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Burnham Radio Station

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U.D.C. 621.396.7

To meet modern traffic demands, the P.O. Radio Station at Burnham, Somerset, has been enlarged and re-equipped, and the new equipment was put into service in November, 1948. This article gives a brief history of the station, an outline of the traffic circulation system and a description of the apparatus now in use.

Introduction.

A LONG-DISTANCE low-frequency commercial radio telegraph service between ships at sea and this country was inaugurated in 1920 at the Post Office radio station at Devizes. By 1925 the requirement for simultaneous communication on more than one channel necessitated the provision of separate receiving and sending stations, so new stations were built at Burnham-on-Sea for receiving, and at Portishead, 19 miles away, for sending, the senders being keyed by the operators at Burnham over land-lines connecting the two stations. From that date, and especially after the later introduction of services on high frequencies (which gave world-wide coverage), the traffic grew steadily until in 1938 it reached an annual total of three million words. The station equipment and organisation at Burnham were then scarcely adequate to meet the traffic demands at peak periods. During the war, several radio stations were established overseas by other administrations to collaborate with Burnham in a unified organisation. After the cessation of hostilities, it was decided to retain these stations for post-war commercial purposes and to organise traffic to and from ships of the British Commonwealth on a new system. This system, described in the following section, and the expected increase in traffic necessitated the provision of more facilities, and a somewhat different organisation from that which the then existing equipment and accommodation at Burnham could provide, so it was decided to enlarge and completely re-equip the station.

System of Working and Facilities

Before the war there were twenty-five operating positions at Burnham for dealing with ships' radio traffic. Of these, twenty-four worked the long-distance services on low and high frequencies and the remaining one, separately accommodated, provided the usual short-range coast station services on medium frequencies, viz. telegraph and telephone communication on frequencies of 500 kc/s and 1·5 - 3Mc/s to ships within a nominal 300-mile radius. The long-distance both-way service is usually worked on six high-frequency bands, near 4, 6, 8, 13, 17 and 22 Mc/s, and the area between the inner range of satisfactory high-frequency reception (the skip distance) and the coast stations' service range is covered by the low-frequency service on 110-160 kc/s. Outgoing traffic is, however, also regularly transmitted via the high-power, very-low-frequency (16 kc/s) sender at Criggion or Rugby.

Until the latter part of the pre-war period, all operators listened for incoming calls and traffic with ships was dealt with as the ships were contacted. With the high-frequency services this method of working resulted in excessive calling and much waste of time and effort, so the "search-point" or "group working" system was inaugurated. In this system, which has proved very successful, operators work in groups, one or more groups being allocated to each frequency band, and the functions of finding ships and taking their traffic are separated. One operator in each group searches continuously for calling ships and the others deal with the traffic after the searching operator has contacted the ships. Variability of the number of traffic operators allocated to any group also contributes considerably to the success of the system. In the old building, however, group working was necessarily restricted to small teams of operators within convenient oral call of each other, so the full advantage of the system could not be obtained. Outgoing traffic for ships in all parts of the world was dealt with by direct contact and also to a limited extent by broadcasts from Rugby at fixed periods of the day, ships later acknowledging receipt of broadcast messages.

In the new system of working, the world is divided into a number of areas, each area being served by its own Area Station (Fig. 1). Each of these stations is provided with multiple sending and receiving facilities, and the overseas area stations are linked to London by high-speed, point-to-point circuits. Burnham, the area station for Area 1 (which is subdivided into Areas 1A, 1B and 1C), is linked to London by direct land-lines. All ships operating under the new system notify their movements to the appropriate area stations, and this information from all stations is recorded at Burnham in the "Ships' Bureau" where a record of each ship's position, destination, expected time of crossing into a new area or of reaching port, and similar information is kept. The outgoing traffic for ships is routed according to instructions given at the Bureau ; traffic for Area 1 is

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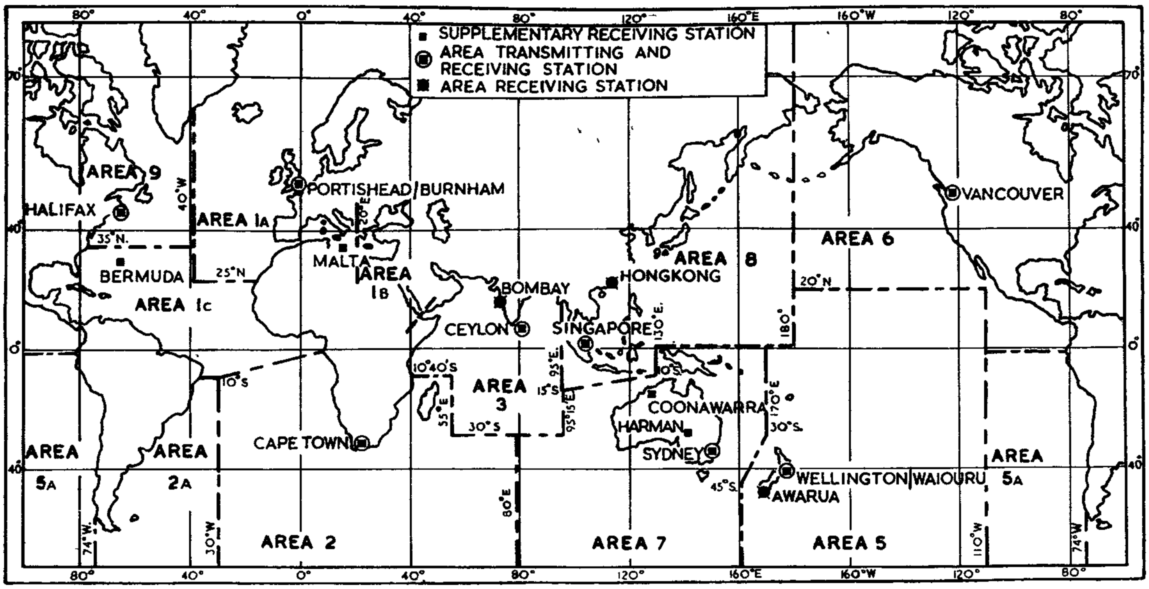

Fig. 1.—Areas, Area Stations and Supplementary Receiving Stations for Long-Distance Ship-Shore Radiocommunications.

broadcast at four-hourly intervals from the Portishead and Criggion (or Rugby) radio stations under control from Burnham, and that for other areas is forwarded to the appropriate area stations for inclusion in their broadcasts. Traffic from British Commonwealth ships within Area 1, and also world-wide traffic to and from ships which do not work within this system, e.g. foreign ships, is dealt with in the original way, that is each ship calls or is called and after two-way communication is established, the messages are passed.

