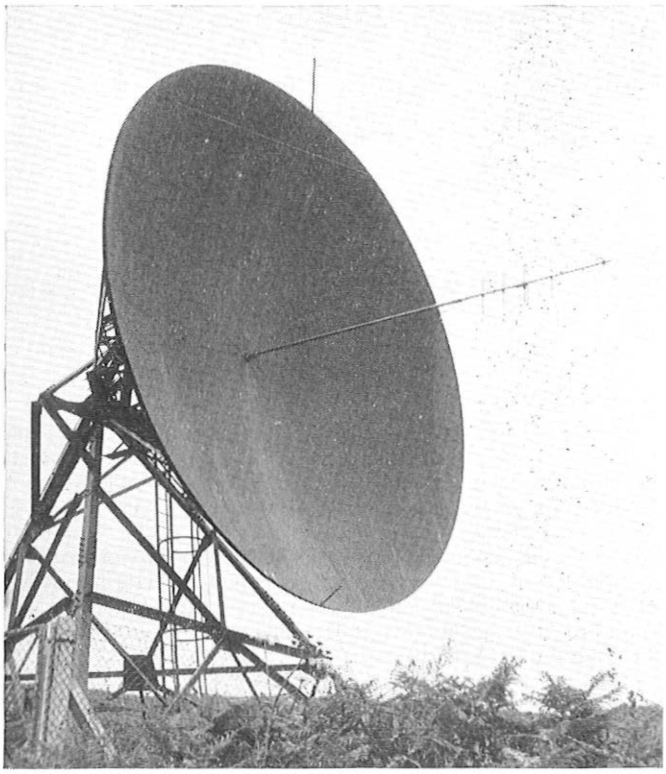


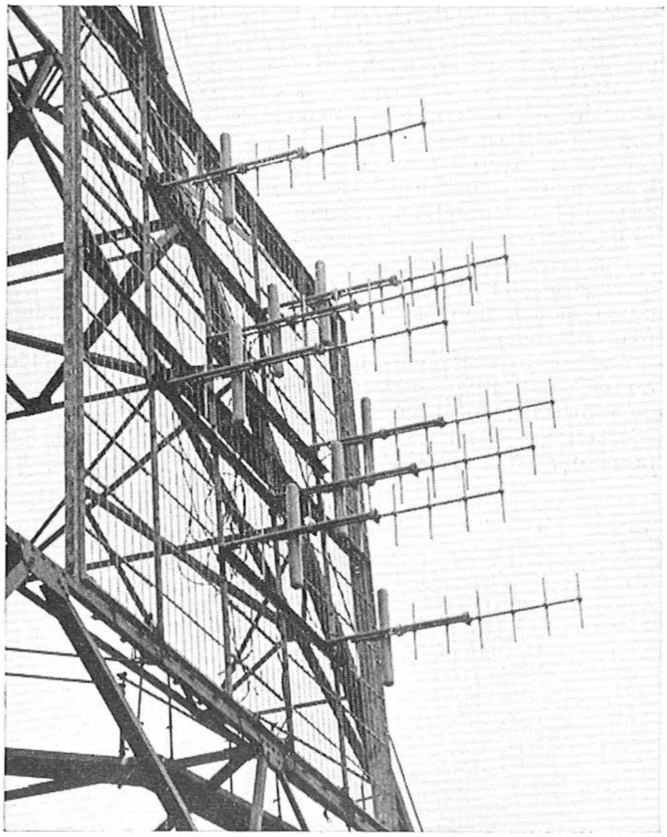
Fig. 3—One of the Channel 9 aerials

power dissipation of each amplifier is only a few milliwatts, a small thermostatically-controlled heater is fitted inside the container so that low temperatures, which might lead to condensation of moisture, are avoided.

Receivers

The receivers used are modified versions of the standard vision receiver for direct pick-up links (Radio Receiver, No. 25A[1]).

On the standard receiver the automatic gain control (a.g.c.) system is effective over a range of input signal-levels of 40 dB. This range is insufficient for the conditions encountered on Alderney, and it has been extended to 60 dB by the use of delayed a.g.c. on early stages of the receiver that were previously not controlled. By this means the overload point of the receiver is increased by some 20 dB, and distortion of the very high-level signals occasionally received at Alderney is largely prevented.



The photograph shows the aerial temporarily mounted for test purposes

FIG. 4—One of the Channel 11 aerial arrays

On inland links where direct pick-up receivers have been used to provide vision signals the accompanying sound signal has usually been transmitted over a conventional program circuit. This method is rather costly for the Channel Islands link, and the cheaper alternative of receiving the broadcast sound-signals has been adopted. The standard vision-receiver is modified to allow the extraction at intermediate frequency of a signal which is fed to a separate sound-receiver. The sound receiver has its own independent a.g.c. system, with an effective range of 60 dB.

The intermediate-frequency amplifiers of the vision receivers are fitted with two sound-channel-rejection filters, one tuned to suppress the co-channel sound signal, and the other the adjacent-channel sound signal. The intermediate-frequency amplifier in one of the Channel 11 receivers is provided with a further narrow-band rejection filter to suppress the vision-carrier of the French Channel F11, but this filter is brought into use, by means of a remotely-controlled switch, only when severe interference is experienced.

Microwave Link

The microwave radio-relay link connecting Alderney to Jersey operates in the 2 GHz band and provides three uni-directional broadband channels. The path length is 35 miles and is almost entirely over water. Height diversity is provided at the receive terminal to reduce the effects of surface reflections. The two receiving aerials are mounted on the I.T.A.'s mast at Fremont Point, at heights of 90 ft and 180 ft, and in each receiver a switch automatically selects the aerial providing the better signal.

The baseband bandwidth available on each broadband channels extends to about 8 MHz. The lower 3 MHz of this bandwidth is occupied by the 405-line television signal, and at a frequency of 7·5 MHz a sub-carrier is inserted which is frequency modulated by the accompanying sound-signal.

Supervisory Link

A bothway u.h.f. radio link operates over the same path as the microwave link. It provides a speaker circuit, a signalling channel by means of which an alarm may be extended from Alderney to Jersey, and control facilities which extend to Jersey the control of the channel-selection switch and control of the band-stop filter in one of the Channel 11 receivers.

SYSTEM PERFORMANCE

The signal received at Alderney is subject to fading and interference for a small proportion of time, but the degradation due to these effects may not always be severe enough to render the signal completely unusable for re-broadcasting purposes. For this reason the description "program marred" has been introduced to cover those occasions when the signal, though usable, is below the standard normally regarded as acceptable for rebroadcasting. Program-marred time typically amounts to less than 2 per cent of time, taken over a period of several months. The time for which the signal is unavailable, or is unusable for any reason, is much less, and is under 0·1 per cent of time.

The waveform performance of the link depends on the adjustment of the broadcasting transmitter as well as that of the receiver, and some variation from time to time is to be expected. Typically, however, using a pulse-and-bar test waveform[2] an overall K-rating of 3 per cent is obtained, though in making the measurement the increased half-amplitude duration of the sine-squared pulse which results from the vestigal-sideband mode of transmission is disregarded. The line-time non-linearity of the links is measured using a saw-tooth test waveform and is typically 7 per cent.

The signal-to-noise ratio at the receive terminal varies considerable, according to propagation conditions. Measurements of the noise level cannot readily be made during program hours, and the available information is derived from a single daily observation and the incidence of the program-marred condition. The daily measurements indicate that on the Stockland Hill link a typical ratio for the unweighted wideband r.m.s. noise and peak-to-peak signal levels is 38 dB. On the Chillerton Down link the ratio is some 6 dB to 8 dB lower, but in this instance the noise level is raised by interfering co-channel signals. The program-married classification is applied when the signal-to-unweighted r.m.s. noise ratio

[1] ELKINS, N. A., MILLS, D. E., and FENSOME, L. D. W. A Receiver for Direct Pick-Up Television Links. *P.O.E.E.J.*, Vol. 53, p. 239, Jan. 1961.

[2] MACDIARMID, I. F. Waveform Distortion in Television Links. *P.O.E.E.J.*, Vol. 52, pp. 108 and 188, July and Oct. 1959.

falls to 26 dB or less, but marred time arises also from causes other than noise so that a ratio of 26 dB is exceeded for rather more than 98 per cent of time.

On the Stockland Hill sound receivers noise levels of −35 dB to −40 dB relative to the signal level, corresponding to 40 per cent modulation of the broadcasting transmitter, are typical, while on the Chillerton Down receivers the relative noise levels are usually some 5 dB higher. In both cases the total harmonic distortion of the sound signal, when the transmitter is modulated to a depth of 80 per cent at a frequency of 1 kHz, is normally 30 dB below the level of the fundamental.

A Resin-Encapsulated Termination for Coaxial-Pair Cables

C. P. SELF†

U.D.C. 621.315.212.2:621.315.687.3

The point of entry of a coaxial cable which terminates in a buried-repeater case must be sealed. The coaxial pairs are terminated on sealing-ends, which must be capable of withstanding the pneumatic pressure within the cable. The control pairs of the cable are brought out on a flexible cable-tail, terminated on a multi-socket connector. The cable termination is then encapsulated in a suitable resin. This article describes the method by which such a resin-encapsulated termination is formed.

INTRODUCTION

A coaxial cable which terminates in a buried-repeater case must be sealed at its point of entry. The seal is incorporated in the cable termination; it takes the form of a brass gland which is soldered to the lead cable-sheath and sealed to the repeater case by an O-ring seal.

The cable termination has to support the coaxial pairs so that they can be terminated on sealing-ends, which form the electrical connexions between the coaxial pairs and the flexible connecting leads from the amplifier equipment. The sealing-ends must be capable of withstanding the pneumatic pressures contained in the cable, the termination acting as an air block between the cable and the amplifier equipment so that the pressure in the cable is isolated from the equipment and does not fall when the lid of the repeater case is opened. Fig. 1 shows two resin-encapsulated terminations fitted in a buried-repeater case.* One termination is longer than the other to allow the connexions on the lower termination to be more readily accessible.

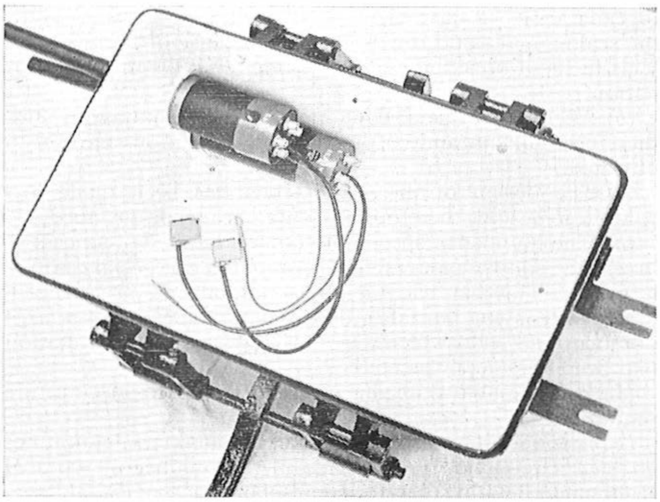


FIG. 1—Two resin-encapsulated terminations in a buried-repeater case

TERMINATING METHOD

The cable gland is fitted by passing it for a distance of approximately 10 in. along the cable (see Fig. 2) and then soldering it to the lead sheath after removal of the polythene outer sheath. The cable end extends beyond the gland for approximately 6 in., and from this section the lead sheath is removed to expose the coaxial pairs and the paper-insulated 10 lb/mile control pairs. A flange on the gland has an O-ring seated into it so that, when the termination is fitted into the case and a circular nut is tightened, the O-ring seal completely envelopes the cable-entry hole and securely seals the termination into the case. The other side of the flange is grooved to form a firm key to a resin block, which will be cast over the cable core after terminating operations have been completed.

Each sealing-end consists of a centre pin, which is supported centrally within an outer cylindrical metal casing by two small annular blocks made of polytetrafluorethylene (PTFE), a heat-resistant plastic. Two rubber washers of approximately the same diameter as the PTFE blocks are sandwiched between the blocks, and, when the sealing-end is assembled, the blocks are compressed, expanding the rubber washers radially so that they grip the centre pin and the inner wall of the metal

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* CLINCH, C. E. E., and STENSON, D. W. Housing of Repeater Equipment Underground. *P.O.E.E.J.*, Vol. 56, p. 158, Oct. 1963.

casing. In this manner a hermetic seal is produced. To terminate a coaxial pair it is cut to the required length, and the outer conductor and the screening tapes are removed to allow the centre conductor to extend for ¼ in. beyond the tapes and ⅛ in. beyond the outer conductor. Short lengths of PTFE tubing are inserted between the inner and outer

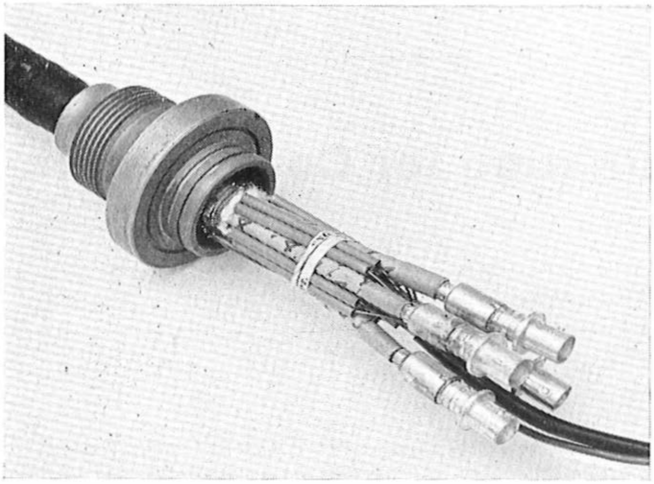

FIG. 2—Cable termination prepared for the resin-encapsulation operation

conductors to reinforce the polythene dielectric in the event of it being damaged by heat during soldering. The centre conductor is soldered to the centre pin of the sealing-end, and the outer conductor is connected to the metal casing by soldering it to a ferrule which is associated with the sealing-end. It is essential to solder completely round the edges of the ferrule where it joins the body of the sealing-end and also round the outer conductor, to prevent the ingress of liquid resin into the coaxial pair.

When all the coaxial pairs of the cable have been connected to sealing-ends the paper-insulated control pairs are jointed to plastic-insulated stranded wires, which are drawn into a short length of plastic tubing to form a flexible cable-tail, the other end of which is terminated on a multi-socket connector. Two connexions are taken from the lead cable-sheath within the termination and are extended to the equipment wiring: one connexion is terminated on the multi-socket connector with the control pairs, and the other is terminated separately on a spade connexion. The joints in the control pairs, which will eventually be contained in the resin block, are insulated by paper jointing sleeves. At the cable butt, where the pairs emerge from the lead sheath, the spaces in between the pairs are tightly plugged with cotton-wool to prevent liquid resin seeping into the cable before hardening can take place; if this were allowed to happen the cable would be stiffened where it is required to be flexible, i.e. where it bends away from the amplifier towards the duct-mouth, and, in addition, voids would result in the cured resin block.

When the wiring has been completed the termination is supported vertically for the resin-encapsulation operation. A 6 in. length of 2½ in. diameter rubber tube is used to form the mould in which the resin is cast. The mould is tightly clamped, by means of a worm-drive clip, over the flange of the cable gland. A lug, which locates the label for indicating the details of the coaxial-cable pairs, is cast in the resin by cutting a ½ in. diameter hole in the mould and covering it with plastic tape. A template is placed over the top of the mould to hold the coaxial pairs and the flexible cable-tail containing the control pairs in position. The epoxy resin used to encapsulate the cable termination is a type already in use in the field for constructing air-blocks in pressurized-cable systems; it has acceptable electrical properties and produces low exotherm.* The resin and the hardener are mixed together in the proportions of approximately equal parts by weight, thoroughly stirred and poured through a hole in the template to fill the mould. The conductors and joints are completely surrounded by liquid resin up to the level of the flanges on the sealing-ends. The setting time for the resin is dependent upon the ambient temperature, but it is approximately 2 hours under normal conditions. When 24 hours have elapsed the resin is set hard and the rubber mould can be cut off. Layers of plastic tape are wrapped round the cable where the polythene outer sheathing was removed and the lead sheath was soldered to the gland. A completed termination is shown in Fig. 3.

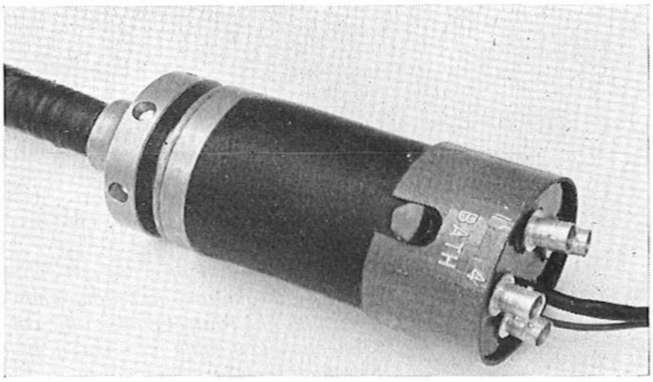

FIG. 3—Completed resin-encapsulated termination

During the development of this termination method it was found that, in order to prevent the appearance of irregularly shaped voids in the resin cast, it was necessary to have a flexible mould to ensure a tight seal between the mould and cable gland, and to ensure that resin did not shrink away in places from the mould during the curing process.

ADVANTAGES OF RESIN-ENCAPSULATED TERMINATION

The resin-encapsulated temination has the following advantages over the types of termination previously employed.

(*a*) The coaxial tubes, being totally surrounded in a block of resin, are held in a fixed position, and movement is prevented, when the cable-tails are uncoiled for installation in the buried-repeater case. If movement is allowed it is transferred to the sealing-ends, and this has been the cause of the hermetic seals in them breaking and producing air leaks in the termination.

(*b*) There is no metal container for the termination, and, therefore, difficult and costly soldering operations have been obviated.

(*c*) The design of the sealing-ends has been made less complicated, and, therefore, they are cheaper to produce.

(*d*) The number of special piece-parts has been reduced.

(*e*) The control pairs are not terminated on special ceramic terminals. This has had the effect not only of producing a direct cash saving but, also, of removing the cause of a large number of air leaks which were detected when the termination had been completely assembled.

(*f*) It is capable of being easily modified to meet future requirements.

(*g*) The adoption of the resin-encapsulated termination has enabled a reduction to be made in the number of types of sealing-end held in stock for small-diameter coaxial cables.

(*h*) It has been established in practice that satisfactory

* Exotherm—the generation of heat by chemical change within the mass of mixed resin and hardener.

terminations can be more consistently produced by this method. The rejection rate has been reduced, and a considerable saving in material and labour charges effected.

CONCLUSIONS

Buried-repeater cases are being installed between repeater stations on carrier routes consisting of coaxial pairs of 0·375 in. diameter, to reduce the amplifier spacing and, thereby, allow an increase in the traffic-carrying capacity of the coaxial pairs. The type of termination shown in Fig. 4 has permitted the 0·375 in. diameter tubes to be terminated on the existing type of sealing-end for this size of coaxial tube, and, at the same time, the termination has been made sufficiently small to be accommodated at the entry points of the existing type of buried-repeater case. For future schemes a much smaller and cheaper sealing-end has been developed, and this is being tested to take full advantage of the resin-encapsulation method.