With the resumption of radiotelegraph service to and from ships at sea, the traffic rose rapidly above pre-war level, and better facilities were required for traffic control and for the development of the group working technique. It was to meet these requirements and to improve the general receiving facilities that the station was re-equipped.

Working Facilities.

For group working in the high-frequency bands, the search-point operators require continuous omnidirectional reception, and each traffic operator also needs the best practicable reception from any direction he may select at any moment. Omnidirectional aerials and a fan of relatively high-gain aerials with a special aerial distribution and selection system were provided to enable each operator to select the appropriate aerial for reception of the traffic with which he is concerned at the moment. Aerials can be used simultaneously by any number of operators without interaction.

For answering ships and sending traffic, all operators require quick and easy sender control and keying facilities. Access to and keying of senders can be effected by the operation of lever-type and morse keys provided at each operator's position, and since the operators in one group generally share the use of a sender, a system for giving engaged signals is also provided. Team working in a group necessitates immediate communication between the members who may not always be within convenient oral call of each other, and also necessitates means of advice to the search-point operator when members of his group are free to take traffic. To meet this and all the other intercommunication requirements of the station, a special system giving very comprehensive facilities was provided, which, in addition to the facilities mentioned above, gives flexibility in the number of traffic operators allocated to any searching operator and direct communication between all operators and the circulation control position.

For low-frequency working, high-gain receiving aerials are unwarranted, and the best reception is frequently obtained by directional discrimination against unwanted signals. Crossed-loop aerials, which may be used omnidirectionally or directionally, and a distribution system enabling all four L.F. operators to use the aerials simultaneously and independently were, therefore, provided. Sender control and intercommunication facilities similar to those for the H.F. operators were also provided although group working is not at present used. All operators are provided with modern high-grade communications-type receivers.

The outgoing traffic for Area 1 has to be broadcast at fixed times of day, and accordingly it is necessary that the operators at the broadcast positions have overriding control of the senders. The sender control circuits throughout the station are, therefore, so arranged that exclusive control by the broadcast operators can be effected.

For general traffic circulation and control, facilities are required for the rapid reception or despatch of traffic over the inland network ; quick circulation of message forms within the station via the circulation control point and Ships' Bureau (where distribution, checking and overall control are effected, and routing instructions given) ; rapid intercommunication between all staffed points and ready availability of shipping information at the Bureau. To meet the traffic circulation requirements, traffic over the inland network is received and despatched by twelve teleprinters, and for internal traffic circulation conveyors link the circulation control tables with the operators' positions in each wing of the building. Shipping information is available in a visible index record at the Ships' Bureau and a pictorial presentation of the locations and courses of ships at sea is provided by movable arrows on three large wall charts.

The layout of the station and a more detailed description of certain of the above-mentioned provisions are given in the following sections.

receiving positions for long-distance ship-to-shore traffic. The far end of Wing B accommodates six receiving positions equipped for medium-frequency Coast Station services, and the remainder of Wing B is occupied by teleprinter and broadcast positions. The central control room contains the traffic circulation control positions, the Ship's Bureau and the P.B.X. The building is well lit, both naturally and artificially, and the room noise caused by the operation of typewriters and teleprinters is materially reduced by acousti-cellotex tiles lining the ceiling, and insulation boarding lining the walls of all three wings. There is a V-belt conveyor running centrally through

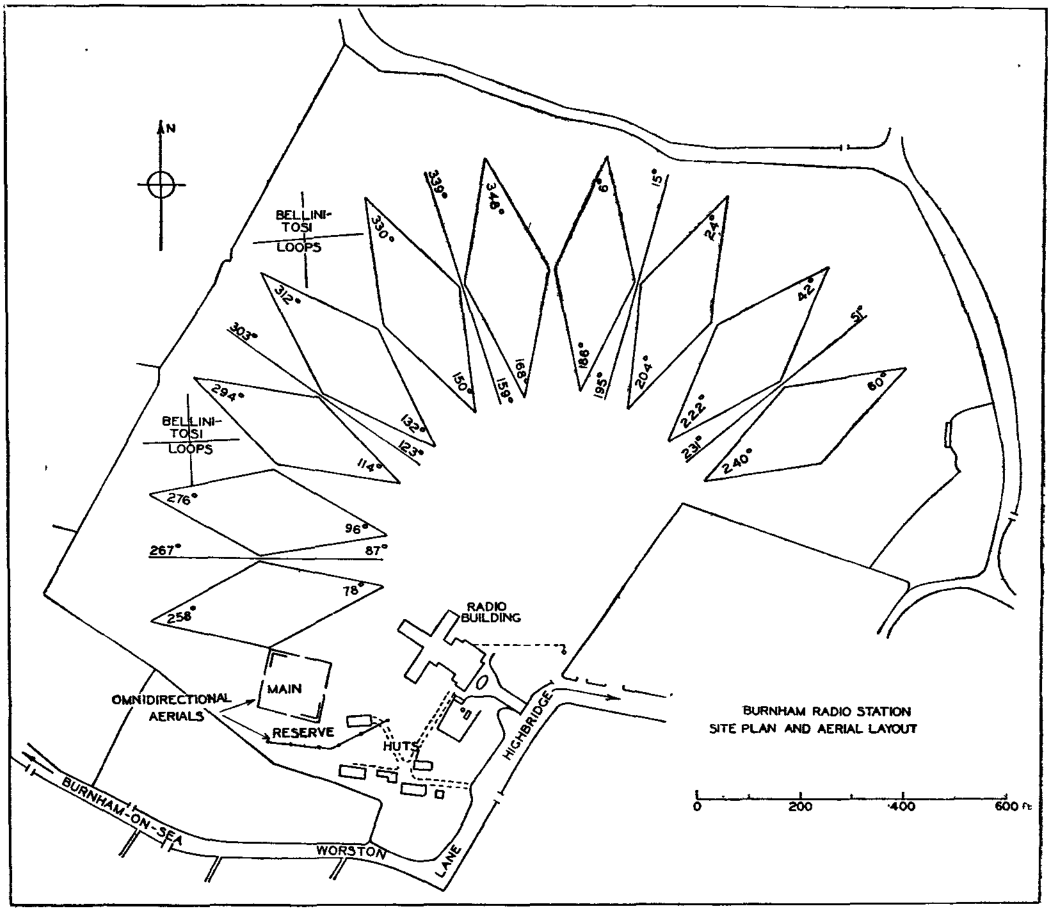

Fig. 2.—Burnham Radio Station Site Plan and Aerial Layout. (M.F. and Miscellaneous Aerials Omitted).