In the future, it can be expected that improvements will be made in amplifier equipment and in the buried-repeater cases in which it is contained, but the resin type of termination can be readily modified and adapted to meet these changes.

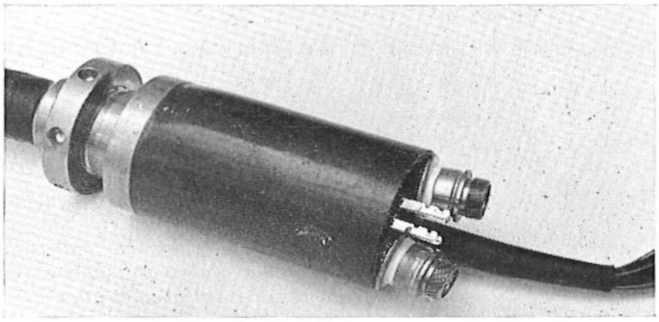

FIG. 4—Completed resin-encapsulated termination for 0·375 in. coaxial pairs

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Book Reviews

"Low-Noise Electronics." W. P. Jolly, B.Sc., C.Eng., F.I.E.E. English Universities Press, Ltd., 149 pp. 41 ill. 25s.

This book discusses the fundamentals of new devices such as masers, parametric amplifiers (semiconductor type as well as electron-beam type), and lasers. The first few chapters will be helpful in gaining the background knowledge of quantum mechanics. It is mainly addressed to students and beginners. However, practising engineers may find it useful on occasions.

D. C.

"Digital Transistor Circuits." J. N. Harris, P. E. Gray, and C. L. Searle. John Wiley and Sons, Ltd. xv + 220 pp. 104 ill. 36s. cloth, 20s. paper.

This is Volume 6 in a 7-volume series on diodes and transistors, covering both the physics of the devices and their application in circuits. The basic circuit properties of transistors has been dealt with in Volume 3; this volume is concerned with transistor digital circuits from the point of view of both the circuit designer and the logic designer.

A description is given of three simple models which can be used to describe the electrical behaviour of a transistor in the static "on" and "off" conditions and leads on to a detailed explanation of the behaviour of a transistor in the transitional state, described in terms of the charge control parameters. A clear understanding is given of the factors involved in a switching transistor.

The basic logic-circuit elements, such as gates, bistables and monostables, are described and the Boolean algebraic equivalents are given, together with a review of Boolean algebra. The use of clamp diodes and non-saturating switching circuits is well covered by concise explanations.

The chapters are not overloaded with mathematics but enough is given to enable the various circuits to be analysed.

The book is well written with ample explanatory diagrams, although there are a number of small points about which one might quibble such as in the diagram on p. 68 where two symbols $^{v}1$ and ^{v}I are used which are difficult to distinguish. Also, on p. 44 it is stated that there is no advantage in a circuit design which produces a large emitter-junction reverse voltage in the off state. This is misleading because in a circuit where minimum off delay is of prime importance, a high reverse bias may be used in order to reduce the storage delay time.

For many students and circuit designers the book will be worth buying if only for the two final chapters, for here, under one flyleaf, is a comparison of the merits of all the commonly used types of logic circuits—RTL, DTL, TTL, etc. This section also serves as an introduction to integrated circuits because although the circuits are dealt with as if made in discrete components, they are fundamentally similar to the integrated-circuit form.

W. T. L.

"Fixed Resistors." G. W. A. Dummer, M.B.E., M.I.E.E., M.I.E.E.E., M.I.E.R.E. Sir Isaac Pitman and Sons, Ltd. xi + 241 pp. 117 ill. 50s.

The author, a well-known authority on components, has drastically revised this second edition of the "bible" on fixed resistors. The importance of resistors will be appreciated from the fact that over a wide range of electronic equipments using conventional components, resistors account for about 50 per cent of the total components used, and are virtually the basic building bricks with which electrical equipments are built. In view of the increasing stress placed on the reliability of equipment, it is essential that considerable care is taken in the selection of the right type of resistor for each application, and in deciding the operating conditions. This book is particularly helpful in this respect.

In this edition, most chapters have been enlarged to include information on the newer types such as metal-film and metal-oxide resistors, while two chapters have been added to cover resistors for integrated circuits and the reliability of resistors. This latter information is derived from both test results and actual working equipments. The results illustrate the wide range of reliability which can be obtained from any one type of resistor, and show that the environment and loading conditions mainly determine the failure rate.

There is an interesting chapter covering a wide range of non-linear resistors with positive and negative temperature coefficients, with details of both thermal-sensitive and voltage-sensitive types.

For the researcher and the student there is a bibliography giving 28 pages of references to other works on resistors.

The book will prove most valuable to circuit designers, and it is considered that it should be made compulsory reading for all engineers concerned with the physical realization of electrical equipment.

W. T. L.

A Motor-Driven Cleaner for 2,000-Type and 4,000-Type Selector Banks

B. A. GREEN, C.ENG., M.I.E.E., M.I.PROD.E., and H. BLAKEY†

U.D.C. 621.395.636.004.55

Present methods of bank cleaning involve the use of time-consuming, hand-held tools. This article describes a motor-driven cleaning tool which is adjustable for different bank assemblies and has a pre-determined time cycle. The unit is driven by a 50-volt a.c. motor and has been designed to use established bank-cleaning tapes. A number of safeguards have been included to ensure that damage to the bank cannot result from misoperation.

INTRODUCTION

The present manual methods of cleaning two-motion selector banks were adopted only after much experiment had established both the efficacy and the safety of the procedure. Briefly, these methods are based on the use of a hand-held tool with a sickle-shaped blade, loaded with a braided-cotton tape forming a readily renewable cleaning-pad. Three types of tape are available: Tape No. 1, which is plain cotton and was selected as being reasonably free from fluff, Tape No. 2, which is also of cotton but is loaded with an industrial soap and a mildly-abrasive material, and Tape No. 3, which is the same as Tape No. 1 but with the addition of mineral oil on the basis of 2 gm/yd.

Although effective, present methods are tedious, time consuming and out of keeping with a modern approach to maintenance. Fortunately, the present-day needs of the British Post Office were largely anticipated by the development of a bank-cleaning machine by Ericsson Telephones, Ltd., of the Plessey Telecommunications Group, in 1958. The need for an alternative method of two-motion selector-bank cleaning was accentuated by the post-war conditions of the middle 1950s when the Company's installers found that they were working in exchanges where building work was still proceeding. In one particular exchange the presence of cement dust created considerable trouble during the installation and testing of very large numbers of two-motion selectors. A preliminary design of motor-driven cleaner was introduced with a fair measure of success. As is usual with new projects, these early experiences disclosed some of the unexpected problems of mechanizing selector-bank cleaning, such as the difference in friction between new and old banks, the variation in work load between 2, 3 and 4-bank-set assemblies, variations in the frictional load, and difficulties presented by the different types of contamination.

To be an economic proposition a motor-driven cleaner must clean effectively, save operator time and be versatile in application. The equipment currently being introduced as part of British Post Office maintenance policy meets these basic requirements, and may be regarded as a direct descendant of the machines used by Ericsson's installation teams.

GENERAL DESCRIPTION OF MACHINE

The machine is provided in kit form, as shown in Fig. 1; in Fig. 2 it is shown assembled for use on 4-bank-set assemblies.

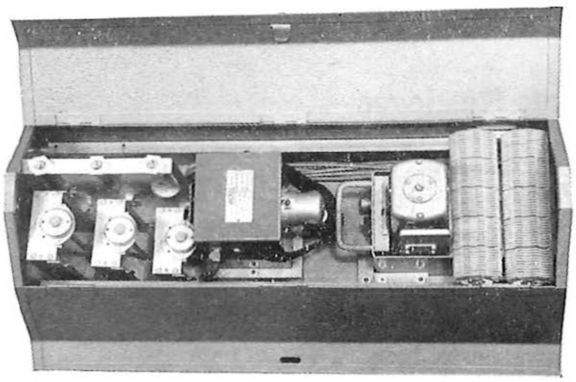
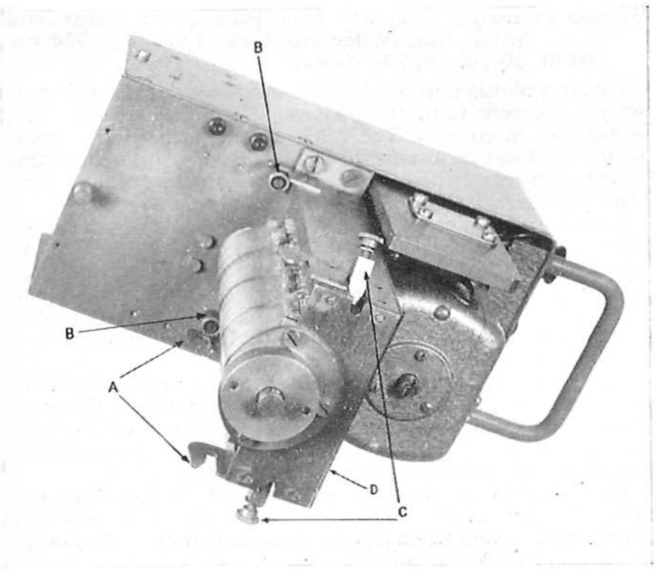


FIG. 1—Bank-cleaning equipment in carrying case



A—Upper and lower catch-plates
B—Micro-switches
C—Quick-release mechanisms
D—Lower support plate

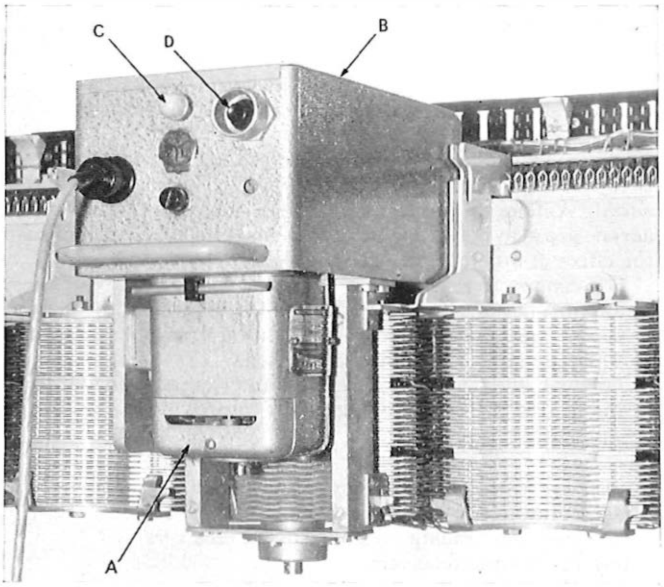
FIG. 2—Underside view of assembled machine

The cleaner takes the place of the 2,000-type or 4,000-type selector, and, in use, is located in the selector cradle associated with the bank being cleaned. The locating lugs or catch-plates (A in Fig. 2) ensure that the machine is in the correct

† Mr. Green is with Ericsson Telephones, Ltd., and Mr. Blakey is in the Exchange Equipment Design and Installation Standards Branch, Telecommunications Development Department, Telecommunication Headquarters.

horizontal position relative to the bank. To ensure that the machine occupies the correct vertical position, a pair of micro-switches are fitted in such a way that they operate only when the weight of the machine is borne by the selector cradle. Unless both micro-switches are operated by the spring-loaded plungers (B in Fig. 2) it is impossible to start the cleaning operation. This provides a very considerable safeguard against the possibility of damage to the bank itself.

The front panel of the unit (Fig. 3) accommodates a recessed 50-volt a.c. supply socket, fuse holder, a lamp and the push-type starting-switch. A screw-driver-operated potentiometer, for setting up purposes, is also accessible from the front. Studs are fitted at the side of the unit to locate in



A—Driving motor
B—Motor control unit
C—Indicator lamp
D—Start push-button

FIG. 3—Machine in position ready for use

the selector-cradle bayonet-slots. The power supply is from a 50-volt isolating transformer, and a connecting cord, 20 ft long, connects the transformer output to the panel-socket on the cleaner. The fractional-horse-power motor which powers the cleaning blades (A in Fig. 3) is mounted with its axis vertical.

The motor control unit (B in Fig. 3) houses the motor reduction gear, a subsidiary reduction gear which controls the duration of the cleaning cycle, a full-wave rectifier, and the two 600-type relays which directly control the starting and stopping of the cleaner. The cleaning wafers, which will be described later, are carried on a square-section arbor. This is axially pivoted in a manner which spreads the load on the motor as the wafers pass through the bank. The cleaning kit contains three arbors as well as three extension

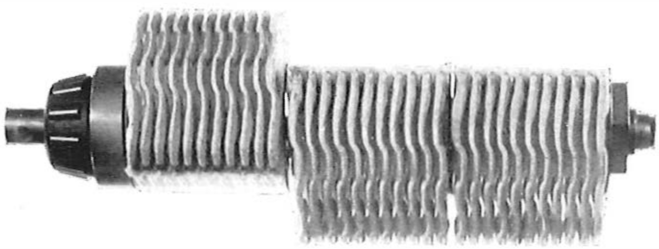


FIG. 4—Arbor and cleaning wafers

frames which are each equipped with a lower bearing seating and a quick-release mechanism (C in Fig. 2) that frees the whole of the lower support plate (D in Fig. 2).

Successful operation of the cleaner depends on a sound design of cleaning wafer and the use of the standard Post Office cleaning tapes. In the present design the comb-like wafer, moulded in polypropylene, has buttressed supporting fingers through which the tape is threaded. The flatness of the tape is ensured by the width of the slots and the manner in which it is secured by stapling over two fixing lugs. The wafers are supplied, taped, in units of 11, clamped ready for use. The centre hole fits the section of the arbor with little free movement. Fig. 4 shows three taped units fitted on an arbor, ready for use.

OPERATION OF THE EQUIPMENT

The initial assembly of the cleaner is straightforward. An arbor and extension frame are chosen to match the type of banks to be cleaned, the frame is fixed to the underside of the motor control-unit by four screws, the appropriate number of units of assembled cleaning wafers are slipped on to the arbor, and the arbor is loaded into the machine by removing the lower support plate. When a spline on the upper end of the arbor has been engaged in a key-way in the motor driving-shaft, the lower support plate is replaced and secured. With connexion of the 50-volt supply, the machine is ready for use.

A busied selector is removed from its cradle and the cleaner is fitted in position. The brightly glowing lamp (C in Fig. 3) indicates that the machine has taken up the correct position relative to the cradle. When cleaning selector-banks with the equipment for the first time it is necessary to test that the cleaning wafers will cut-in smoothly into the bank levels. This is done by advancing the lower group of wafers by means of a tommy bar passed through a hole at the lower end of the arbor. This precaution is one which need only be repeated at the commencement of each shelf of switches, and, as the tommy-bar has a further function, it may be left in position, rotating with the arbor when the machine is working.

The start push-button (D in Fig. 3) is then depressed and the machine drives the upper groups of wafers into the bank, followed by the lower group (or groups) 180° later. If the button is released within the first 2 seconds the machine will stop immediately; if it is held depressed for more than 2 seconds, the drive will automatically continue to complete 18 full revolutions in approximately 30 seconds. At the end of this duty-cycle the motor-control relays ensure that the upper wafer are brought to rest clear of the bank contacts. The lower group of wafers may then be withdrawn from the bank by using the tommy bar to rotate the lower end of the arbor, and the machine can then be removed from the selector cradle. If for any reason the wafers do not clear the bank at the end of their duty-cycle the indicator-lamp will remain slightly dimmed, a useful feature when the user is working on the lower shelves of a rack and is unable to observe the position of the wafers in comfort.

CONCLUSIONS

The machine, which is now coming into use in British Post Office exchanges, has built-in safeguards which will ensure that it can be used with the confidence that damage to banks should not occur.

The well-established bank-cleaning tape has been retained, the duration of the cleaning cycle has been predetermined, and elaborate precautions have been taken to ensure the correct adjustment of the machine and wafers with the bank. A restriction is suggested on the number of banks to be cleaned before wafers are changed, and routine methods are being devised to use the machines to best advantage and to reduce considerably the work required of maintenance staff.

New Radio-Interference Equipment Vehicles

A. S. McLACHLAN and F. W. GORMAN†

U.D.C. 621.396.669.8:621.391.823:629.11

At the present time the British Post Office maintains a force of 350 *radio-interference investigation officers throughout the country. These officers deal annually with some* 65,000 *complaints concerning the radio and television broadcast services. To aid them in this task they are supplied with special vehicles equipped with measuring and tracing apparatus. Two types of vehicles are used in this work: for the simpler work a small 5 cwt vehicle is used; for the more difficult interference cases, and for dealing with interference with reception in Bands* IV *and* V, *a more fully equipped* 10 *cwt vehicle has been provided.*

INTRODUCTION

The number of complaints of interference with radio and television broadcast services, received annually by the British Post Office, has steadily decreased from a peak of nearly 170,000 in 1955 to just over 65,000 in 1966. Although the annual number of cases has been reduced the problems of tracing sources of interference remain.

When it became clear that the existing vehicles and equipment used in radio-interference work were reaching the ends of their useful lives a study was made to determine the requirement for replacements to deal with the present-day problems. In the course of the survey, Telecommunications Regions and Telephone Areas were consulted, and many of the ideas and suggestions received were incorporated in the design of the new vehicles and equipment. At the time when the preliminary design and development was taking place the new ultra-high-frequency (u.h.f.) television service was being introduced, and facilities for dealing with this were incorporated from the beginning.

GENERAL REQUIREMENTS

For some years the numbers of complaints relating to medium-wave and long-wave reception have been decreasing, while the number of complaints relating to television reception has been increasing. Special attention had, therefore, to be given to the problems of tracing sources of interference with television reception, especially sources of continuous-wave or modulated continuous-wave interference. This type of interference is generated, for example, by the frequency-change oscillators of radio or television receivers and by industrial and medical radio-frequency (r.f.) apparatus.

Interference caused by Barkhausen oscillations in the line output valves of television receivers can be traced satisfactorily only by the use of a portable television receiver. This type of interference is usually referred to as "windscreen wiper" interference because, when the source is a television receiver tuned to a B.B.C. program in Band I interfering with a receiver tuned to I.T.A. in Band III, it takes the form of a vertical band moving slowly back and forth across the television screen. The same type of interference is experienced in Bands IV and V from receivers tuned to either Band I or Band III, but in this instance, because the line standards are different, the band is broken up and appears as dots or lines in a pattern that moves diagonally across the screen.

For tracing a source of continuous-wave or modulated continuous-wave interference which may be close in frequency to the carrier of the wanted signal the only suitable method is to use a panoramic receiver coupled to a direction-finding aerial. A television receiver, a high mast and appropriate aerials are also necessary for demonstrating to a complainant the effect of an efficient receiving system.

For economic reasons it is desirable that as many of these different functions as possible should be combined in the one piece of equipment, and that, as far as possible, standard commercial equipment should be used.

To deal with all the types of interference encountered in the field it is, therefore, necessary to provide the following equipment.

(*i*) Vehicles to carry equipment and staff.
(*ii*) Portable television receivers.
(*iii*) Portable tracing and measuring receivers.
(*iv*) Panoramic receivers.
(*v*) Direction-finding aerials.
(*vi*) Demonstration aerials.
(*vii*) Rotating masts for direction finding.
(*viii*) High masts to raise the demonstration aerials to a suitable height.
(*ix*) Benches and soldering-iron points to facilitate the carrying out of on-the-spot suppression of small appliances.
(*x*) Power supplies to run the equipment.

Not all this equipment is necessary for every case of interference, and most can be dealt with using only a portion of this apparatus. As the present force of 350 investigation officers requires some 300 vehicles to carry out its tasks it would have been uneconomic to provide the full facilities in every vehicle. It was decided, therefore, to have two classes of vehicle and equipment to deal with the following two broad categories of complaint.

(*i*) Those where the source of interference is known or may be relatively easily traced by simple means, and where suppression may be effected by standard methods. These cases form the bulk of the work.

(*ii*) Those in which the source of interference is difficult to trace and may be a long way from the affected receiving installations, and where measurement and demonstrations are necessary. At present, all complaints of interference with u.h.f. reception are included in this category.

Because the radio-interference staff may have to spend long hours in their vehicles in the course of tracing interference, monitoring transmissions or suppressing apparatus, special attention was paid, in the vehicle designs, to the layout and seating. The vehicles have been fitted with interior lining to

† Radio Regulatory Branch, Network Planning and Programming Department, Telecommunications Headquarters.

reduce condensation and to provide a good internal appearance.

Vehicles in Post Office garages must be left unlocked because of fire risk; therefore, lockable reinforced-plastic security screens have been provided between the driver's compartment and the rear compartment in all vehicles. These screens can be removed for normal working.

10 CWT RADIO-INTERFERENCE VEHICLE

For dealing with the complaints referred to earlier under category (*ii*) a limited provision is being made of 75 vehicles fully equipped to investigate all type of interference. This provision is on the basis of one vehicle for each of the 59 Telephone Areas plus an additional vehicle for Areas which are large territorially or have a large number of difficult cases.

FIG. 1—Five cwt radio-interference vehicle

5 CWT RADIO-INTERFERENCE VEHICLE

A commercial 5 cwt van has been used as the basis for the vehicle designed to deal with the complaints described earlier as category (*i*). This vehicle is illustrated in Fig. 1.

It is often inconvenient for an investigation officer to carry out suppression work on small appliances such as vacuum cleaners, sewing-machine motors, etc., in people's homes. Owners are naturally reluctant to lose the use of their appliances for any length of time, especially where interference affects a broadcast receiver other than their own. From the Post Office's point of view, it is uneconomic to have to make a special journey back to a central workshop with each item that has to be suppressed. The most efficient method of working from every point of view is, therefore, to provide in the vehicle facilities for fitting suppression components on the spot. For this reason the 5 cwt vehicle has been provided with a small working top, underneath which a nest of six drawers is provided for storing tools and suppression components. Light for the working area is provided by a green-tinted roof light which can be opened, if required, for ventilation. For soldering, a 12-volt d.c. supply is provided from an enlarged vehicle battery. Anchorage points are fitted at the rear and front edges of the bench so that apparatus can be secured for travelling.

The usual passenger's seat is dispensed with and its place is taken by a working position set back into the body of the vehicle. This seat, because of its position and the consequent difficulty in fitting safety belts, is not suitable for carrying a passenger, and the 5 cwt vehicle is satisfactory only for one-man working. Fig. 2 shows a rear view of the 5 cwt radio-interference vehicle with the equipment which may be normally carried.

When the issue of these vehicles is completed there will be approximately 200 of them in service.

FIG. 2—Interior view of the 5 cwt vehicle

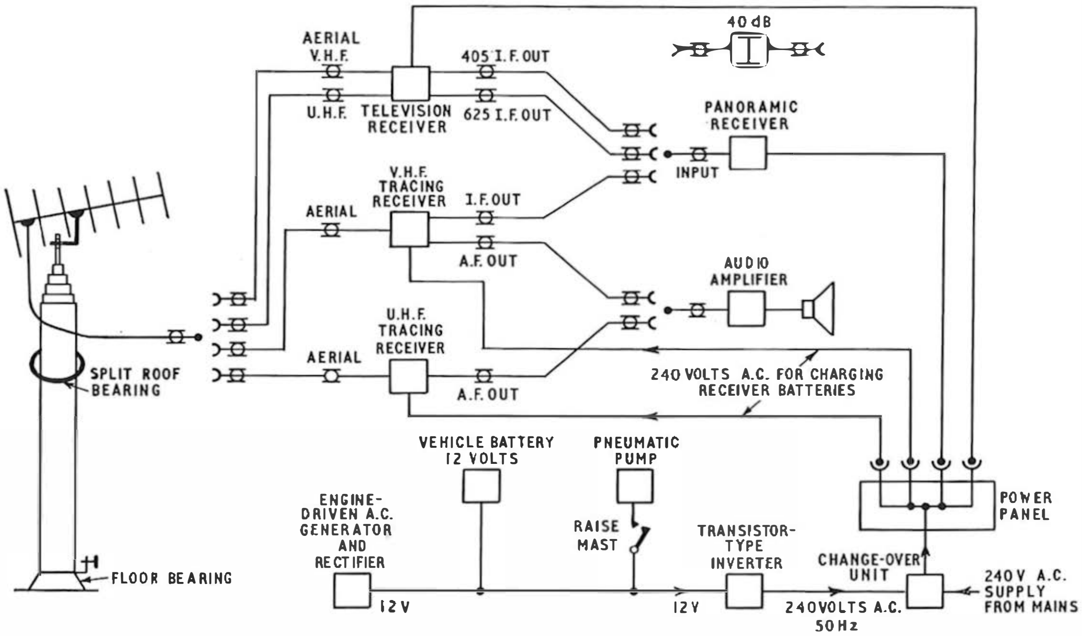


FIG. 3—Arrangement of equipment and power supplies in the 10 cwt vehicle

To meet all the requirements as economically as possible each separate piece of equipment has been made to serve as many individual functions as possible. Fig. 3 shows in block schematic form the connexions of the equipment in the vehicle, and the functions of each part are described in the following text. The vehicle (Fig. 4) is a standard Type 2 10 cwt Morris van that has been modified in the following details.

(*i*) Part of the rear floor has been lowered to accommodate an operator's seat and to provide the necessary leg room. This seat has a movable back which can be positioned either for a passenger facing forward in the usual manner or for an operator sitting directly in front of the panoramic receiver and facing the off-side of the vehicle.

(*ii*) Side windows have been provided to give the operator an all-round view, and to provide light and ventilation.

(*iii*) Provision has been made for the mounting of a pneumatic mast in the centre of the vehicle within easy reach of the operator.

(*iv*) Two box compartments have been mounted on the roof to carry normal commercial-television and Band II

FIG. 4—Ten cwt radio-interference vehicle

FIG. 5—Interior layout from the operator's seat

aerials, which are used for direction finding, field-strength measurements and demonstrations.

(*v*) A large hatch has been provided in the roof above the operator's seat to allow easy access to the head of the mast, for fitting the aerials as required, and to gain access to the aerial boxes without climbing on to the roof of the vehicle. The hatch also enables the operator to take a direct bearing on a source of interference by looking directly along the path of the main beam of the aerial.

(*vi*) A heavy-duty battery and a large a.c. generator have been substituted for the normal vehicle battery and generator to provide power to operate the television receiver and the panoramic equipment.

(*vii*) An apparatus bench with universal fixing points and safety rails has been fitted. The shape of the bench has been designed so that the face of the television receiver can be seen by the operator when seated in the operator's seat, but cannot be seen from the driver's seat, or from directly in front or from the off-side of the vehicle. A writing flap is positioned in slides under the television receiver so that it can be extended into the writing position when required. The bench has three drawers and two open lockers easily accessible from the operator's position, and a closed locker accessible from the rear of the vehicle.

A view of the layout from the operator's seat is shown in Fig. 5.

Pneumatic Mast

The pneumatic mast has three main functions. Firstly, it is fitted in the centre of the vehicle, in rotating bearings, and can be used in the unextended position as a mast for direction finding. Secondly, while fitted in the vehicle, it can be extended for field-strength measurements to a maximum height of 24 ft by a small electrically-driven pneumatic pump, which is mounted under the bench. So that the mast may be freely rotated when in the extended position a non-return valve is fitted in the air inlet and connexion is made via a flexible tube and a bayonet connector. Water is precipitated inside the mast by the action of compressing and releasing the air, and by condensation. To prevent this water from entering the vehicle the air is exhausted outside the vehicle when the mast is lowered; this is done by means of a second flexible tube and bayonet connector.

The third function is its use to demonstrate to a complainant the effect of an efficient outdoor aerial. For this purpose the mast may be easily removed from the vehicle by lifting it through the split bearing on the roof after undoing one hand-tightened turn-screw at the bottom. A tripod,

FIG. 6—Operator erecting the pneumatic mast for use remote from the vehicle

accommodated in the rear cupboards, is provided to support the mast when it is used remote from the vehicle. Fig 6 shows the erected mast on its tripod. This function has proved especially useful in dealing with complaints of interference with u.h.f. reception: over 70 per cent of complaints referring to this service have been shown to be due to the use of inefficient aerials or otherwise faulty receiving installations.

The mast consists of six high-tensile light-alloy sections. It is not keyed and will remain erect under air pressure for about half an hour. To ensure rotation of an aerial at the head of the mast, and to keep the mast erect for long periods,

(μV/m) at v.h.f. and 13 dB (μV/m) at u.h.f. However, if an interfering signal as low as this exists at a complainant's premises it is usually possible to move the vehicle and orientate the aerial so that the received interfering signal is effectively increased by approximately 10 dB, thus facilitating direction finding.

In addition to its role in the vehicle, the television receiver may be used remote from the vehicle as a hand-held tracing receiver, and is particularly valuable in tracing the windscreen wiper type of interference. The receiver is also used when the investigation officer wishes to demonstrate an efficient aerial

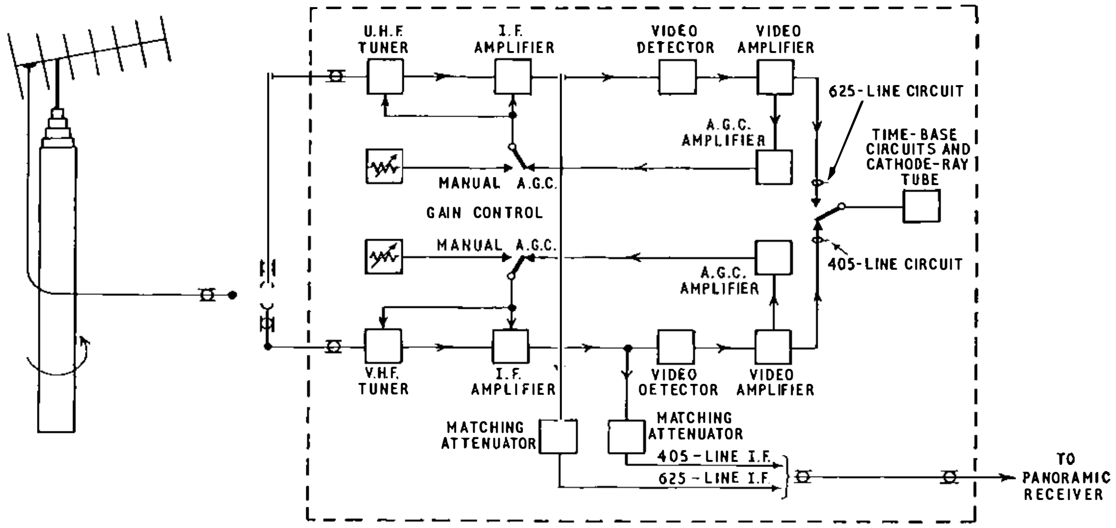


FIG. 7—Block schematic diagram of the Television Receiver No. 4A

clamping collars are provided. When required, these must be tightened by hand, section by section, as the mast is erected.

Television Receivers

Two types of television receiver have been provided: one is a general-purpose hand-held tracing receiver, and the other is a modified version for use in the 10 cwt vehicle. The television receivers are commercial transistor-type dual-standard models, and capable of receiving all television channels in the v.h.f. and u.h.f. bands. A block schematic diagram of the receiver used in the 10 cwt vehicle is shown in Fig. 7.

For direction-finding work the receiver used in the 10 cwt vehicle has been specially modified so that its i.f. outputs can be connected to the panoramic receiver. In this way the operator can observe on the cathode-ray-tube display of the panoramic receiver all signals present in the i.f. pass band of the television receiver. A switch for disabling the automatic gain control (a.g.c.) and replacing it with a manual gain is provided. This is necessary because the effects of the a.g.c. would make direction finding difficult by tending to oppose the variations in received-signal amplitude on which direction finding depends. The input stages of the receivers have been screened to increase the immunity to direct break-in of signal or interference by paths other than the aerial.

The minimum amplitude of an interfering signal which is easily visible on the panoramic display tube in the presence of the vision carrier is about 1 μV, giving the direction-finding equipment an overall sensitivity of approximately 6 dB (μV/m) at v.h.f. and 13 dB (μV/m) at u.h.f. This order of sensitivity enables the equipment to be used in investigating the more difficult interference cases where the interfering field strength affecting television reception may be as low as 6 dB

and receiving installation to a complainant. When used remote from the vehicle the receiver is powered by its own inbuilt rechargeable batteries.

Panoramic Receiver

The panoramic receiver is a commercial panoramic display unit, tunable over the frequency range 5·2–60 MHz. A block schematic diagram of the receiver is shown in Fig. 8. Its frequency coverage enables it to be used with any receiver having an i.f. output in the range 5·2–60 MHz. The panoramic receiver is a double superheterodyne having i.f.s of 5·2 MHz

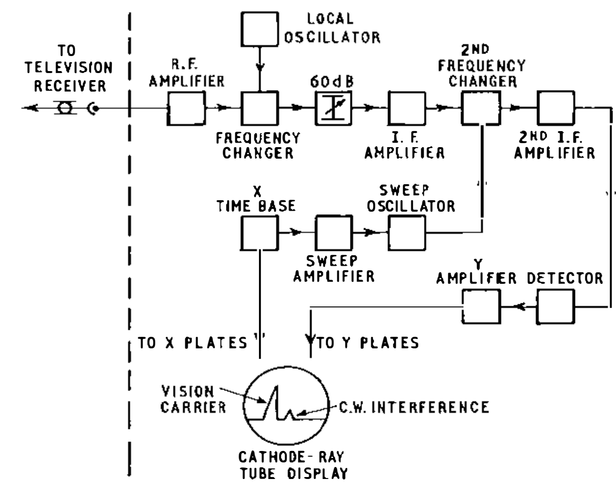


FIG. 8—Block schematic diagram of the panoramic receiver, Radio, Receiver, No. 33A

and 720 kHz. A maximum sweep width of 1 MHz can be displayed on the cathode-ray tube; this sweep width may be narrowed to less than 30 kHz, allowing signals close to each other to be separated.

In its normal role in the vehicle the receiver is connected to either the 625-line or 405-line i.f. output socket of the television receiver. Since only 1 MHz of the television receiver i.f. can be displayed at any one time it is necessary for the operator when searching for the interfering signal to tune the panoramic receiver through the i.f. pass band of the television receiver. It is possible with this receiver to distinguish a low-amplitude interfering signal when it is only 10 kHz away from the wanted carrier. For tracing interference with reception of a v.h.f. frequency-modulated signal the panoramic receiver may be used in conjunction with the v.h.f. tracing receiver, and it may also be used with communication receivers if the need arises.

Portable Tracing and Measuring Receivers

When the provision is completed it is intended to have transistor-type portable tracing and measuring receivers for each of the three frequency bands 0·15–1·6 MHz, 30–220 MHz and 470–875 MHz. The medium and long wavelengths are already catered for by Radio Receiver No. 27A, which is a portable transistor-type tracing receiver with measuring facilities; it covers the frequency range 0·15–1·6 MHz.

A new transistor-type receiver (Receiver, Radio, No. 31A) for the v.h.f. bands is being developed to replace the existing obsolescent valve receivers. For the u.h.f. bands a transistor-type tracing receiver with measuring facilities (Receiver, Radio, No. 34A) has been developed and is now in service.

The three receivers are shown in Fig. 5 and are, from left to right,

(*i*) the u.h.f. receiver (No. 34A), above the panoramic receiver,
(*ii*) the v.h.f receiver (No. 31A), to the right of the television receiver, and
(*iii*) the medium-wave and long-wave receiver (No. 27A).

These receivers may also be carried and used with the 5 cwt vehicle when required.

Audio Amplifier

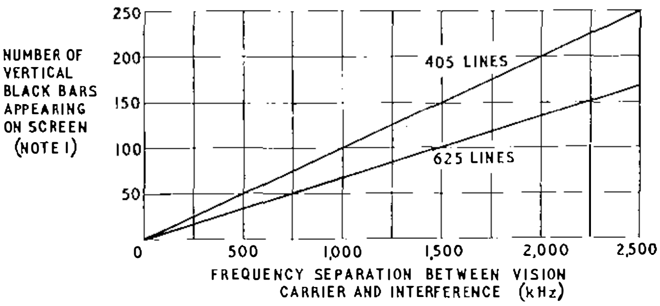
The vehicle is equipped with a small portable transistor-type audio amplifier that is primarily for use with the radio measuring and tracing receivers, which are not provided with their own loudspeakers. When extra audio amplification is required the amplifier is connected to the audio phone jacks of the radio equipment.

Coaxial Patching Panel

The coaxial patching panel is conveniently mounted on the right of the operating position. Its purpose is to terminate, at a central point in the vehicle, all the inputs and outputs of the radio equipment. This greatly simplifies the operation of the equipment, and the operator needs only short coaxial patching cords for interconnecting the equipment. A 40 dB general-purpose attenuator and the whip aerial are also brought out on coaxial sockets on the patching panel.

LOCATING A SOURCE OF INTERFERENCE

When tracing a source of television interference the operator moves his vehicle into a position where the interference is visible on the screen of the television receiver, and, by observing the nature of the degradation of the picture, he can decide on the method to be used for tracing the source. If the interference is continuous he can, by noting the number of interference lines on the picture and referring to the curves shown in Fig. 9, estimate the frequency separation between the wanted and unwanted signals. Then, by suitable adjustment of the sweep-width and tuning controls of the panoramic receiver, he can display the interference on the cathode-ray tube of the panoramic receiver. Once the interference is displayed in this way the aerial can be used for direction finding on an intensity basis, and the vehicle can be moved to take check bearings. Great care and a certain amount of skill are necessary to use this equipment in the u.h.f. bands because of the presence of large reflections which can be very misleading.



Note: If the interference pattern is diagonal, the frequency separation between the vision carrier and the interference is obtained by counting the number of diagonal black bars intersecting the top of the screen.

FIG. 9—Relationship between the number of black bars produced by continuous-wave interference on a television screen and the frequency separation between the vision carrier and the interfering signal

CONCLUSION

Provision is being made of vehicles and equipment to meet the needs of the radio-interference services for the next decade. For economic and operational reasons two types of vehicles have been used, and most of the equipment is portable and capable of being used in a number of different roles. This provides for flexibility and gives scope for Telephone Areas and Telecommunications Regions to deploy the equipment to the best advantage in whatever circumstances obtain locally.

Notes and Comments

New Year Honours

The Board of Editors offers congratulations to the following engineers honoured by Her Majesty the Queen in the New Year Honours List.