Station Layout

The re-equipping of the station entailed constructing a new building, installing modern equipment, augmenting the power supplies, extending the site, constructing a new aerial system, and scrapping the heterogeneous collection of old internal and external plant. To accommodate the aerial system, which is illustrated in Fig. 2, the site area had to be approximately quadrupled. The new building, illustrated in Fig. 3, consists of three wings, each 60 ft. × 24 ft., constructed in standard prefabricated hutting and radiating at right-angles from a 35 ft. square central control room. Wings A and C accommodate the 32

each wing and a flat-band conveyor mounted above the V-belt conveyor in Wing B to facilitate the distribution of messages.

The Wall Charts.

The wall charts are illustrated in Fig. 4. The largest is 14 ft. × 31 ft. 6 in. and shows the world in Mercator's projection between latitudes 65° North and South. Two smaller charts, 14 ft. × 12 ft., show, to a larger scale, the more congested areas of the North Atlantic and of the coastal waters round the British Isles. They are painted on steel plates, and magnetic arrows carrying the ship's call sign are used to indicate

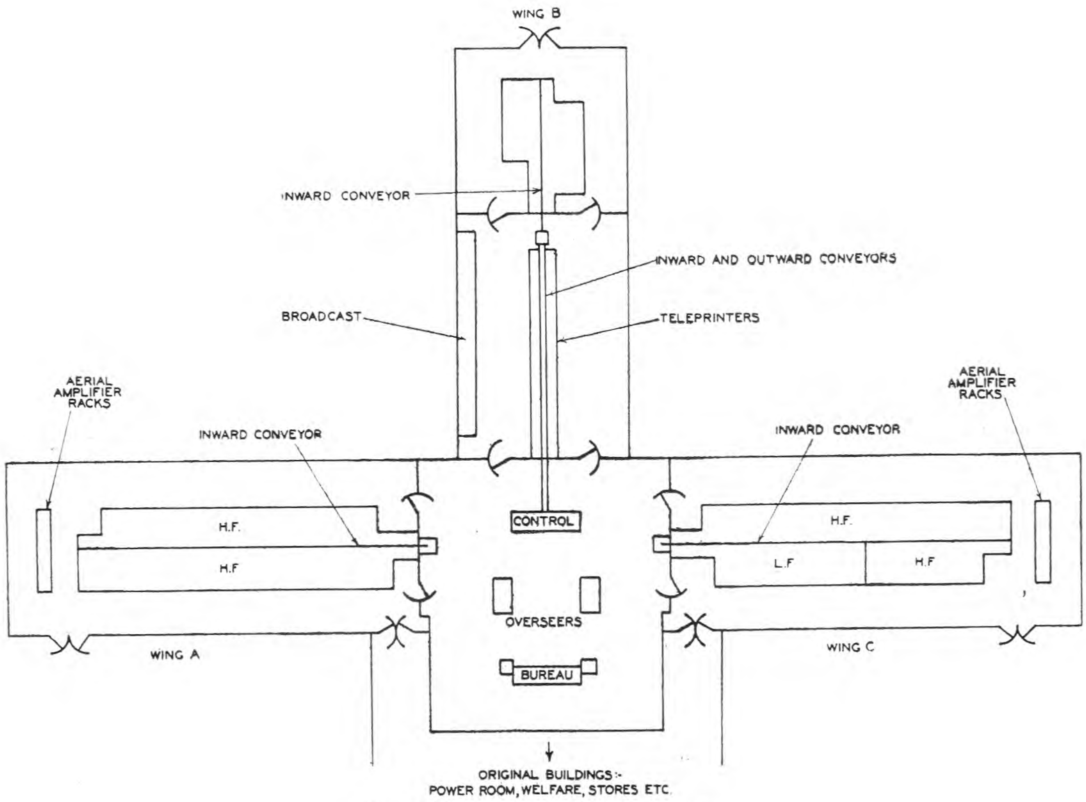

FIG. 3.—PLAN OF NEW BUILDING.

on the charts the position and course of ships. Under exceptional conditions, e.g. accident at sea, these charts may be a vital necessity as they enable the ships' movements to be better visualised and therefore better controlled.

HIGH-FREQUENCY RECEIVING EQUIPMENT

Aerial System.

The H.F. aerial system is arranged to receive signals in the frequency range 4 to 22 Mc/s from all parts of the world. All-round coverage combined with the highest practicable directivity gain is achieved mainly by the use of a number of horizontal rhombic aerials. This type of aerial can be designed to have a suitable directional response throughout most of the required frequency range and, because of its relatively uniform impedance-frequency characteristic, it is well suited to operate in conjunction with the