Engineering Department	G. A. C. R. Britton	Lately Senior Executive Engineer	Member of the Most Excellent Order of the British Empire
External Telecommunications Executive	A. G. German	Senior Executive Engineer	Member of the Most Excellent Order of the British Empire
External Telecommunications Executive	F. A. Symons	Senior Technician	British Empire Medal
London Telecommunications Region	R. V. Harris	Executive Engineer	Member of the Most Excellent Order of the British Empire
London Telecommunications Region	M. E. Hewitt	Senior Technician	British Empire Medal
South Eastern Telecommunications Region	A. H. C. Knox	Chief Regional Engineer	Imperial Service Order
South Eastern Telecommunications Region	R. E. Ibbett	Executive Engineer	Member of the Most Excellent Order of the British Empire

Recent Award

The Board of Editors has learnt with pleasure that Her Majesty the Queen has awarded the Royal Victorian Medal (Silver) to Mr. H. A. Pyle, Technical Officer, South Central Telephone Area, London Telecommunications Region, for meritorious services to the Royal Household.

Board of Editors

Mr. L. F. Scantlebury has resigned from the Board of Editors concurrently with his retirement from the Post Office. The members of the Board wish to express their appreciation of the valuable services rendered to the Journal by Mr. Scantlebury during the past 17 years.

Circulation of The Post Office Electrical Engineers' Journal

The Board of Editors is pleased to note the continuing increase in the circulation of the Journal, as shown by the following statistics.

Journal Issue	Number of Copies Printed
Vol. 60, Part 1, Apr. 1967	33,400
Vol. 60, Part 2, July 1967	33,730
Vol. 60, Part 3, Oct. 1967	34,000
Vol. 60, Part 4, Jan. 1968	34,200

Approximately 10 per cent of the Journals are sold to overseas readers in more than 70 countries.

Back Numbers of the Journal

The Journal endeavours to keep a stock of the more recent back numbers to assist students and other interested readers, but this involves extra storage, insurance and handling costs, and an extra charge to cover these expenses is often made by other publishers. The Board of Editors has decided, reluctantly, to increase the cost of back numbers of the Journal to 3s. 6d. each (5s. inland mail, 5s. 3d. overseas mail) from 1 April 1968 to recover these costs.

Supplement and Model Answer Books

Students studying for City and Guilds of London Institute examinations in telecommunications are reminded that the Supplement to the Journal includes model answers to examination questions set in all the subjects of the Telecommunication Technicians' Course. Back numbers of the Journal are available in limited quantities only, and students are urged to place a regular order for the Journal to ensure that they keep informed of current developments in telecommunications and receive all copies of the Supplement.

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 always given at the end of the Supplement to the Journal. The books at present available include recently published editions of Telephony and Telegraphy A (February 1967) and Telecommunication Principles A (January 1968).

Notes for Authors

Authors are reminded that some notes are available to help them prepare the manuscripts of the Journal articles in a way that will assist in securing uniformity of presentation, simplify the work of the Journal's printer and draughtsmen, and help ensure that authors' wishes are easily interpreted. Any author preparing an article for the Journal who is not already in possession of the notes is asked to write to the Managing Editor to obtain a copy.

It is emphasized that all contributions to the Journal, including those for Regional Notes and Associate Section Notes, must be typed, with double spacing between lines, on one side only of each sheet of paper.

Each circuit diagram or sketch should be drawn on a separate sheet of paper; neat sketches are all that are required. Photographs should be clear and sharply focused. Prints should preferably be glossy and should be unmounted, any notes or captions being written on a separate sheet of paper. Negatives or plates are not needed and should not be supplied.

Syllabuses and Copies of Question Papers for the Telecommunication Technicians' Course

The syllabuses and copies of question papers set for examinations of the Telecommunication Technicians' Course of the City and Guilds of London Institute are not sold by *The Post Office Electrical Engineers' Journal*. They should be purchased from the Department of Technology, City and Guilds of London Institute, 76 Portland Place, London, W.1.

T. H. Southerton, B.Sc.(Eng.), C.Eng., M.I.E.E.

After early experience in the Midland Region and S Branch war group, Mr. Southerton joined the Post Office Factories as Engineer on production processes, flow methods and work measurement. Successively Factory Manager, Deputy Controller and Controller, he led an efficiency drive embracing economic, technical and operational change. In 10 years, productivity doubled with better control of quality. Mr. Southerton has a friendly down-to-earth approach which blends well with shrewdness and toughness. His wide appreciation of industrial problems was sharpened at the Duke of Edinburgh's Study Conference and the London Business School. He thus brings a wealth of experience to the telecommunications business as Director of Management Services.

R. A. C.

H. Barker, B.Sc.(Eng.), C.Eng., M.I.E.E.

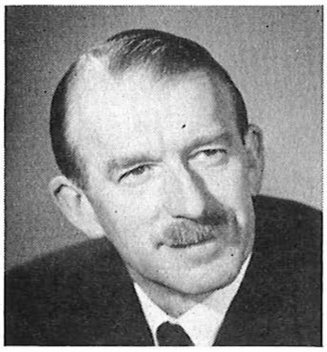
Mr. H. Barker has been appointed as the first Director of the Network Planning and Programming Department. This newly formed Department is responsible for the planning and provision of the main trunk network down to group switching centres, and of space communications, submarine cables and overseas radio. Both approachable and determined, Mr. Barker is well equipped to amalgamate the components of his new Department into an effective team. His knowledge of transmission work, his energy and drive will enable him to lead his Department to success in the formidable tasks imposed by the rapid growth of demand for long-distance telephone and data services.

C. E. C.

J. A. Lawrence, T.D., Hon. C.G.I.A., C.Eng., F.I.E.E.

John Lawrence's appointment t Deputy Director of Engineering as hea of switching development recognizes distinguished career which has earned a international reputation. Reed-electroni systems have been his main responsibilit in recent years, and they owe much t his inventiveness, enthusiasm and under standing. His insight and powerful use o short-cut methods in design and estima ting, seemingly intuitive at times, sten from long experience—practical exper ience of maintenance, of circuit desig and testing, of radar and other militar equipment, of system design and evalua tion. With his unflagging energy, wid experience and flair for management, h will surely succeed in matching switchin development to modern needs and tech niques. His colleagues will wish him well

L. R. F. H.



J. Piggott, B.Sc.(Eng.), C.Eng., M.I.Mech.E., F.I.E.E.

Almost immediately after entry to the Post Office as E.E., John Piggott was seconded to Postal Services Department to study the potential for mechanization; this set the pattern for his future. He became Staff Engineer of Power Branch and, later, of Postal Engineering Branch when it was set up in 1966. His recent promotion to Deputy Director of Engineering in charge of Design and Development at Postal Headquarters can be seen as the culmination of his career in mechanical and electrical engineering. His expert knowledge, combined with a keen intellect and friendly disposition, fit him admirably for this new post. His many friends wish him every success.

G. M. M.

J. Balcombe, B.Sc.(Eng.), A.C.G.I.

Mr. Balcombe was appointed Controller of Factories on 1 October, 1967. The first half of his career, starting in 1933, brought him a wide range of experience in telecommunications during service in the Engineering Department, Region and Telephone Area. Since 1950 he has worked in I Branch, first as A.S.E. and then, from 1959, as Staff Engineer. During this period he took the leading part in modernizing the Post Office approach to acceptance of plant from its suppliers and campaigning for improved quality control by them. His wide circle of friends in the Post Office and Industry wish him success and enjoyment in his new sphere of work.

W. A. H.

T. J. Rees, C.Eng., M.I.E.E.

T. J. Rees, recently appointed D.D.E (Service and Sales Department), joine the Post Office as a Probationar Inspector in 1938. He served for period in the Nottingham Section, North Mid land District and the Midland Region be fore joining the Royal Signals in 1943. O his return in 1947 he spent 2 years as a A.E.E. in Coventry Telephone Area, an in 1949 was appointed E.E. in th Telephone Branch, Engineering Depart ment. Appointed S.E.E. (1954) and A.S.E (1960) in O Branch, he became R.E (Maintenance) of L.T.R. in June 196 and C.R.E. (Service and Staff) in th same Region in May 1965. We wish hi all possible success in his new post.

A. J. T.

F. A. Hough, O.B.E., M.Sc.(Eng.), C.Eng., M.I.E.E.

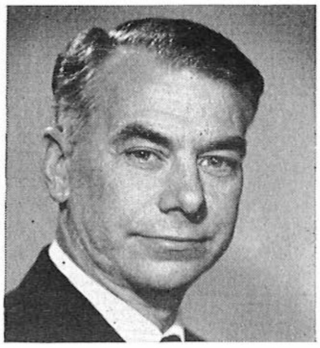
Mr. F. A. Hough, after receiving a M.Sc.(Eng.) degree, joined the Post Office in 1932. Wide experience of Area, Region and Engineering Department work, with a 6½-year break for military service (M.B.E. and mentioned in despatches), was followed by 3 years in LM Branch working on the first transatlantic submarine telephone-cable project: the valuable part he played in this work was recognized by the award of the O.B.E. As C.R.E. of the London Postal Region (1956) and C.M.T.O. (1959) Mr. Hough broadened further his already considerable experience. His recent appointment as D.D.E., Power, Civil and Mechanical Engineering Division, is a translation back entirely compatible with his lifelong interest in engines, cables, poles and holes.

A. G. L.

A. E. Jemmeson, B.Sc.(Eng.)

Arthur Jemmeson, who was promoted to Staff Engineer early in 1965, first took charge of OWS Branch and, later, P Branch of the Engineering Department. In both these capacities he quickly made a significant contribution. Wide experience coupled with an all-round capability—a distinguishing characteristic of his career—made him an obvious choice to head the Engineering Department reorganization team which was set up in 1967. Indeed, much of the new Post Office organization and structure bears the stamp of his flair and ingenuity. His recent appointment as Deputy Director of Engineering, Postal Mechanization Department, was warmly welcomed by his very many friends and colleagues. We wish him every success in his new role.

K. A. H.



W. H. Maddison, T.D., B.Sc., C.Eng., F.I.E.E.

W. H. Maddison has been appointed Assistant Secretary in charge of the Public and Private Services Division of the Service and Sales Department. To this post he brings a wealth of experience and knowledge of telecommunications in both the technical and managerial fields. He has had experience in industry, in the Post Office Research Department, in a Telephone Area, in the development of exchange equipment and subscribers' apparatus, and in the Post Office Factories Department. During the Second World War he became involved in A.A. defence, specializing in radar, and rose from Second Lieutenant to Lt.-Colonel. Of recent years he has represented the Post Office on a number of B.S.I. Committees. All success in his new post!

W. J. E. T.

W. N. Lang, E.R.D., B.Sc.(Eng.), C.Eng., M.I.E.E.

W. N. (Bill) Lang joined the Post Office as a Youth-in-Training in Scotland West Telephone Area in 1939. After service in the Royal Corps of Signals, 1941–1946, he read engineering at Glasgow University, graduating in 1950. After a period at the Central Training School, he was promoted to E.E., London, in 1954. His appointment to Oban cable station in 1956 started 9 years of extensive experience in submarine-cable work, including the U.S.–Bermuda, COMPAC and SEACOM cable projects. Following 2 years as Telephone Manager, Oxford, and a year as an A.S.E. in OCG Branch, his appointment as Service Controller, Scotland, comes as no surprise to his many friends in the Post Office.

A. W. W.

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

The appointment of Mr. H. J. Revell as Director, Telecommunications, Scotland, is a fitting climax to 30 years devoted to the telephone service north of the border. Experience in every Scottish Telephone Area, engineering appointments up to Chief Regional Engineer, and 11 years in the Telephone Manager field furnish a unique background to his present appointment. Mr. Revell combines a strong and dynamic approach to management with a great capacity for concern about the well-being and aspirations of the individual employee. Telecommunications Headquarters Scotland is fortunate that it will be facing the pressures and problems of the coming years under his command.

R. C. B.

E. Davis, C.Eng., M.I.E.E.

Mr. E. Davis has been appointed Controller of the Trunk Planning Branch in the L.T.R. after a varied career at Headquarters and in the Regions, specializing in the development and planning of transmission systems. He was for some years Managing Editor of this Journal. As a member of the London Trunk and the International Switching Task Forces, he made a considerable contribution to the success of both ventures. He took over the leadership of the National Trunk Task Force last year. Eric Davis' energy, drive and the care with which he checks his facts are well known to his many friends and colleagues, as are also his friendly disposition and dry humour. We wish him success in his new venture.

H. E. F.

F. W. J.Webber, B.Sc.(Eng.), C.Eng., M.I.E.E.

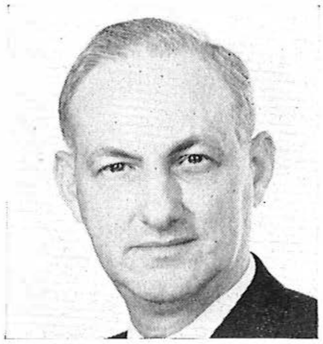
A career which started as a sea-going wireless operator and now progresses to Head of Division in the Telecommunications Personnel Department, gives some idea of Bill Webber's broad experience; Research, Engineering Department, Regional Headquarters, and Telephone Area, he has served them all. In recent years he has been mostly concerned with the many staff negotiations which have been such an essential part of the improvement in engineering productivity. His clear insight into the problems, and his absolute integrity and thoroughness have been major factors in the success which has been achieved. His many friends will wish him further success in exercising the wider responsibilities he is now undertaking.

D. C. B.

W. L. A. Coleman, B.Sc.(Eng.), C.Eng., F.I.E.E.

The appointment of Mr. Coleman as Director of the Midlands Telecommunications Region has given great pleasure to all his colleagues. He has completed 40 years of Post Office engineering, serving in the Engineering Department and three Telephone Areas before the last 15 years as Regional Engineer and C.R.E., Midland Region. Those who know him are aware of his keenness, energy and drive. He has the freshness and enthusiasm to inject into the changing organization the new spirit that is now required. He has always shown considerate interest in the staff in his charge, and this attribute, which reciprocates loyalty, should enable the Midlands Telecommunications Region to progress successfully under his leadership.

G. A. P.



D. Baker, C.G.I.A., C.Eng., M.I.E.E.

Denis Baker commenced as a Youtl in-Training in 1942 and progresse through the A.E.E. and E.E. limite competitions, his work including exchang maintenance, and external and equipme planning. As S.E.E. he was responsibl for the detailed accommodation an equipment planning for establishing new Central Engineering College; fo merly to be at Harlow this is now bein built at Stone. As A.S.E. he was o manpower productivity questions, i cluding leading a working party to stud the system of performance statistics i Canada and to formulate a comparabl system for the British Post Office. H wide experience and friendly, quiet y firm, manner will equip him well f new problems as Planning Controlle North Eastern Postal Region.

R. O. B.

J. S. Whyte, M.Sc.(Eng.), C.Eng., F.I.E.E.

After seventeen fruitful years of transmission research John Whyte was seconded in 1965 to H.M. Treasury to take charge of the division concerned with computer applications in Government Service. His success in changing from research to administrative work in this very active area is a measure of his adaptability and broad outlook; and of the shrewd business sense that his easy manner may conceal, for commercial pressures are severe in the computer world. He is well equipped to lead the Long-Range Planning Division, with its wide technical, economic and sociological interests. We wish him well in his work: may he also have leisure for photography and mountaineering!

H. B. L.

G. P. Copping, B.Sc.(Eng.), C. Eng., F.I.E.E.

Mr Copping joined the Post Office as a Probationary Assistant Engineer (old style) in 1938. After training he served in the External Plant and Carrier Groups at Dollis Hill. During the war he was commissioned in the Royal Signals, returning to Research Branch in 1946. With outstanding energy and enthusiasm he conducted a highly successful research into the mechanization of letter-mail handling, leading the team which made laboratory models of the machines now going into service. He continued this development on his transfer to P and PE Branches. His many friends will wish him success in his well-deserved appointment as Staff Engineer in charge of the Letter Machinery Branch in PHQ/PMD.

G. N. D.

C. E. E. Clinch, B.Sc.(Eng.), C. Eng F.I.E.E., F.S.S.

In progressing from Youth-in-Trainin to Staff Engineer, Charles E. Clinch ha had a more varied experience than mo Post Office engineers. It has embrace subscribers' apparatus, telephon exchange work, transmission system electronic-exchange development an latterly, the technical aspects of broa casting and other radio-regulato matters. His duties have taken him to a parts of the country and to many countri overseas, ranging from Lebanon to th U.S.A. His large circle of friends an acquaintances at home and abroad wi wish Charlie every success in his ne post, which takes him into yet anoth field of Post Office activity—the mec anization of the parcel post.

T. K.

I. G. White, C.Eng., M.I.E.E.

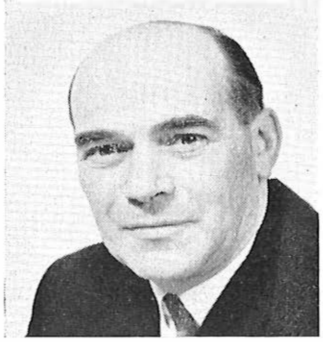
Ivor White has been appointed Staff Engineer, Project Engineering Branch, Postal Headquarters. After receiving training in the Gloucester Telephone Area he moved to the Home Counties Region in 1948 as A.E.E. Through the E.E. Competition in 1952 he joined the Engineering Department, Power Branch, where, amongst a variety of work, he designed semiconductor rectifier units. Promoted S.E.E. in 1960 he turned his considerable energies to mechanized parcel sorting, and introduced the highly successful tilted-band machine. He was promoted A.S.E. in 1965. Mr. White is known for his wide vision, his penetrating and logical approach to complex problems, and for his deep sense of purpose; the success of the new Branch is assured.

J. P.

A. E. T. Forster, C.Eng., M.I.E.E.

Mr. A. E. T. Forster, Staff Engineer, Datel, Telex, and Telegraph Systems Planning and Provision Branch, entered the Post Office in 1935. From 1939 to 1946 he was on War service. He joined the Telegraph Branch in 1946 and was engaged on development of the telegraph automatic-switching system. In 1953 he was promoted S.E.E. in charge of the development of the present national and international telex system. In 1963 he was seconded to SHAPE Technical Centre, and returned to the Telegraph Branch 1966 as A.S.E. in charge of telegraph transmission and machine development. Mr. Forster is known nationally and internationally as an expert on telegraph-switching systems, and this long experience will stand him in good stead in his new appointment.

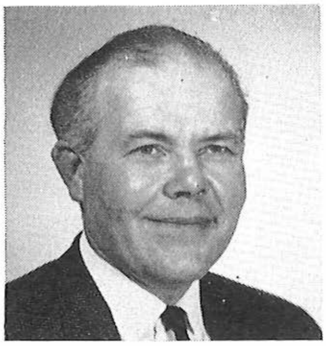
J. R.



T. C. Harding, T.D., C.Eng., M.I.E.E.

Mr. T. C. Harding, who joined the Post Office in 1930, was an A.E.E. in the old North Midland District when the war interrupted his career. As a Territorial officer he was called up in August 1939 and subsequently rose to the rank of Lt-Colonel in the Royal Corps of Signals. After demobilization he was promoted to S.E.E.. in the Research Branch, and in 1957 to A.S.E. in charge of the development of subscribers' apparatus. The Telephone 706, the Trimphone and many other items were developed under his capable direction. With this wealth of experience Terry Harding is assured of success in his new appointment as Staff Engineer in Provisioning and Supplies Department, where he will be responsible for the application of value-analysis techniques.

A. J. F.



P. J. Edwards, C.Eng., M.I.E.E.

Jimmy Edwards started in 1942 as a Youth-in-Training in the Birmingham Test Section. During a varied career, embracing h.f. radio, television and microwave links, he has always tackled the problems before him with enthusiasm, and has become an expert in each subject. He returned to I Branch on promotion to A.S.E. in 1965 and pursued, with his customary vigour, the problems of rationalizing the specifications for local cables and the replacement of copper by aluminium conductors. His well-deserved promotion to Staff Engineer of the new Power and Ancillary Systems Branch will not surprise those of us who know this cheerful, direct, forceful and most likeable chap. We wish him well.

D. G. J.

B. R. Horsfield, C.Eng., M.I.E.E.

Joining the Post Office in Leeds in 1933 and the Engineering Department in Leeds in 1941, Mr. Horsfield became a widely acknowledged expert in signalling. He visited the U.S.A. in 1947 and, subsequently, served on the Working Party that formulated the first S.T.D. proposals for the United Kingdom. He was seconded to India in 1953 for 6 months on behalf of the United Nations. Promoted to A.S.E. in 1961 he became expert in electronic switching. A valued colleague, always concerned with the welfare of his staff, his appointment as Staff Engineer is welcomed by his many friends, who wish him success in his new post.

J. A. L.

E. V. Partington, B.Sc.(Eng.), C.Eng., M.I.E.E.

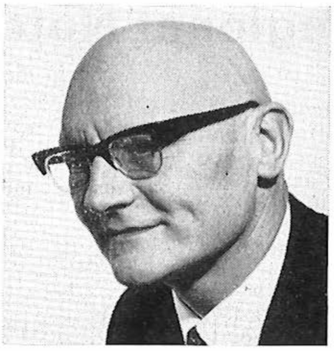
After a firm grounding in the Circuit Laboratory, Eric Partington worked on many aspects of telephony; this included 5 years on external planning in Australia. Later he spent 2 years as Chief Engineer (P. & T.) in the Sudan, following which he was promoted in 1964 to A.S.E. on work study of maintenance. Mr. Partington has always taken a real interest in people, and this has been shown by the active part he has played in Society affairs—first as President of S.P.O.E. and, later, as Treasurer of the A.S.R.E. His background, interests and personality ideally suit him for his new post, as Staff Engineer of the Customers' Maintenance Services Branch.

C. A. M.

K.'A. Hannant, B.Sc.(Tech.), C.Eng., M.I.E.E.

Keith Hannant, appointed Staff Engineer in the Telecommunications Management Services Department, began his career as E.E. in 1950 in the Liverpool Telephone Area. He came to Headquarters in 1958 on promotion to S.E.E., after 5 years in Regional Headquarters—a unique range of experience for a post-war graduate entrant. He did excellent work in his field of exchange planning and design, notably in network planning for S.T.D. and some overseas projects. In 1965 he moved, as A.S.E., to management work in OCG Branch dealing with grading and organization, and since September 1966 has concentrated on legislative aspects of the Post Office reorganization. His personal qualities and background should ensure his success in his new assignment, and we all wish him well.

A. E. J.



P. E. Brownlow, C.Eng., A.M.I.Mech.E

Mr. P. E. Brownlow, who has been appointed Chief Motor Transport Officer, Motor Transport Division, entered the Post Office by open competition as M.T.O. III in 1949. After completing his apprenticeship in the L.N.E.R. Locomotive Works at Doncaster he served with R.E.M.E., mainly in the Middle East. On demobilization he lectured at Doncaster Technical College before joining the Post Office, where his ability, enthusiasm and industry were speedily recognized by rapid promotion. His many friends inside and outside the Post Office were very pleased to hear of his new appointment and wish him continued success. Members of the old M Branch were particularly happy as he was the first member of the Branch for 30 years to be appointed C.M.T.O.

M. C. H.

N. B. Rymer, M.B.E., T.D., C.Eng., M.I.E.E.

Norman Blake Rymer shouts fo Wales at Twickenham. Elsewhere, h hardly raises his voice. This may give th erroneous impression of a tacitur nature. In fact, he is essentially a doe rather than a talker, and has always bee ready to have a go. He came to the Pos Office in Cardiff in 1936 as an Ope Probationary Inspector, spent the wa years with the Royal Corps of Signals i Europe, and, on return, passed the E.E examination and went to the Engineerin Department. Principally an outside man he has also had considerable experienc with transmission and testing equipments He brings to his appointment as th "Chief Inspector" the ideal experienc and temperament to command the respec of the contractors and the loyalty of hi staff.

F. A. H.

Book Review

"Words and Waves." A. H. W. Beck, Weidenfeld and Nicolson. 225 pp. 69 ill. 25s. board, 12s. 6d. paper.

In the belief that the intelligent layman should be able to reach an informed opinion on technical matters which affect his way of life, Professor Beck has attempted to provide him with an appreciation of the technical background to telecommunications. A second aim has been to encourage senior schoolchildren to consider a telecommunications career.

The book has two main sections: a very readable outline history of electrical communication; and, at greater length, a survey of such subjects as wave motions and forms, bandwidth, modulation, feedback, noise, transmission systems, information theory, cybernetics, and so on. Though the book is aimed at him, the layman is likely to find the technical section rather heavy going. The author might have allowed more for the layman's unfamiliarity with the habits of technical thought and speech, and could well have been less ambitious in his treatment of the subjects chosen. There is no discussion of such major non-electrical problems as that of the gathering, handling, and distribution of communications traffic, even though S.T.D. is cited as a prime example of a technical development which significantly affects the public.

In spite of the defects mentioned, an intelligent layman with a little persistence should find the book interesting. For sixth-formers, it may be too fragmentary to achieve its purpose, but if the school science staff or others can provide any necessary enlargements, it may prove stimulating.

J. T.

Book Received

"Electromagnetic Theory: Static Fields and Their Mapping." Ernst Weber. Constable and Company, Ltd. xii+590 pp 175 ill. 22s.

This Dover Publications paperback edition is an unabridge and corrected republication of the work first published b John Wiley and Sons, Inc., in 1950 under the title "Electro magnetic Fields, Theory and Applications, Volume 1—Mapping of Fields." In this book the static electric an magnetic fields generated by motors, generators, trans formers and other components are described, together wit the methods that have been used to map them.

The first three chapters in the book survey and analys static fields, noting, in particular, the physical relationship existing between electrostatics, magnetostatics and electro kinetics. The rest of the book, and by far the larger part deals with field-mapping methods, stressing equally th analytical and practical aspects. Methods of mapping one dimensional fields include simple applications of the super position principle to systems of point and line charges, lin currents, and simple geometrics of spatially distribute charges and currents. The experimental method of mappin complex geometries, especially the analogies utilized in th electrolytic trough, is contrasted with graphical and numerica field-plotting methods. The uses of electrical and magneti images and inversion in mapping one-dimensional fields i presented, and two-dimensional field problems are solve with analytical functions, conjugate functions and conforma mapping. Orthogonal co-ordinate systems are used to dea mathematically with three-dimensional problems.

The book includes six appendices containing an annotate bibliography and explaining the fundamentals of vecto analysis, Bessel functions and Legendre functions.

Regional Notes

Eastern Region

Telephone Distribution in a Mediaeval Town—Lavenham

Lavenham is a well-preserved mediaeval wool town, and so it is not surprising that it heads a list of picturesque Suffolk villages that need to be preserved as far as possible in their original condition. Consequently, back in 1961, the West Suffolk County Planner approached the Post Office to see if it would be possible to remove the overhead wires from the main streets Church Street and High Street. Due to a period of financial stringency nothing was done until 1964.

In that year, the Telephone Manager met the Eastern Electricity Board and the Suffolk Preservation Society to discuss the problem. However, no extra costs could be incurred for amenity improvements in 1964, as Post Office policy was then to clear outstanding requests for service by March 1966.

Eventually in 1966, the Eastern Electricity Board approved an amenity grant to put their services underground. Consequently, the Telephone Manager, using his devolved powers, agreed to advance the development of Lavenham to take advantage of the opportunity for joint trench construction. West Suffolk County Council were also prepared to do the final reinstatement. This was an opportunity not to be missed, as a part-development scheme would soon be necessary for the following reasons.

(*a*) Parts of the duct were congested due to piecemeal expansion with small cables over the years.

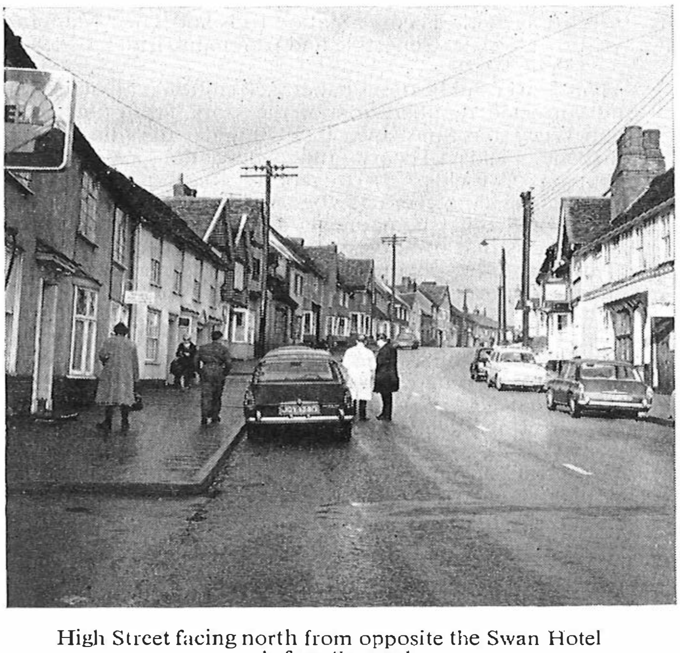
(*b*) At the north end of High Street up to five drop wires had been erected on Eastern Electricity Board poles—to provice service to waiting customers.

(*c*) Two new housing developments had to be served.

(*d*) Relief was necessary for the village of Preston where a line connector was already in use.

(*e*) Last, but not least, the Eastern Electricity Board were removing their poles, on which Post Office wiring was supported.

A cabling scheme was prepared, therefore, for both sides of High Street and Church Street using the Eastern Electricity Board trench wherever possible. Thirty-eight block-wiring points were used, but it was still possible to make use of six pole positions which could be reached without difficulty by the maintenance engineer, and were off the main streets or were well-camouflaged by the existing trees. Singleton jointers buried the spur cables to each terminal block and connected them to the main cable by means of taped joints.



High Street facing north from opposite the Swan Hotel before the work

When the development was complete, the recovery of the poles was done with an Electricity Board crane. This work was observed by television cameras for the benefit of the "viewing" public. The Post Office Simons hoist was used to recover 14 chimney brackets from roof tops whose strength was extremely doubtful.

The same scene after the work was completed

When this part-development of Lavenham was finally completed the architects and the Suffolk Preservation Society sent their congratulations and appreciation to all concerned for their co-operation in the removal of the proliferation of poles and wires from Lavenham main streets. The Telephone Manager stated in reply that the Lavenham part-development had only been made a practical proposition by West Suffolk County Council bearing the reinstatement costs. In fact, with joint trench construction and free reinstatement the actual cost compared quite favourably with a normal ring-type, drop-wire distribution scheme.

So a dream of the Suffolk Preservation Society, Town and Country Planners and their Associates, had come to life, but to some, these ancient streets without visible means of communication seem lifeless.

R. W. J.

Scotland

Storm Damage

A storm of hurricane force on the 14 and 15 January 1968 caused serious damage to telephone plant in Scotland.

Extensive damage to aerial cables and overhead junction routes was experienced in Dundee, Glasgow, Edinburgh and Scotland West Telephone Areas. 25,000 subscribers' circuits were affected and over 100 exchanges isolated due to external-plant damage and failure of power plants not equipped with standby engines.

Installation work was suspended in all the affected Areas and with the assistance of gangs loaned by the N.E. Region the situation was progressively brought under control. By 29 January all controls were reported to be operating normally though heavy rain storms were maintaining a high level of fault reports, particularly in Glasgow and Scotland West Telephone Areas.

Restoration of service was, of course, on a temporary basis. It is estimated that permanent restoration will involve an expenditure of 500,000 man-hours.

Serious damage was also caused at two microwave radio stations in the Scotland West Telephone Area. At Riddingshill, near Dumfries, a large paraboloidal horn aerial, transmitting telephony and television to Belfast, broke loose from its mountings and swung round to smash against the tower, narrowly missing the adjacent receive horn. The fault occurred at 1.30 a.m. and by 4 a.m. emergency staff had managed to reach the station and restore service by re-connecting wave-guides in the station to an old dish aerial remaining on the tower. A few minutes later at Green Lowther, the next station north on the Carlisle–Kirk O'Shotts route, winds of up to 130 m.p.h. stripped the 2 in. thick asphalt roof covering off the station and flung it against the tower and aerials. Handrails on the tower were broken and a small horn aerial carrying B.B.C. 2 and telephony was badly damaged. Because of the storm the station was inaccessible until later in the day when, amongst the remains of the roof, a rigging gang secured aerials to prevent further damage. The feeder to a dish aerial on the tower was damaged, but a spare length was found and the dish was panned, with service being restored using this aerial on the afternoon of 16 January.

Spare aerials have been located for both stations and are being installed as weather permits.

During the same storm, the submarine cable carrying circuits from Coll and Tiree via Mull to the mainland failed. All contact with the two islands was lost except for v.h.f. communications between the airfield and nearby aircraft. A cable ship was sent to repair the cable but, meanwhile, Regional staff prepared a single-channel v.h.f. radio link using new Transceivers 2A. One terminal was flown to Tiree and erected at Scarinish while the other terminal was set up near Tobermory on Mull. Communication was established on the morning of Thursday 18 January, and the link was then in almost continuous use until the submarine cable was repaired in the afternoon of Sunday 21 January.

E. S.

South-Western Region

Flood Damage to Bideford "Long Bridge"

Bideford "Long Bridge" has spanned the River Torridge since A.D. 1280. A stone bridge was built over and around the original timber bridge some two hundred years later and its present shape was acquired in 1925 when it was widened. The varying spans of the 24 arches are due to the different lengths of the original timber lintels. The bridge is maintained by a trust fund owning property in the town and was exempted from the Trunk Roads Bill of 1946. Besides carrying the A39 trunk road the bridge carries a number of Post Office cables in steel pipes suspended below the upstream and downstream footways.

On the 10.30 p.m. B.B.C. news summary on Tuesday, 9 January 1968, it was announced that flood water had damaged the bridge and that it was in danger of collapsing altogether. A member of the staff heard the report and, realizing the implications, immediately arranged a meeting of officers concerned to decide on possible courses of action.

At this stage it was known that one of the buttresses between two arches at the western end of the bridge had collapsed. A gas main was fractured and leaking but there was no apparent damage to Post Office plant. The cables involved were the Barnstaple–Widemouth coaxial cable carrying transaltantic (TAT-3) traffic, Barnstaple–Bude trunk cable, Barnstaple–Bideford and Bideford–Torrington junction cables and two 200-pair local cables. If the bridge collapsed breakage of these cables would mean serious disruption of service.

Power was removed from the coaxial power-feeding section affected and the circuit controls advised of the possibility of failure. The air pressure by-pass was disconnected at the stations on either side of the bridge and air bottles provided at each end to feed the affected section. Junction circuits were rerouted to avoid the possibilities of total exchange isolation. The planning engineer for the area was called for meetings on the following day.

At the meeting on Wednesday no decision could be made as to how the cables could be rerouted. This was due partly to the complication of private ownership of the bridge. Meanwhile, assuming that permission would be obtained to lay out cable on the undamaged part of the bridge, stores were being collected, the patching of junction circuits was continuing, and a scheme was being prepared to provide emergency service should there be a total breakdown. To guard against public-supply failure affecting the coaxial system a mobile generator was provided at Bideford repeater station.

By lunch-time on Thursday permission had been obtained to lay out the interruption cables on the upstream footpath of the undamaged section, and the damaged portion was spanned by aerial steels terminated on a pole on the upstream side of the west bank and the superstructure of the bridge itself. The main difficulty was to find suitable attachment points on the bridge. The bridge engineer eventually agreed to the use of the footpath corbel at the fifth pier, providing that a "bracing" steel was passed under the arch and fastened to the corbel on the opposite side of the sixth pier.

A 30 ft medium pole was erected on the west bank about twenty yards upstream, and on the east bank the concrete carriageway was excavated for 15 yd and three duct-ways laid to link manholes. Cable was laid out in preparation for erecting the suspension wires at next low water.

The method of attachment to the bridge was causing some concern. Besides the obvious technical difficulties of the work there existed considerable danger to the men involved, and there was the possibility of renewal when work on the bridge began. A free-standing "anchor" was used instead, this being constructed from a modified steel pallet loaded with concrete blocks. On Friday morning this was placed on the footpath adjacent to the bridge parapet, the bridge engineer's authority having been sought and granted. The cables already laid out were hand lashed to the steel suspension wires and drawn across the river to terminate on the pole.

At this late stage a new problem arose. It had been intended that the cables could cross the road on the west bank, overhead from the pole to the parapet of the Town Hall. The Bideford Borough Surveyor now had misgivings over the safety of the parapet and forbade its use. It was now late afternoon but the difficulty was solved rather dramatically. Within minutes of the surveyor's decision a small gang of workmen, employed by the contractor holding the local contract for such work, passed the scene on their way home. They were stopped and within a very short time the road was being excavated. By 10 p.m. five ways of p.v.c. duct had been laid across the road and concreted in place. Further duct was laid at the rear of the footway to the manhole at the west end of the bridge and the cables drawn in.

Arrangements were made to commence changing over on Saturday morning and to change over the coaxial pairs on the Saturday night. With shift working the whole operation was completed by the following Tuesday morning.

The cables laid out on the bridge were protected using steel capping fixed to the surface of the footpath. This protection will be necessary during the progress of repair work on the bridge.

Tribute must be paid to the alertness and foresight of the staff who started planning the operation as soon as the facts were known, and to all those who worked long hours in bad conditions to see the task through to a successful completion.

K. L., G. B., and J. P.

Associate Section Notes

London Centre

"Time Assignment Speech Interpolation (TASI)" was the subject of a very interesting lecture by Mr. C. E. E. Clinch on 8 November 1967. We can always be assured of a very enjoyable and instructive evening when Mr. Clinch visits us and this one was no exception. His description of the various ways and means of making a few pairs of wires do the work of many was first class.

On 4 December we were again assembled in Fleet Building, this time for a talk by Mr. R. L. Moxon on "The Post Office Tower and the Network of Microwave Radio-Relay Links." Mr. Moxon described the technical characteristics of the links and stations as well as the construction and layout of the equipment in the Post Office Tower. His talk was illustrated with colour slides and proved very informative.

Mr. B. H. House and Mr. J. P. Keller were the speakers at our meeting on 9 January. The subject was "Organization and Procedure for Local Automatic Exchanges," and described the background to the current methods of operation and the procedures in use for maintaining local automatic exchanges. How the procedures can operate in practice was also discussed, and an outline given of possible future maintenance techniques. The questions afterwards showed what an interesting subject this was to those present.