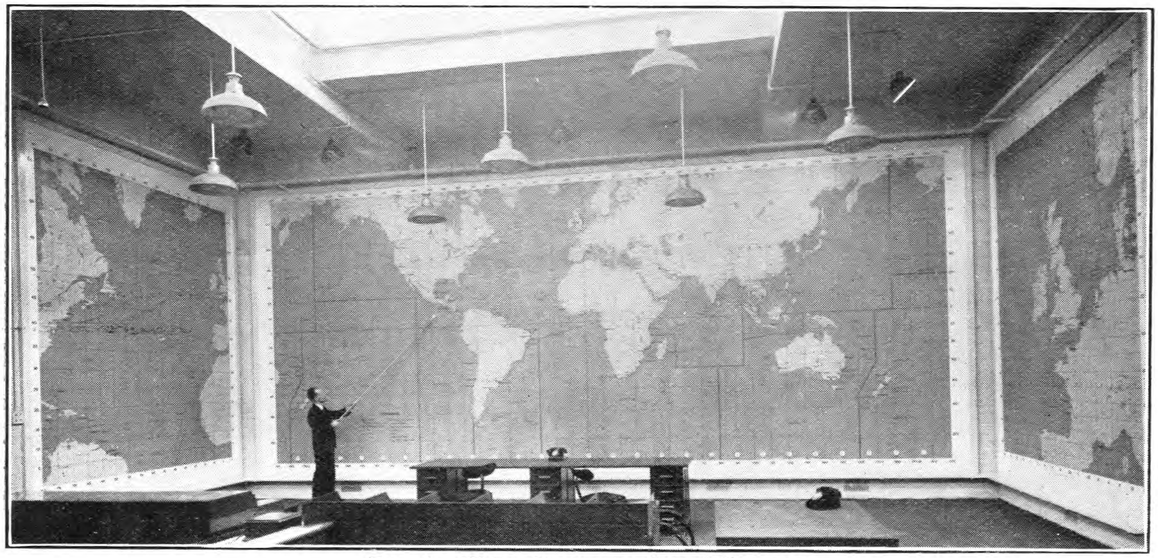

FIG. 4.—WALL CHARTS IN SHIPS' BUREAU.

distribution system described later. For a rhombic aerial to operate efficiently, it must be terminated resistively in its characteristic impedance at the end remote from the receiver. If this termination, which for unidirectional working takes the form of an absorbing resistor, is replaced by a second receiver correctly matched to the aerial at all frequencies, the wanted input signal to the first receiver is unaffected, and since the arrangement is symmetrical it will be seen that by connecting both ends of each aerial to the receivers via the distributing system (which is designed to effect the necessary matching) it is possible to obtain simultaneous bi-directional reception on each aerial, resulting in a 50 per cent. saving in the number of aerials required. Ten such aerials, each of side-length 246 ft. and side-angle 140°, have been erected at a height of 102 ft. above ground, each aerial serving two diametrically opposed zones 18° wide. It will be seen from Fig. **2** that the rhombic aerials are arranged fanwise in a semi-circular arc round the station, this arrangement effecting maximum economy in site area and supporting structures, as well as ensuring a reasonable degree of freedom from mutual interference between aerials. Interspersed with the horizontal rhombic aerials, there are five vertical bi-directional half-rhombic aerials, of the same side-length and side-angle, which supplement the performance of the former, particularly at the lower frequencies where the response of the horizontal aerials to signals arriving at very low angles is poor. Since the horizontal and vertical aerials respond predominently to waves polarised in their own plane, and in practice an electromagnetic wave tends to become randomly polarised after ionospheric reflection, the two aerial systems are complementary.

In addition to the directional aerial system, a number of omnidirectional aerials are provided, primarily for use at the search-point receiving positions. The omnidirectional aerials consist of six horizontal V-dipoles, and as a reserve in the event of storm damage there are six separately supported vertical dipoles. The aerials are all of the multi-wire cylindrical cage construction and sufficiently aperiodic to enable one aerial of each type to cover one frequency band.

Distribution System.

The signals received from ships lie in six discrete frequency bands and the aerial-to-receiver distribution system, which is shown in Fig. **5**, is designed to distribute the signals from any of the aerials to any combination of the thirty-two receivers This is done in the case of each rhombic aerial by amplifying the signals in a multi-band amplifier, then distributing them at equal level to all receiving positions by means of transformers and resistance networks, and finally connecting each receiver to an appropriate aerial by selective switching. In this installation it is the amplifiers which serve as terminating impedances for the double-ended rhombic aerials, and to ensure a good front-to-back aerial response ratio the amplifiers must each have a substantially constant resistive input impedance. They must also effect a good compromise between contribution of noise, distortion due to overload, and gain to offset the loss of the distribution network. The design adopted has six narrow pass-bands corresponding to the ships' bands, each band being separately amplified. This allows a low-noise valve to be used without danger of overloading it by unwanted signals, and still permits the input coupling arrangements to give a satisfactory impedance characteristic. The noise figure achieved is approximately nine times, and the gain of the amplifier is approximately 25 db.

The distribution system is divided into two for economy and convenience in cabling Wings A and C of the building. This division is effected by a resistive network, and then the output to each half is transformed from 75-ohm to 10-ohm impedance to which twenty outlets to receiving positions are connected. Series and shunt 150-ohm resistors in each outlet provide adequate buffering against the impedance variations at the receiving positions (where variations from practically short-circuit to open-circuit occur) and against possible whistles due to the coupling of the receiver inputs. The distribution of signals from the omnidirectional aerials differs from that for the rhombic aerials, only in that prior to amplification the signals from all of the six aerials are passed through a combining unit which prevents interaction between the aerials and provides a suitable input for the standard amplifier which follows it. Receivers are connected to the appropriate aerials by selective switching, the first switch permitting the selection of directional aerials or omnidirectional aerials; if directional reception has been selected, then by a second switch horizontal or vertical aerials may be selected; a third switch, which is continuously rotatable and marked with the cardinal points of the compass, is used to select any particular direction. The system is working very satisfactorily, cross-modulation and blocking due to unwanted signals is

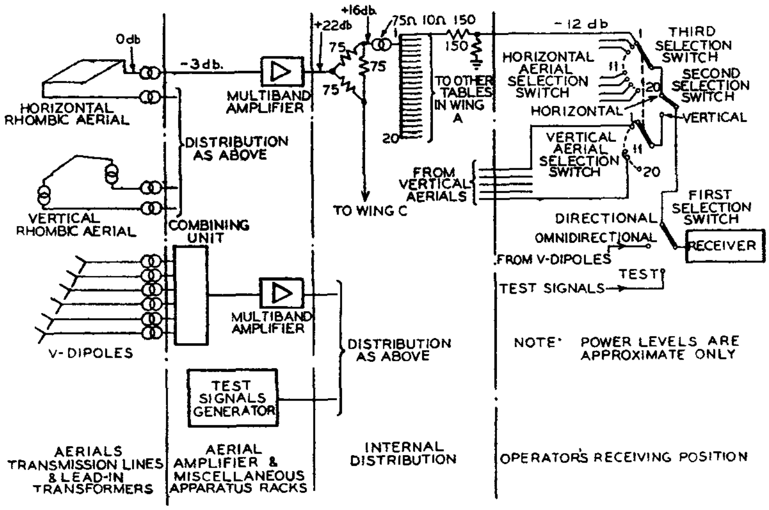

FIG. 5.—H.F. AERIAL DISTRIBUTION SYSTEM.

no worse than in direct reception, and the cross-talk ratio for signals on the same frequency, but from different aerials, is at least 20 db.

To give an indication to the operators of the sensitivity of their receivers, and to serve as a frequency calibration, low-level test signals from crystal oscillators are available at each position. There is one such test signal lying near the middle of each frequency band and it is keyed with continuous dots to differentiate it from any other signals. The level of these test signals at the receiver input is 1 μV and when the 5 kc/s intermediate frequency bandwidth is used, this gives approximately 20 db. signal-to-noise ratio in the receiver output. Higher level test signals are available to engineering staff for checking automatic gain control and limiting action.

Receiving Positions.

The layout of a traffic operator's H.F. receiving position, of which there are twenty-eight, can be seen from Fig. **6**. The receiver is the Marconi Type CR 150 communications receiver, and immediately on its right is the switch panel for aerial and test signal selection. On the right of the operator's chair is the sending key with its associated send-receive switch, the microphone for inter-communication purposes, and the sender control box with two additional keys at the bottom for intercommunication. Search points are equipped with a switchboard similar to the sender control box, for intercommunication. The conveyor for transporting incoming radiograms to the central control room can be seen dividing the two lines of tables.

Fig. **6**.—Receiving Positions in Wing C.

Four positions are equipped for high-speed morse reception from such ships as the R.M.S. *Queen Mary* or *Queen Elizabeth.* For this service, which works at about 100 bauds, the single-tone output signals from the receiver are fed into a thermionic relay which has facilities for re-shaping signals by curbing or limiting, and correction of signal bias; the double-current output from this relay is then used to operate an undulator.

Low-Frequency Receiving Equipment

Aerial System.

The L.F. aerials are a non-resonant T-aerial provided for reserve purposes, but used when noise and interference are low, and two sets of Bellini-Tosi crossed-loop directional aerials for use when interference or noise is troublesome (one set being a reserve in case of damage to the other). The loops are triangular, the base being 204 ft. and the height 84 ft. Each pair is supported at the centre by a 105-ft. tubular steel mast and at the sides by 16-ft. poles, and is connected to two 600-ohm balanced transmission lines by transformers housed in a weatherproof metal box at the base mounted near the mast at a height of 10 ft. The transmission lines, which extend for approximately 900 ft. to the building, are run on the diagonals of a square to reduce interaction to a minimum. A separate sense aerial is not provided, the signals for sense purposes being derived from the combined pair of loops through a third transformer and transmission line, the latter being run above and well separated from the other two lines.

The medium-frequency coast station requirements are met by the provision of two quarter-wave vertical aerials resonant at 1,300 kc/s and 3,000 kc/s, and one non-resonant inverted-L aerial for the 500 kc/s frequency band.

Aerial Distribution.

The L.F. aerial and distribution system provides for directional aerial reception at each of four operators' positions. The polar diagram of the directional aerials is a cardioid, and each operator can adjust his null direction without affecting the others. Individual control of the amplitude and phase angle of the sense signal, which is necessary for the attainment of a good null, is provided in a local amplifier, which also produces the 90° phase shift needed to produce a cardioid polar diagram. The arrangement is shown in Fig. **7**, from which (for simplification) the switching for producing omnidirectional and figure-of-eight characteristics has been omitted. These characteristics are produced by normal direction-finding technique.

The gain of the loop amplifiers is approximately 25 db. and the gain of the sense and the operators' amplifiers in tandem is variable between 12 and 25 db. The phase-shift control enables a change to be made of approximately plus or minus 33° throughout the frequency band, this wide control of phase angle being necessary due to departure from plane vertical polarisation of the received waves. As the losses in the aerial, the transmission lines and transformers are small, and the gains of the amplifiers exceed the subsequent losses in the distribution system, any

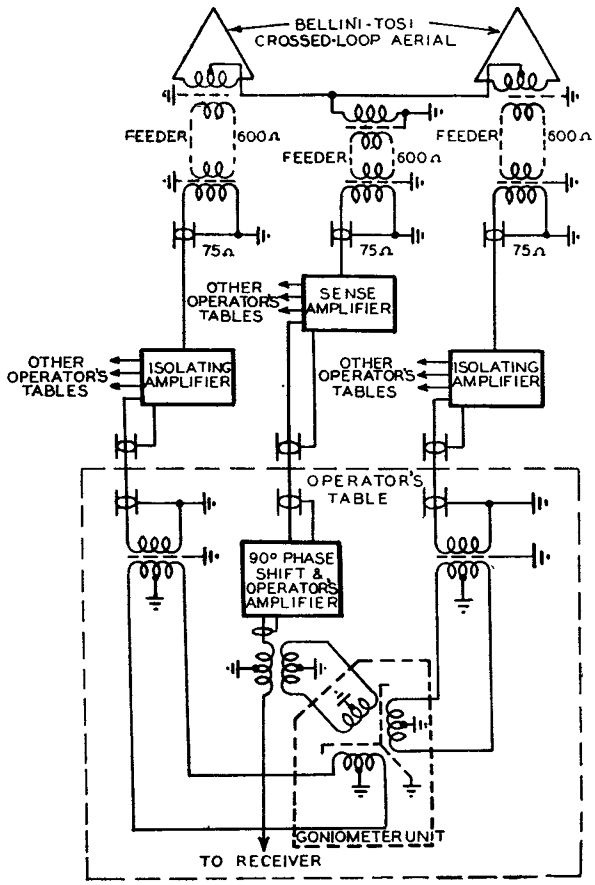

FIG. 7.—L.F. AERIALS AND DISTRIBUTION SYSTEM.

degradation of signal-to-noise ratio will be dominantly due to the amplifiers. The result achieved is that signals received in the presence of the minimum radio noise will be degraded by not more than about 1 db. when using the receiver bandwidth of 300 c/s. For most of the time the radio noise field will be higher and the degradation correspondingly less. The maximum to minimum ratio obtained by the goniometer depends on the diiection of the signal but is at least 30 db.