The annual quiz between London Telecommunications Region and Home Counties Region took place at Canterbury on 17 November with Canterbury the worthy winners, having gained 31 points against London's 25. Both teams were well supported and after a very good meal we all settled down to a very enjoyable evening. We were very pleased to have with us our President, Dr. P. R. Bray, who was Question-master, and Mrs. Bray who presented the trophy to the winning team. Thank you Dr. and Mrs. Bray for giving up your valuable time to be with us. We wish to thank also the two adjudicators, Mr. F. C. G. Greening and Mr. H. Watkins, the scorer Mr. R. G. Wilson, and the timekeeper Mr. D. Webber. The teams were: Canterbury—N. Sturt (Capt.), M. Butcher, C. Gisby, K. Hounsell, E. Ralph and P. Richards; London—J. Featherstone (Capt.), J. Coombe, B. Simmonds, R. Todd, A. Towner and E. H. White.

R. H. W.

Plymouth Centre

The 1967–68 session opened with a visit to the South Western Gas Board plant at Breakwater Works, Oreston, on 14 November. This is one of the two plants in this country which produces gas from oil using light distillate, a product of the petroleum industry, as its raw material.

The December meeting took the form of a lecture given by Mr. Taylor of Crypton Equipment, Ltd., entitled "Modern Methods of Testing Motor Vehicles." This meeting, coupled with Mr. Taylor's tips on tuning, was greatly appreciated by our car-owning members.

On 23 January a party of our members visited the Portal Paper Mills at Ivybridge, this meeting also being highly successful. The interest shown this year in the Centre is gratifying and we hope that our program to come will help to maintain this interest.

J. B. L.

Swindon Centre

The 1967–68 program commenced in September with a visit by 28 members to the Severn Bridge and the steel works of Richard Thomas and Baldwin, Llanwern, Newport. During the evening, the return journey was made via the Wye Valley to Gloucester for a social evening.

In October, a meeting attended by 17 members was given a talk by Mr. McDonald, Area Engineer, Gloucester, on "Telephone Management." This gave a very good insight into the work of the Area Engineer in the Post Office organization.

For the November meeting, attended by 18 members, Messrs. J. Bowen and R. Harvey gave a talk on "Transistors and Their Applications." This was very interesting, being illustrated with slides and films.

There was no meeting in December, but in January 1968, a visit was made by 10 members to the Metal Box Co. (Plastics Division), Swindon.

W. H. B.

Sheffield Centre

The membership of the Centre is now approximately 300, and the keen interest which is taken in Centre activities is very gratifying. The Magazine Club continues to be a popular facility.

A varied program had been arranged for the winter season and the first item was a visit to A.E.I. Traction Division. At these works, modern production lines and high-precision work are combined in the manufacture of generators and motors. The party also had an interesting preview of an electrically-driven car.

On 4 October a party of 40 members attended the Leeds University regional lecture which was entitled "Tomorrow's World of Communications" and was presented by Mr. W. J. Bray, Head of Research, Dollis Hill. Later the same evening Honorary life membership of the Associated Section was conferred on our ex-treasurer in recognition of his long service to the Centre, and an essay award to Mr. H. Yearle for his paper "A Short History of Magnetism."

Mr. K. Grainger paid a return visit to the Centre on 19 October to present a paper entitled "Pulse-Code Modulation." Some 50 members attended on this occasion.

Adverse weather prevented Mr. J. V. Day from addressing the Centre on "Promotion Procedure" on 23 November, but fortunately Mr. Thompson, Telephone Manager, was able, at short notice, to talk on the same subject to an appreciative audience of 63 members.

On successive weeks in December, two parties of members visited the G.P.O. Television Switching Centre at Manchester to obtain an insight into its operation and enjoy also the Lancashire hospitality offered by their hosts. The parties also visited Granada T.V., Limited, Manchester.

A joint paper entitled "Communications at Eldon House," the Sheffield Telephone Switching Centre, was presented on 14 December by two of our colleagues, Messrs. B. A. Sargent and C. J. Bingham. Present working and future development were covered and a lively discussion ensued.

An enjoyable social was held at Eldon House on 27 January. Entertainments catered for all ages and included a film show and a variety of games. A buffet supper was provided.

K. H. B.

Wales and Border Counties Centres

A Regional Meeting of Associate Section Officers was held in Cardiff on 25 January 1968. This proved to be a most valuable opportunity for interchange of ideas between many who live very far apart and meet but rarely. The Chief Regional Engineer stated that he was pleased that so many centres were obviously very healthy, active and well supported by their members. He hoped that this situation would continue. He noted particularly that there had been very successful and well-attended special meetings and events in Hereford, Cardiff and Chester, and very senior officers had been guest speakers. There was a very full discussion regarding ways and means of maintaining successful centres, and officers from centres perhaps a little less fortunate in this respect were able to gain inspiration and ideas from their colleagues.

A special lecture "Telecommunications of the Future," by Mr. W. J. Bray, Director of Research, is arranged for 26 April 1968, and it is confidently expected that over 200 members in South Wales will be attending. The largest lecture threatre in Cardiff University College has been booked for this occasion.

C. T. L.

Edinburgh Centre

On Monday, 6 November, the Centre heard an informal talk on "Engineering Promotion Procedure" by Mr. W. E. Adams, T.H.Q. Scotland. The system of appraisements was discussed and members were shown the type of form used.

The meeting was well-attended and everyone present enjoyed the talk and the lively discussion which took place later.

On Thursday, 7 December, a visit was made to Kincardine generating station, which is situated on the north bank of the River Forth. Sufficient interest was shown on this trip to plan a visit to another coal-fired generating station at Cockenzie.

Mr. Candlish of Elliott Automation, Ltd., was our guest speaker on Wednesday, 10 January. Mr. Candlish gave a talk on "Microelectronics." The talk was illustrated by a film and slides made at the firm's laboratories at Glenrothes, Fife. The film used was shown on "Tomorrow's World" on B.B.C. 1 last year. This proved to be a most interesting and enjoyable talk.

G. A. K. R.

Glasgow Centre

We have now completed more than half of the session's program and attendances have been good, especially at our first meeting. Here we heard a talk entitled "Dial House Project—Glasgow" by Mr. W. J. G. Barnett, Glasgow T.A. Later talks have included "Computers," "Teleprinters," and "Pulse-Code Modulation," "Transatlantic Communications," and "The New Look on Maintenance." Our annual general meeting is in May.

The Centre is again running a Local Essay Competition, the closing date for entries being 31 May 1968, and we are hopeful of a good response.

Mr. R. M. Fraser resigned as secretary in October 1967 for reasons of health, and all who know Bob thank him for all the good work he did for the Glasgow Centre over the past 4 years.

J. S. M.

Exeter Centre

Attendance so far this year has been good, although not as high as was hoped. Our first talk of the winter session was given by Mr. D. Maynard (Deputy Chief Public Health Inspector, Exeter City Council). The talk, entitled "The Work of the Public Health Inspector," proved most enlightening. Doubtless, members were aware of the field that this public service covers, but few had given a great deal of thought to the subject and were consequently surprised to hear how varied the work can be.

The December meeting heard a paper given by Messrs. M. Doherty and N. Fletcher entitled "Modern Rodding and Cabling Methods." The paper covered all aspects of rodding and cabling, and explained in detail some of the problems that have yet to be solved. Slides illustrated various mechanical aids used in modern techniques.

We are indebted to the speakers for an enjoyable and interesting evening.

T. F. K.

Oxford Centre

This centre was reformed on 26 September 1967 after a lapse of over 20 years. At our inaugural meeting the following members were elected: *Chairman:* Mr. B. V. Wilsden; *Secretary:* Mr. D. A. Green; *Vice-Chairman and Treasurer:* Mr. A. Shepherd; *Committee:* Messrs. Blyde, Heritage, King, Searies, Harrison and Woodford. At the moment our membership stands at over 100, which is a very encouraging starting figure.

Our meetings so far have included talks on "Pulse-Code Modulation," by Mr. G. Bennett, "Crossbar Switching," by Mr. R. Fenn, and "The American Communications System," by Mr. D. Cotterill. We have also seen a selection of technical films.

Future events include visits to the V.C. 10 flight simulators at the R.A.F. Brize Norton station, and to Didcot Power Station, and a talk on "Tape Recording" by Mr. Ray Stanton-King. Our first annual general meeting will be held on 23 April 1968.

Oxford Area staff who are not already members can obtain application forms from any committee member or come along to one of our meetings.

D. A. G.

Subscriptions and Back Numbers

The Journal is published quarterly, in April, July, October and January, at 3s. per copy; the post-paid price is 4s. 6d. per copy (18s. per year) via inland mail, and 4s. 9d. (19s., or 2 dollars 50 cents Canada and U.S.A., per year) via overseas mail. Back numbers will be supplied, if available, price 3s. 6d. (5s. inland mail, 5s. 3d. overseas mail) per copy. With the exception of April and July 1964, July 1965, and January 1966 Journals, copies of the July 1966 and all earlier Journals are no longer available. Orders, by post only, to *The Post Office Electrical Engineers' Journal*, 2–12 Gresham Street, London, E.C.2.

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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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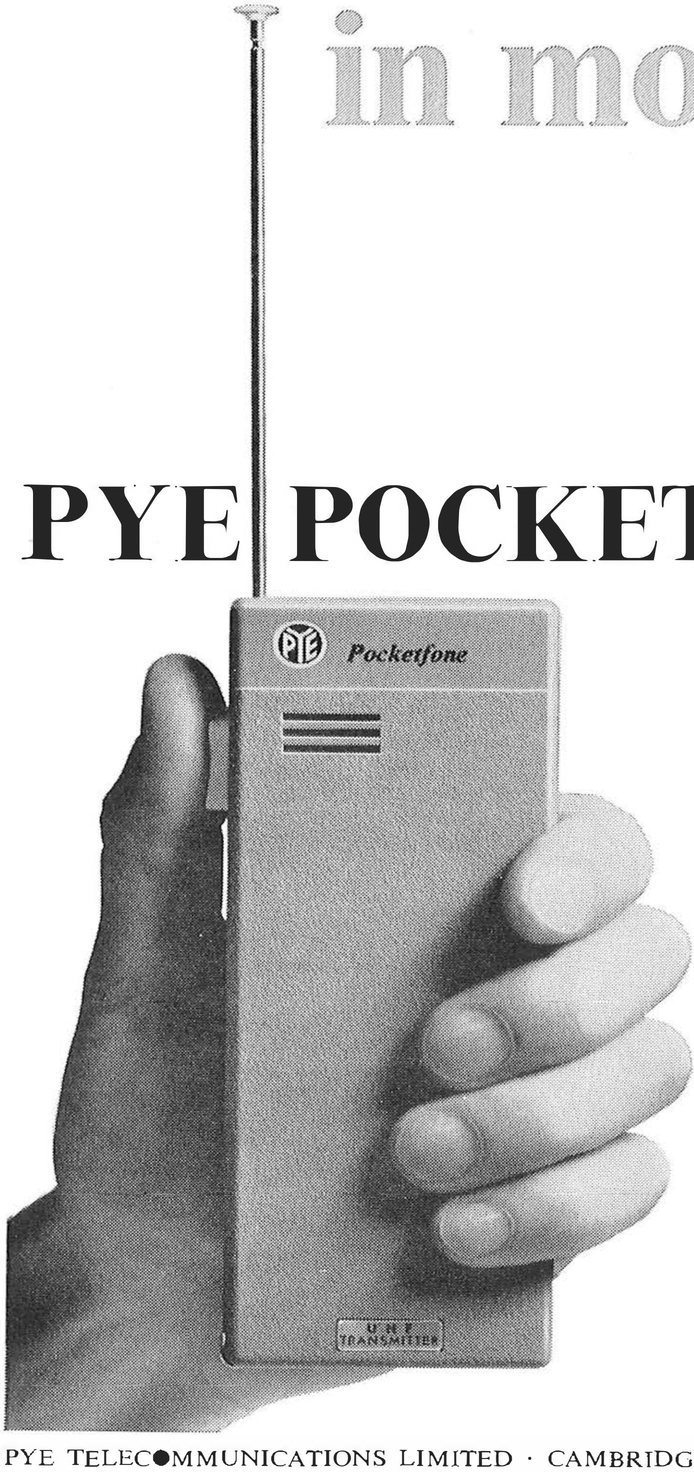

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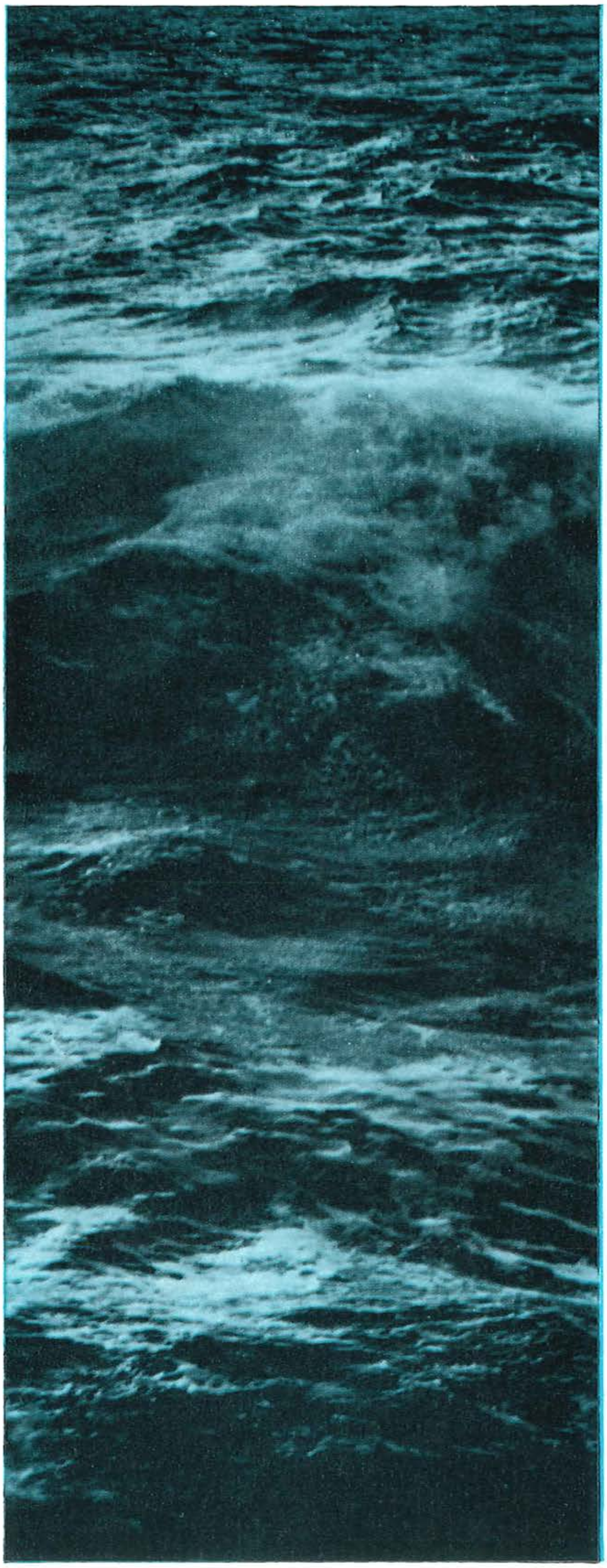

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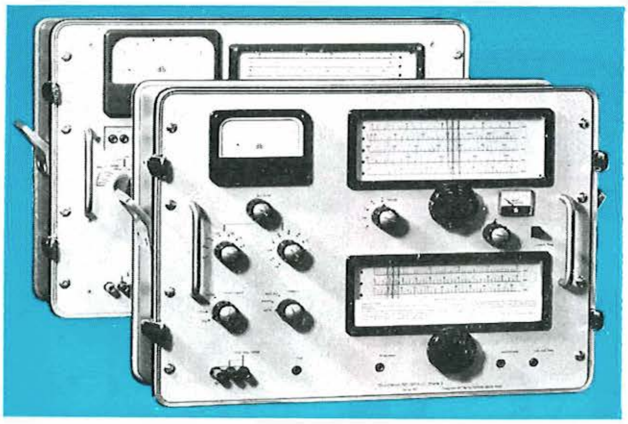

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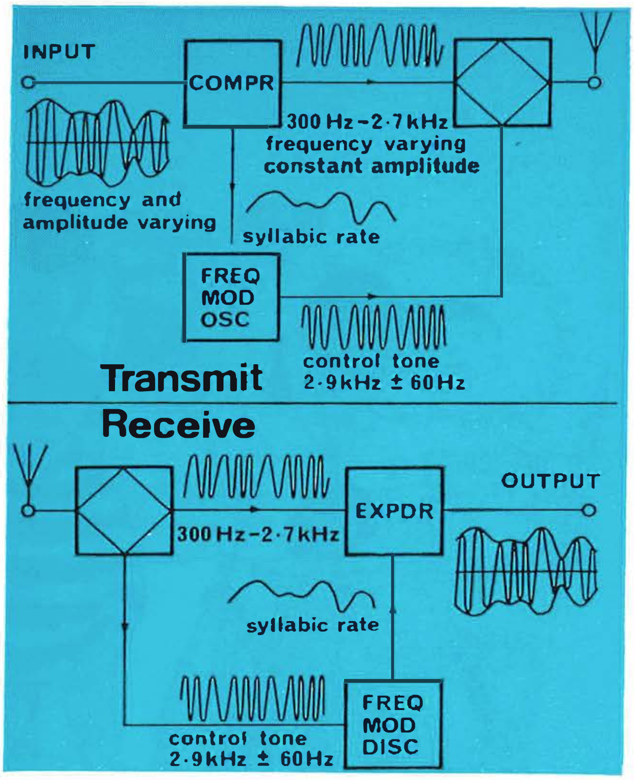