Receiving Positions.

The four L.F. receiving positions differ little from the H.F. positions. A Marconi CR 100 receiver is used instead of a CR 150, and a goniometer with polar-diagram selection keys and a sense amplifier replace the aerial selection switches. Two positions are equipped for high-speed reception.

SENDER CONTROL

The remote control from Burnham of the senders is normally restricted to keying only, but some senders can also be switched on and off and their frequencies changed by remote control. The main group of senders is located at Portishead, and the control of these is effected over two 12-channel V.F. systems supplemented by a telephone order wire. Control of the V.L.F. sender at Criggion or Rugby is effected over V.F. channels via the Central Radio Office in London.

Since most of the outgoing traffic is broadcast, and is therefore controlled from the broadcast positions in Wing B, incoming traffic will normally preponderate at the positions in Wings A and C where a number of operators may, therefore, share the use of a sender for answering ships and for other purposes. Usually one group, headed by its search-point operator, operates on one marine frequency band, and one sender is allocated to that group. Any operator in a group can throw his sender key which links him to the sender allocated to his group, and when he wishes to transmit, his send-receive switch is thrown to "Send," which connects his Morse key to the keying circuit and also gives an engaged signal at all other operators' positions sharing the use of the sender. If the sender is already being keyed, the throwing of his send-receive key to "Send" causes his engaged-signal lamp to follow the signals being sent, thus enabling him to gauge when the sender will be free again. For this system of paralleled keys, single-current transmission is used in the local circuits, the conversion to double-current working for operation of the V.F. equipment being effected in bridge networks which also provide the monitoring signals for the warning lamps.

The control of all senders is generally available at all positions, but the circuits are arranged to permit the uninterrupted use of certain senders for broadcast transmission at specified periods of the day. Warning is given by a flashing signal on the control box at each receiving position when broadcasting is about to start, and this signal becomes a permanent glow when the circuit is finally taken by the broadcasting operators.

INTERCOMMUNICATION SYSTEM

The success of the group system of operating depends largely on easy and rapid communication both between search-point operators and their working operators, and between the central control position and all operating and information points. This is provided by the telephone network indicated in Fig. **8**. Where headphones are normally worn, i.e. at the traffic and search points, one of the earpieces can be switched into the intercommunication network, thus never isolating the operator from his receiver. At the broadcast and central control positions a loudspeaker is used. The search-point operator can switch-in to a receiving point and speak without delay, as in order-wire working, and to ensure immediate attention a visual signal is given at the receiving point. At the central control position (the traffic circulating centre, normally manned by two controlling officers) twin 40-key switchboards are fitted, giving direct access to all operating and information points. At operating points the intercommunication equipment is incorporated in the sender control unit, and at search-points a small 20-key switchboard is fitted. The system is flexible, for search-points can switch out their auxiliary equipment and operate as traffic points, and each search-point can include any traffic operating point in his group, provided only that it is in the same wing of the building. Moreover, a group of traffic working points can be shared between search-points, i.e. a pool of relief traffic operators can be

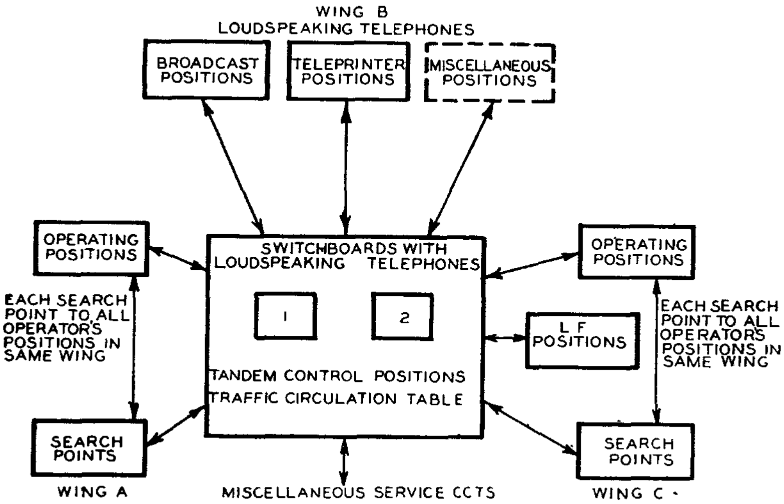

FIG. 8.—THE INTERCOMMUNICATION SYSTEM.

formed when traffic is fluctuating. Experience of working the station has shown that the facilities have effected a great improvement in the station operating technique.

Conclusion.

The annual traffic handled at Burnham rose from less than a million words in 1926 to three million words in 1938, and to seven and a half million in 1949. The increase in traffic handled is an achievement which reflects considerable credit both on the administration and the operating staff, for the latter have often had to work under difficult and trying conditions, especially at Christmas time when traffic rises to several times the normal. The re-equipping of the station has considerably eased the work of the staff and has provided appreciable margin to meet further increases in traffic.

The authors wish to acknowledge the assistance received in the preparation and checking of this article from their colleagues in the Engineering Department and Wireless Telegraphy Section.

Book Reviews

" Communication Circuits." Third Edition. Lawrence A. Ware, E.E., Ph.D., and Henry R. Reed, M.S., E.E., Ph.D. Chapman & Hall, London. 403 pp. 174 ill. 40s.

This is a new edition of a book which is already well known in this country and it includes considerable additions and improvements. The title may be misleading to those not familiar with the earlier editions; in the author's own wording the contents cover " the basic principles of communication transmission lines and their associated networks covering the frequency range from voice through ultra-high frequencies and using the M.K.S. rationalised system of units."

The first third of the book is concerned with conventional transmission line theory and the evaluation of the primary coefficients including skin effect and proximity effect in coaxial and balanced pairs; the essential modified Bessel Functions are introduced in Chapter 1, and a more detailed study of their derivation is relegated to an Appendix. Two chapters are devoted to filters but do not venture beyond Zobel designs; impedance matching via pads and reactive T-sections is then dealt with and this leads up to the use of matching stubs in H.F. lines.

The remainder of the book is concerned with wave guides and the electromagnetic theory of coaxial lines. These are dealt with conventionally and include some information on methods of excitation. The field equations for the guides are carefully developed and are supplemented by an Appendix giving a clear and concise derivation of Maxwell's equations in differential form, for both cartesian and cylindrical co-ordinates.

The book is well written and carefully arranged, and should be of considerable value to the student who wishes to cover thoroughly the subject of transmission theory. Each chapter includes copious numerical exercises and a final chapter sets out 12 experiments designed to lend understanding to the subject matter of the book. R. J. H.

" Matrix Analysis of Electric Networks." P. Le Corbeiller. Harvard Monographs in Applied Science, No. 1. Harvard University Press, 1950. Chapman & Hall. 108 pp. 49 ill. 24s.

The application of matrix algebra to the analysis of complicated networks results in a great simplification of the mathematics involved: for matrix algebra provides the machinery to generalise from simple individual cases to complicated groups and systems. The object of this little book is to present to engineers a simple approach to Gabriel Kron's matrix method of network analysis.

The elements of matrix algebra, stripped of all unessential mathematics, is given in the first chapter. Of particular interest is the demonstration of the rule for determining the elements of the inverse of a matrix and the discussion of its application to specific types of network problem.

In the second chapter an original derivation of Kron's mesh-method formulæ is given: by introducing the idea of an " intermediate " network, the author shows clearly how Kron's square non-singular matrix M passes into the rectangular singular matrix C. The same type of reasoning is applied in the third chapter to the dual problem of analysing a network on a mode-pair (instead of a mesh) basis; and the discussion is illustrated by applications to bridge networks and triode-coupled circuits with inter-electrode admittances.

The fourth and last chapter discusses the final achievement of Kron's method in the field of stationary networks, namely, the analysis of a system in which both voltage and current sources are connected to branches coupled to each other in the most general way.

This book can be warmly commended to those who wish to master Kron's matrix method of network analysis. The reader who has mastered this theory will find himself capable of analysing complicated networks having any number of symmetric or asymmetric couplings and connected to voltage and current generators in any conceivable way. H. J. J.

The Leakage of Direct Current and Potential Gradients in the Ground

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U.D.C. 620.193.7 : 621.315.2 : 621.3.014.6

Corrosion of P.O. cables by leakage currents from tramway systems and electricity supply networks is a serious and widespread problem requiring constant attention. It is important that the basic considerations applying to current leakage and ground potential gradients be widely appreciated and this article explains in simple terms the principal factors concerned and illustrates methods adopted to reduce this type of corrosion to a minimum.

Introduction.

THE study of the flow of direct current in the ground involves conceptions not very generally understood. The earth is a poor and variable conductor, yet the cross-sectional area of the path traversed by a direct current is, at a distance from the electrode, extremely large. There is no means of confining the current to any restricted path ; the resistivity of the soil, the subsoil and lower rock strata vary over extremely wide ranges and the conductivity of the upper layer is greatly modified by the presence of buried metal pipes and other such conductors.

Any attempt to predict the course or intensity of the current flow at any point between two earth electrodes which are buried in the ground remote from one another is thus beset with considerable difficulties.

The conventional forms of earth electrode, plates, plates in coke, strips, pipes or driven rods are all intended to provide a large contact area with the ground, but the greatest economy is attained by distributing the electrodes over a wide area and connecting them in parallel.

Quite as important as the actual resistance to earth of an earth electrode system is the potential gradient around such an electrode when a heavy current is passing. Under these conditions the equipotential curves around an electrode system can be plotted by surface measurements with a high resistance voltmeter connected between an exploring spike and a remote earth connection. The total drop of volts between the electrode and earth is a function of the current and the total resistance to earth, but the potential gradient depends upon the form of the electrode, being greatest in the close vicinity of a single earth rod. Equipotential curves will rarely be concentric circles owing to their distortion by variations in the resistivity of the soil and the presence of conducting pipes or cable sheaths.

Cattle are not infrequently killed by bridging ground potentials caused by current flowing from earth electrodes, but steep potential gradients can be avoided by sinking an earth electrode well below the surface of the ground and using an insulated cable to make connection with it.

In making measurements of the P.D. between a cable sheath or metal pipe and ground, it is important to remember that when the ground is carrying current its potential may be raised above or depressed below that of the general mass of the earth. Thus, the potential of the earth adjacent to a tram rail carrying current may approach that of the rail whereas in the footway it may not differ very much from that of the general mass of the earth. The potential of the rails may be extended to the footway by the practice of bonding iron standards to the rails or by water mains or cable sheaths which cross the road below the track. A network of bare lead cables in damp ducts forms one extensive conducting whole and has a very low resistance to earth. Differences of potential between different points in this network can only arise when currents are flowing in the sheaths and such currents are often picked up from the ground, to which they leak from uninsulated tram rails or from leaky mains.

The conductivity of cable sheaths is relatively high, but the P.D. between different points on the cable due to sheath currents is generally low. Indeed, it is found that far higher P.D.s exist between different points in the ground than exist between different points in the cable network.

In a town containing ramified networks of metal pipes it is no easy matter to select a site for placing an earth electrode intended to act as a reference of zero potential, since such a point must be remote from all buried conducting pipe systems.

Leakage from Tramway Systems.

The diagrams which follow are based on theoretical considerations but serve as a basis for the study of the conditions arising from the presence of tramway systems with uninsulated rail returns and from faults on power distribution mains.

Arrows are used to indicate the flow of current from the contact conductor through the motors to the rails, from the rails to the ground and from ground to cable sheath : they also indicate where current leaves the cable sheath and flows through the ground to the rail, to return to the power source.

The term " true earth " denotes a reference earth so remote from the track and all buried metal structures, such as extensive pipe systems which approach the track at any point, as to be substantially at zero potential. " Local " earth potential is the potential of the ground in close proximity to the conductor under consideration, which, in the following discussion, is generally the P.O. cable.

Fig. **1** shows a long, uninterrupted bare lead-sheathed cable laid parallel with, and at a uniform distance from, a single tramway track loaded by a single concentrated load at the end remote from the supply station—the soil is assumed to be homogeneous. The tram rails are uninsulated from the ground but are assumed not to be earthed deliberately at any point by connection to conventional earth plates : the rails thus assume a potential above that of true earth at their distant end and below that of true earth at the station end.