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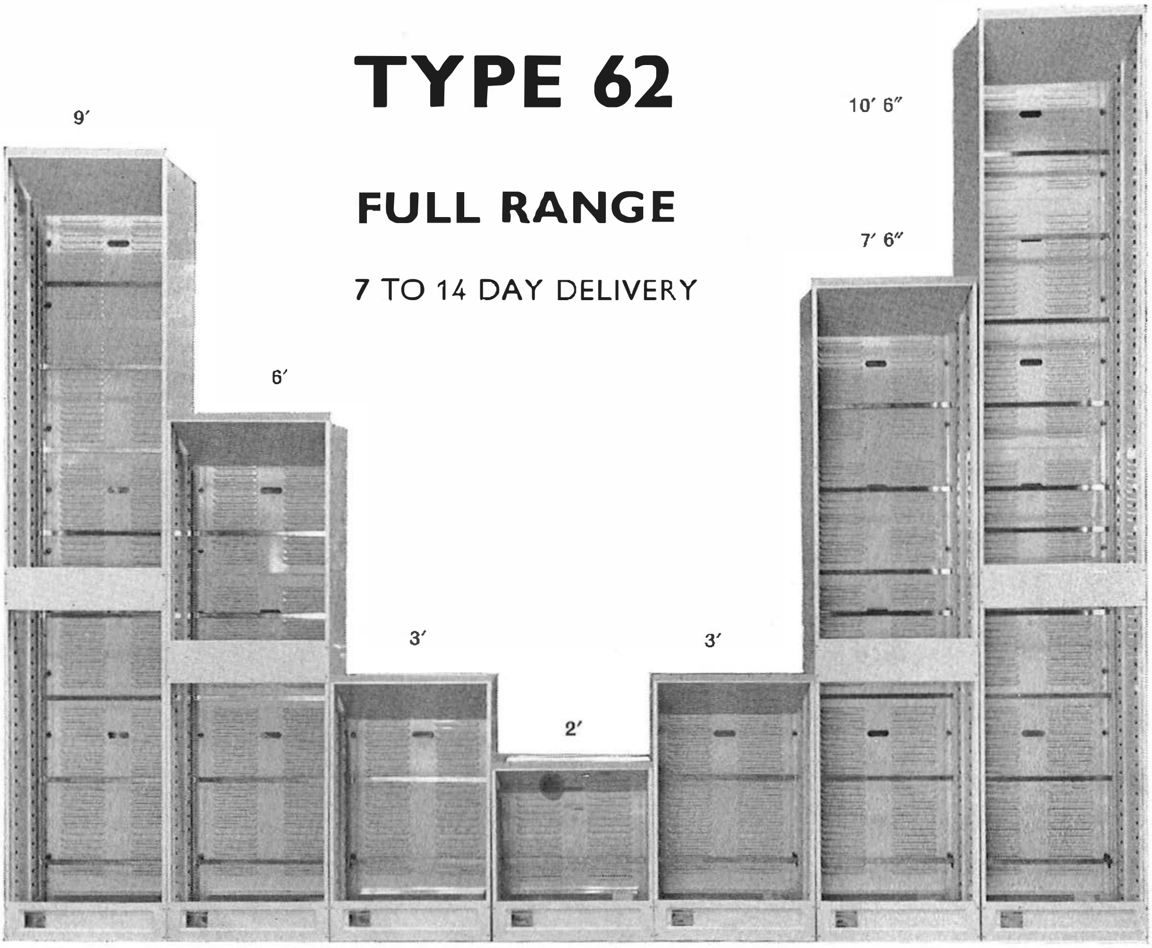

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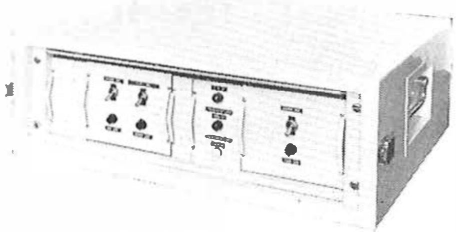

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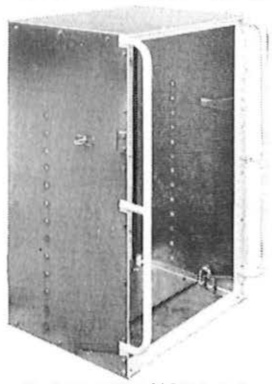

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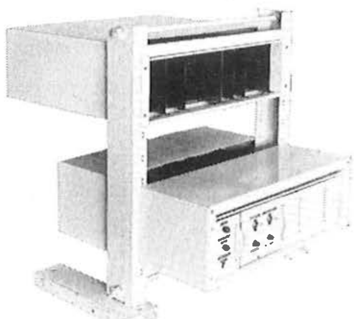

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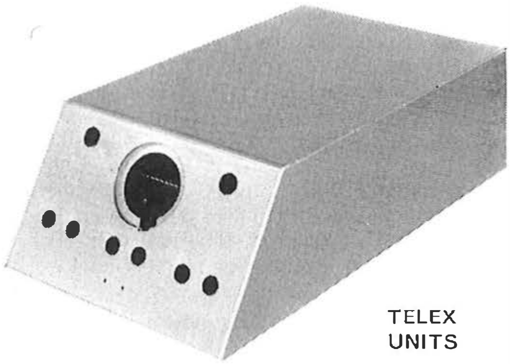

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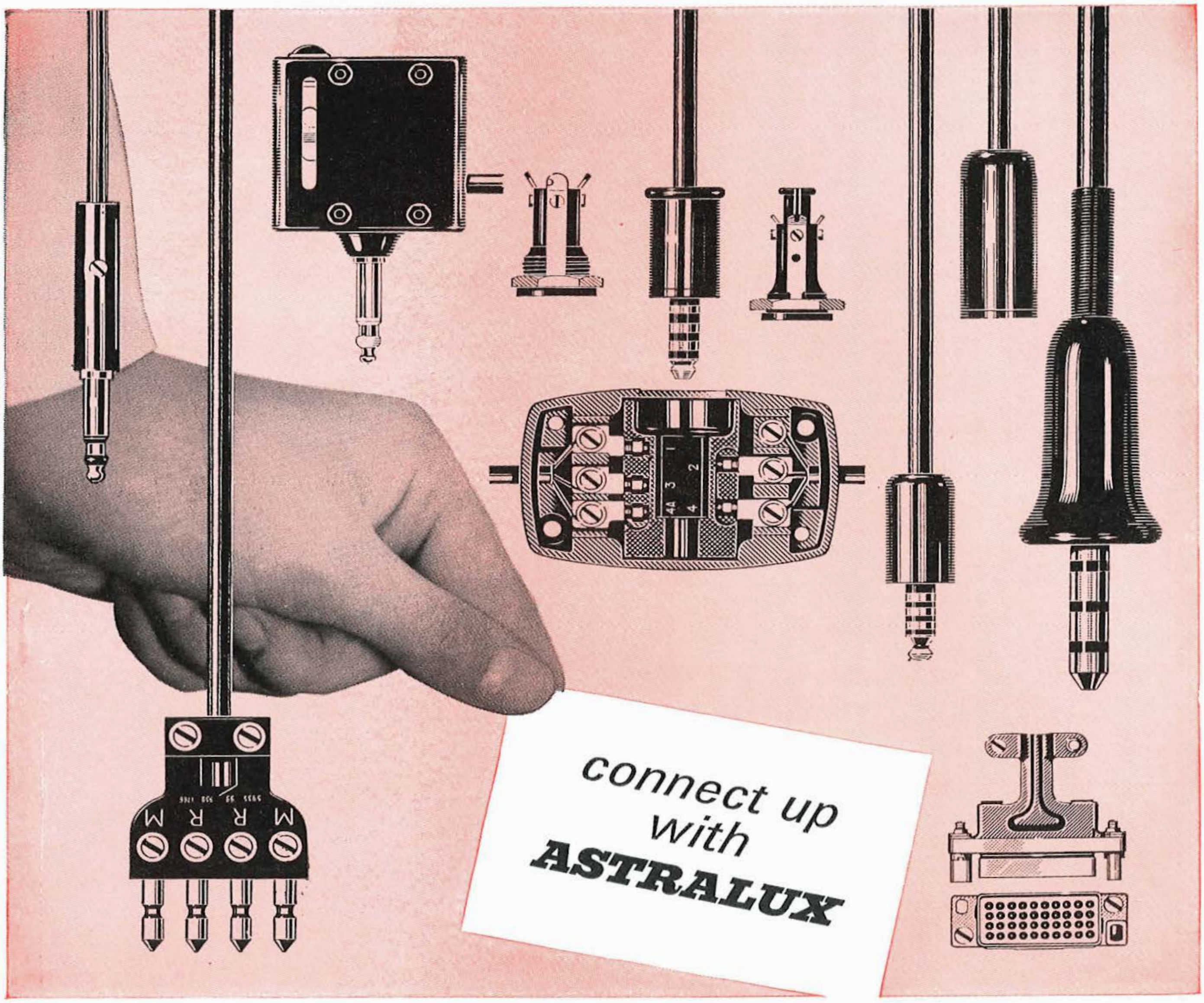

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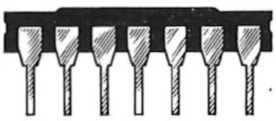

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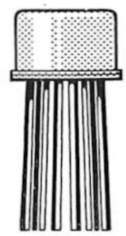

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G.E.C. SHF broadband radio equipments Types SPO 5558 A and B are examples of the range of microwave equipments available. Both equipments are semiconductored, except for a travelling wave amplifier output stage providing a 10 watt output, and operate in the frequency band 5925 — 6425 MHz. The equipments conform to CCIR recommendations. The Type A version of the equipment can provide up to 1800 high quality speech circuits or 405, 525 or 625 — line high definition television in colour with one sound channel, or monochrome with up to four sound channels. The Type B version can provide up to 960 high quality speech circuits or 405, 525 or 625 — line colour or monochrome television with one sound channel. Both equipments are designed specifically for high-capacity, high-density long haul applications. One of the recent examples of the application of G.E.C. 6000 MHz equipment is described overleaf, followed by a specification summary.

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brings latest techniques to 6000 MHz equipment

Specification summary

S.H.F. Semiconductored Broadband
Radio Relay Equipment SPO 5558 A & B

Radio Characteristics

Operating Frequencies:
5925 MHz — 6425 MHz
(C.C.I.R. recommended).
Transmitter Output:
10 watts nominal.
Transmitter Input:
0.3 volt r.m.s. (70 MHz).
Receiver Bandwidth:
± 20 MHz at 3db points.
Receiver Output:
0.5 volt r.m.s. (70 MHz).
I.F. Input and Output Impedances:
75 ohms.

Baseband Characteristics

(i) Telephony

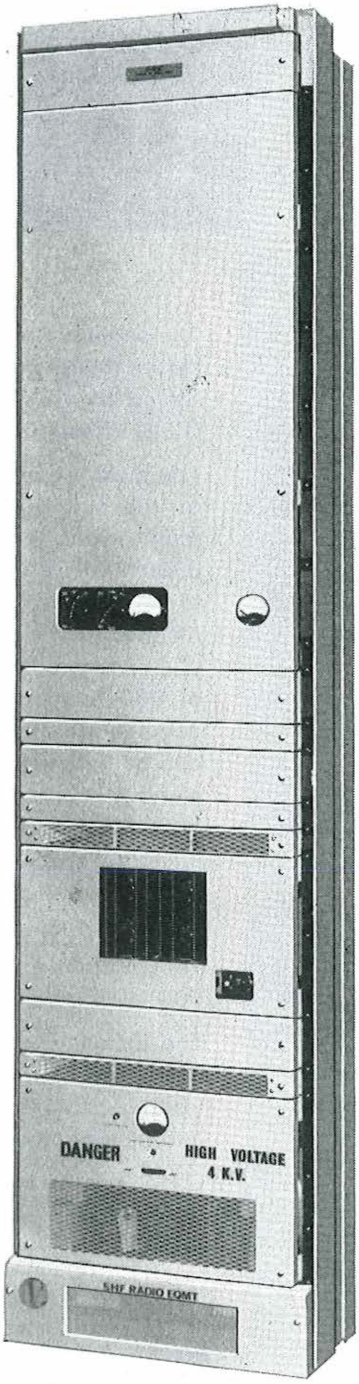
Capacity:
(A) Up to 1800 channels.
(B) Up to 960 channels.
Baseband Frequency:
(A) 300 kHz to 8248 kHz.
(B) 60 kHz to 4028 kHz.
Continuity Pilot:
(A) 9023 kHz (B) 8500 kHz.
Gain Stability:
± 0.2 db over one day.
± 0.5 db over one month.
Pre-emphasis:
To C.C.I.R. Recommendations.
Mean Deviation:
(A) 140 kHz r.m.s. at channel test level.
(B) 200 kHz r.m.s. at channel test level.

(ii) Television

Capacity:
(A) One high definition TV colour + one sound channel or TV monochrome + four sound channels.
(B) One high definition TV colour + one sound channel or TV monochrome + one sound channel.
Video Input and Output Impedances:
75 ohms.
Video Input Level:
Nominal 1 volt peak-to-peak
(Adjustable ± 3 db relative to nominal).
Video Output Level:
Nominal 1 volt peak-to-peak
(Adjustable ± 3 db relative to nominal).
Pre-emphasis:
To C.C.I.R. Recommendations.
Sound Channel
Sub-carrier Frequencies:
(A) 7.00 MHz, 7.36 MHz, 7.74 MHz and 8.14 MHz. (B) 7.5 MHz.

Power Requirements

Supplies:
24 volts d.c. In-built d.c. voltage regulators cater for supply variations of 21.8 volts to 28.15 volts.
Equipment Consumptions:
SHF Radio Rack, comprising SHF transmitter/receiver, meter unit, associated power units and a 24V/AC inverter.
(A) 13 amps (B) 12 amps. Each pair duplicated modulators 2.5 amps.
Each pair duplicated demodulators 1.5 amps.



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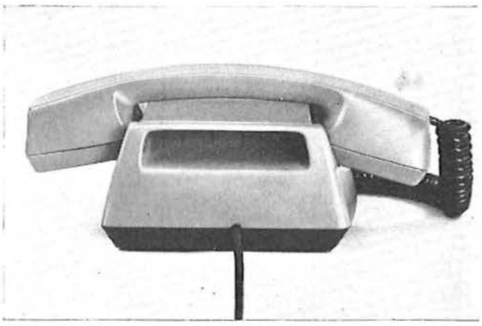

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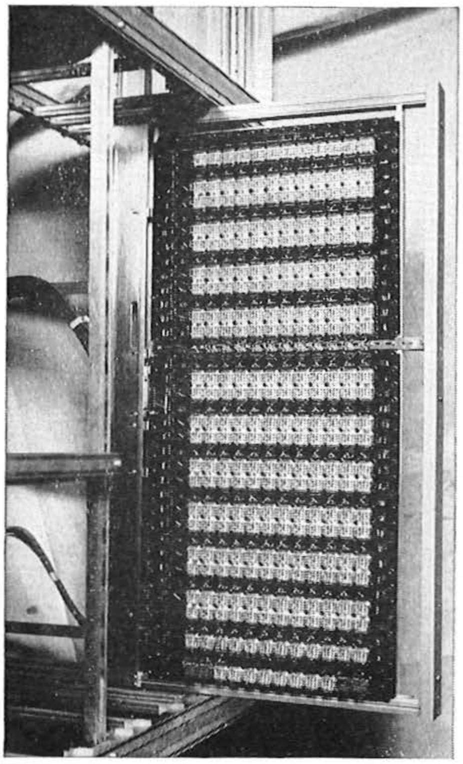

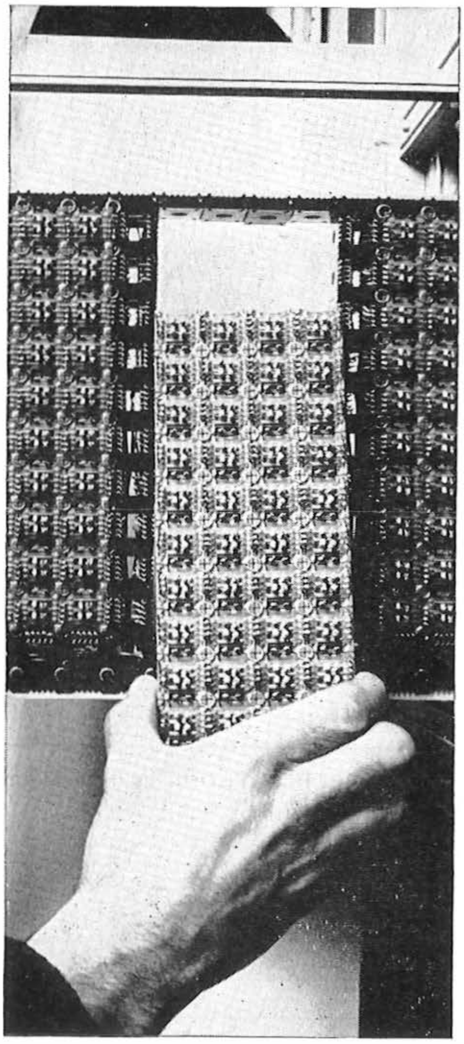

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The REX switching matrix

Switching matrices can be built up in any form simply by clipping reed-relay crosspoints together. Thus unlimited provision for the growth of lines and links is built into the REX system.

The REX switching unit

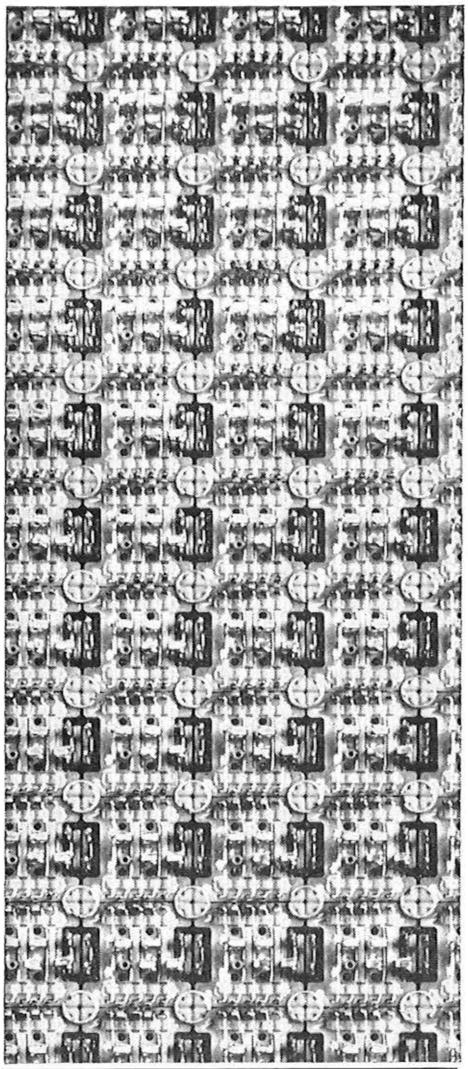
Basic switching arrays are built up out of matrices and are arranged in parallel to form a REX switching unit. Typically, a 1,000-line four-section unit would serve a community with an average calling rate of 150 call seconds per line in the busy hour; other calling rates can be accommodated by varying the number of sections.

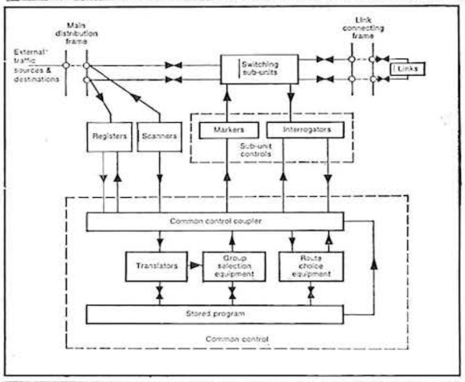
The multi-unit REX exchange

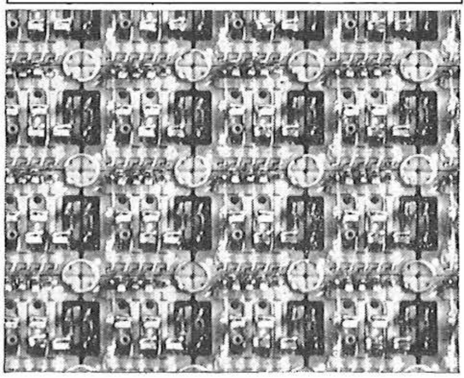
Switching and linking arrangements are provided for all sections of each unit so that complete crosspoint path interconnection is made between all lines of the REX exchange. The special linking pattern adopted can cater for all traffic patterns whilst retaining simplicity of control.

REX electronic control

The REX electronic control has three main areas of activity:
Scanners and Registers: To determine the source and final destination of a call.







Markers and Interrogators: Concerned with interrogating the state of crosspoi paths and marking these paths through the switching sub-units.
Common Control: Processes the neces sary call setting data in accordance wit instruction from the stored programme control so that the calls are routed with maximum utilisation of the switching networks.

Information for administrations

The AEI REX Information Service is one of the most comprehensive programmes ever offered. In addition t brochures and full technical data, AEI will gladly arrange for their lecture tea to visit the engineering staff of intereste administrations to provide an introductory course on basic REX principles. Later, key personnel would receive ful training both at AEI's UK factories and on-site during installation. Training schools staffed and maintained by AEI are also under consideration for territories where reed electronic exchanges are proposed as standard.

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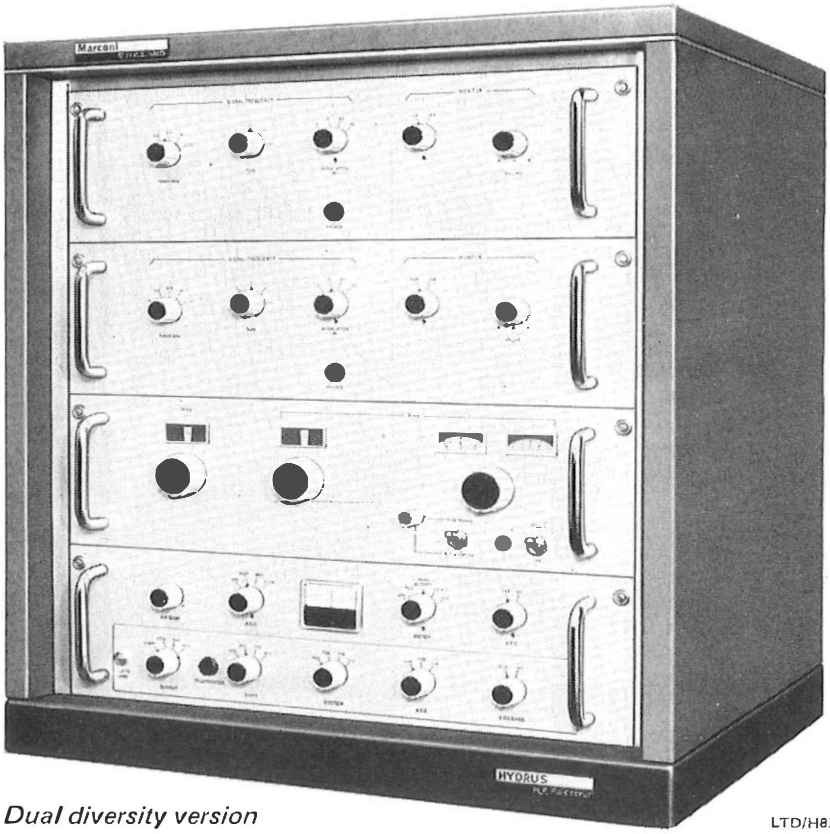

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Plessey ideas in telecommunications

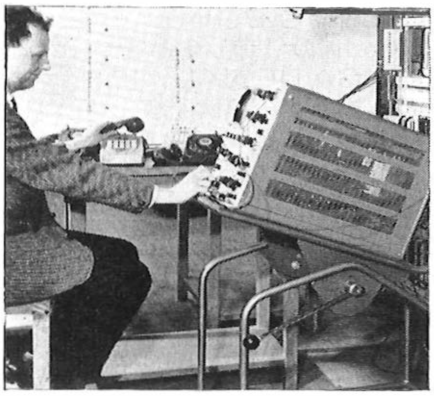
The Plessey Telecommunications Group is the largest organisation in the Commonwealth developing and manufacturing equipment for public and private telephone systems. It is one of the five product groups of The Plessey Company Limited, a major force in the related fields of telecommunications, electronics, radar, radio, automation and avionics.

Ideas in the past
The history of telecommunications is virtually a history of the members of the Plessey Telecommunications Group, from the early days of the magneto telephone to the Strowger automatic exchange system which it helped to develop and on to the very latest electronic switching systems.

Ideas in the present
The Group's switching research and development resources are backed by the Company's basic and applied research activities. Two of the Plessey research centres are continuously engaged on telecommunications projects—the Allen Clark Research Centre at Caswell and British Telecommunications Research Limited at Taplow.

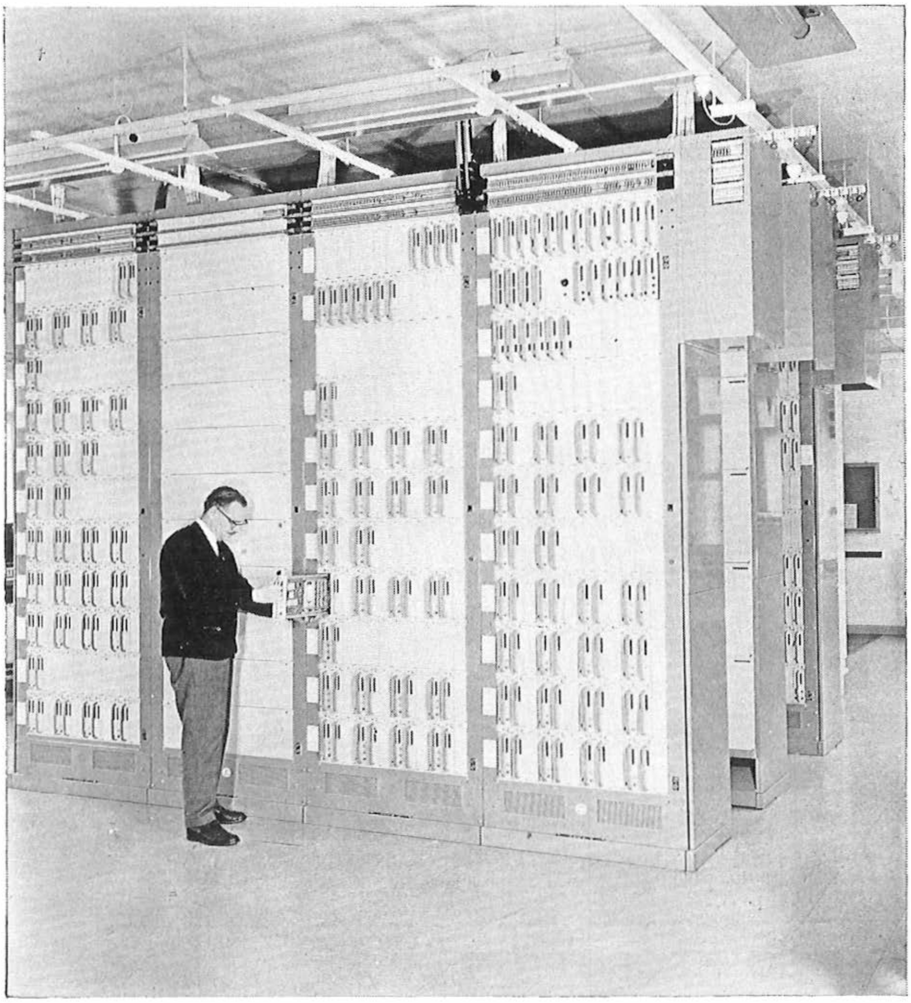
'5005' Crossbar
Plessey has invested many millions of pounds from its own resources in '5005' Crossbar—and is the only British company to have developed a commercial crossbar system. Originally designed for overseas use '5005' Crossbar is now being supplied to the British Post Office for large non-director exchanges, group switching centres and the international 'Gateway' telephone centre in London.
At a time when telephone-operating authorities throughout the world are faced with rapid expansion of facilities '5005' Crossbar meets the need because of its speed of operation, flexibility, versatility and built-in features which will provide STD and other facilities when required.

Pentex
Designated Type TXE2 by the British Post Office and adopted by them in 1966 as standard for exchanges up to 2000 lines, this reed crosspoint system—Europe's first production electronic exchange—is manufactured by the Plessey Telecommunications



1 *Testing prototype model of PEX (private electronic exchange) for 240 lines*

2 *A section of the Ambergate TXE2 (PENTEX) exchange installed by Plessey, and cutover in December 1966*



2

Group and is marketed overseas under the name 'Pentex'.
The cut-over of the first installation was in December 1966 at Ambergate in Derbyshire. It caters for 700 lines, with ultimate expansion to 2000.
Pentex was developed by Plessey in co-operation with the British Post Office under the auspices of the Joint Electronic Research Committee.
Manufacture is proceeding apace to meet orders from the British Post Office for 30 exchanges in 1967 and a further 30 in 1968, together with overseas orders.
Pentex exchanges take up less space, need less maintenance and offer higher switching speeds than conventional electro-mechanical equipment. Microphonic noise is virtually eliminated.

Reed Selector
Plessey in conjunction with the British Post Office has developed the intermediate switching stage of the Reed Selector System. This system, designated TXE6 by the British Post Office, is to be used for extending and replacing Strowger exchanges.
The Telecommunications Group carried out a field trial at the Belgravia exchange in London where intermediate switching equipment was trunked to replace 91 Strowger selectors. This trial proved that Plessey's design fulfilled all the requirements.

Pex
The private automatic exchange (PAX) goes electronic and becomes PEX. Adapting the principles of the Pentex System, Plessey Telecommunications Group are completing the development of this private exchange. It will accommodate both dial and press-button telephones.
The prototype is a 240-line system, which can be progressively enlarged to 480 lines. The design principle can also be used to build exchanges up to about 2000 lines. Modifications are also possible to enable PEX to be adapted for private electronic branch exchanges (PEBX) connected to the public telephone network.

Ideas in the future
Stored Program Control
Designers at Plessey are currently working on the application of stored program control, whereby the switching paths in a telephone exchange can be directed and supervised by computer-like devices. The ideas behind this study are—greater standardisation of equipment, easier extension of exchange at any time, flexibility for subsequent introduction of new subscriber facilities, ability to use new components and devices as they become available.

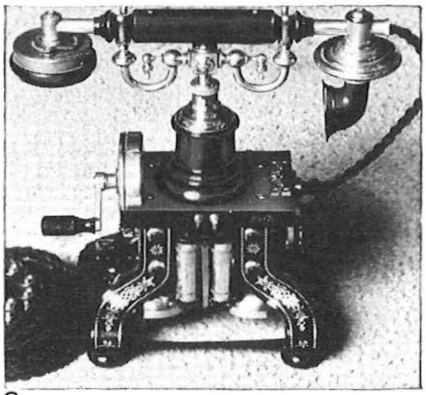
Integrated Switching and Transmission
There is a growing recognition that the traditional interface between transmission and switching equipment must progressively disappear in the face of new techniques.
Plessey is engaged in studying the integration of the switching and transmission of speech and associated signals in pulse code modulated form. The problems are being considered on a national and international network basis with the aims of cost reduction and greater efficiency.

3 *One of the first telephone instruments manufactured by Plessey*

4 *The press-button telephone—the latest developments from Plessey can suit D.C. or V.F. signalling systems*

5 *The Plessey Reed Selector—part of the British Post Office electronic Reed Selector System (TXE6)—for the extension of Strowger exchanges*

6 *'5005' Crossbar equipment at the Hong Kong 'Gateway' exchange*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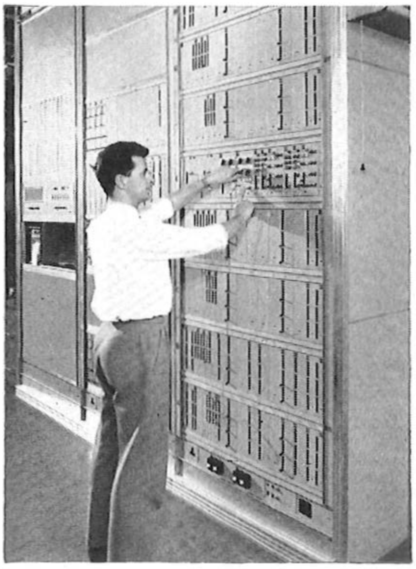
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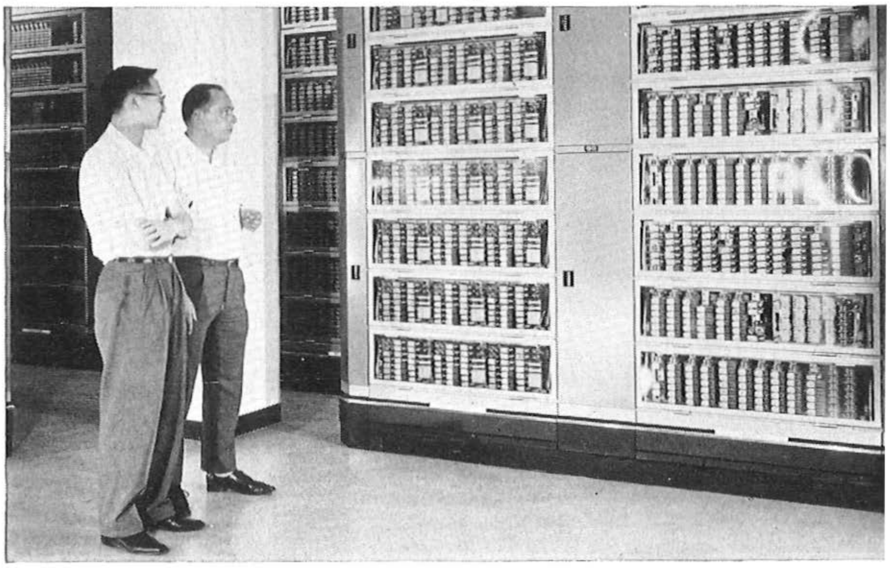
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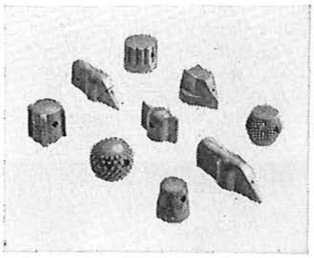

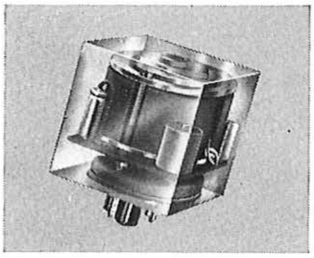

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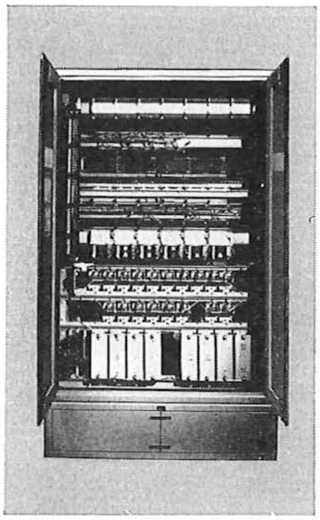

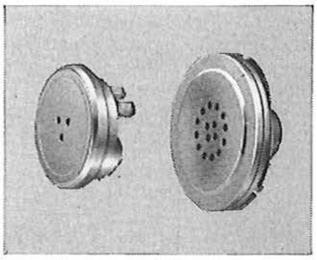

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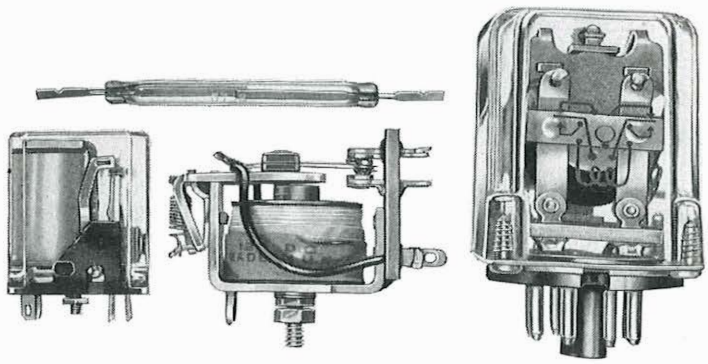

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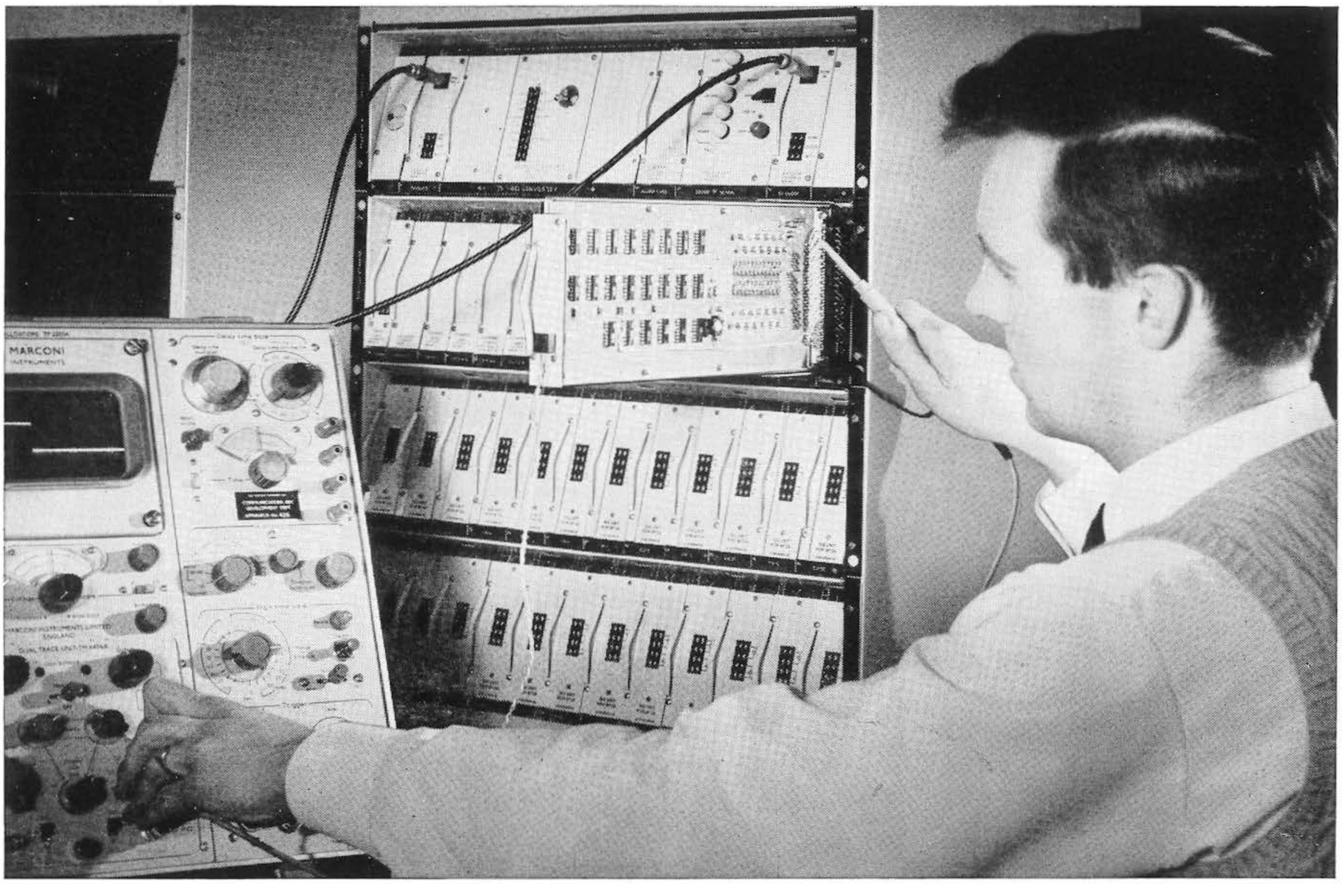

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