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The potential of the cable is above true earth at the distant end and below true earth at the station end. On the other hand, the potential of the cable is below

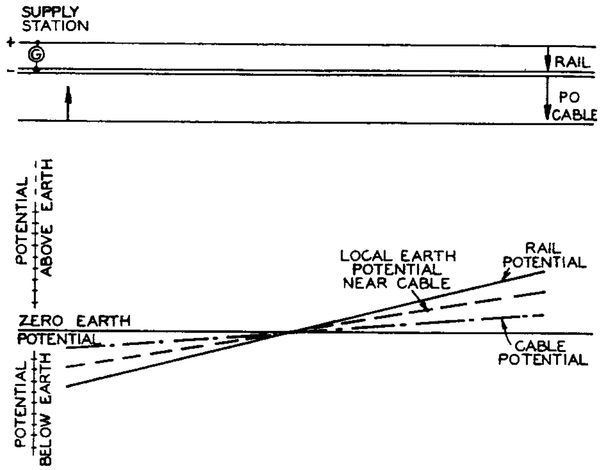

Fig. 1.—Single Concentrated Load at Far End of Tramway.

that of local earth at the distant end and above that of local earth at the station end. That is why current flows from the ground into the cable at the distant end and leaves the cable and flows into the ground and thence to the rails, at the station end.

In Figs. **2** and **3** the vertical intercepts between the curve of cable potential and that of local earth

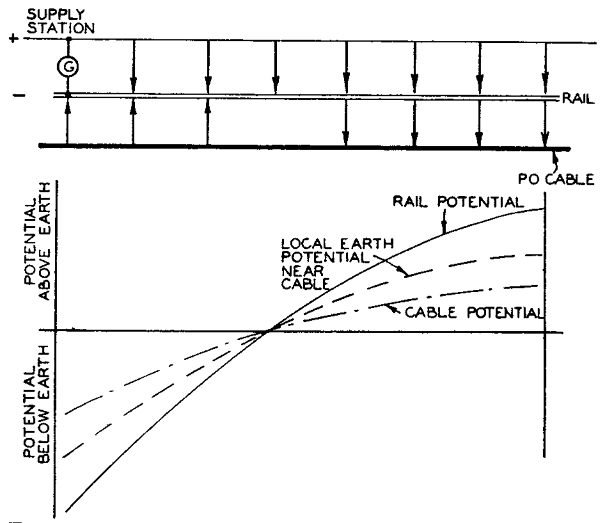

Fig. 2.—Uniformly Distributed Load Along Tramway.

potential indicate the magnitude and direction of the P.D.s which cause current to pass from cable to earth or vice versa. The magnitude of these currents also depends upon the resistance between cable and earth, and when this is high (e.g. due to a dry duct) it is not uncommon to find high values of P.D. between cable and local earth but an insignificant flow of current.

Fig. **3** indicates how the P.D. between cable and local earth is reduced by the use of gaps: the result is that the exchange of current between cable and earth is minimised and so the risk of corrosion is reduced. The pick-up and discharge areas are now distributed

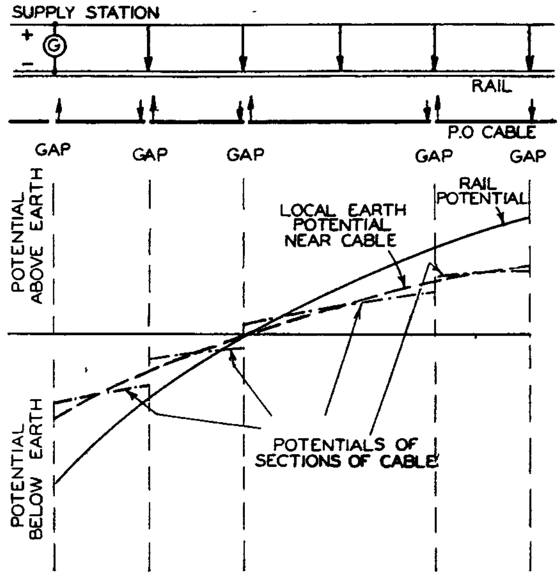

Fig. 3.—Uniformly Distributed Load. Insulating Gaps in P.O. Cable.

over the length of the cable and if the number of gaps was very large the risk of corrosion would be negligible. Other obvious drawbacks would, however, arise.

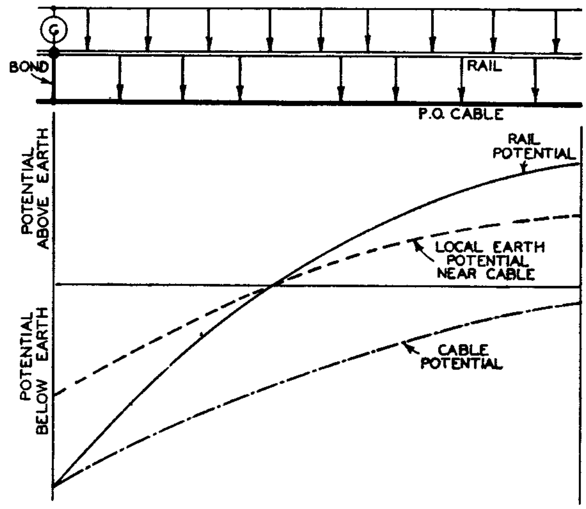

Fig. 4.—Uniformly Distributed Load. P.O. Cable Bonded to Rail.

In Fig. **4** the P.O. cable is bonded direct to the station end of the rail. The effect of the bond or " drainage " connection is to increase the current in the cable and to make the cable negative to local earth throughout its length. Under these conditions, in general, no corrosion would occur. Drainage bonds used indiscriminately may, however, result in dangerously heavy currents being carried by the P.O. cable sheath. Drainage bonds cannot be safely used where some sub-stations are shut down at night, as this condition entirely alters the distribution of potential and leads to increased dangeı of corrosion.

Fig. **5** illustrates the conditions arising when the P.O. cable is bonded through a resistance to the station end of the rail. The resistance is such as to bring that end of the cable to the potential of local earth—elsewhere it is negative to local earth. The

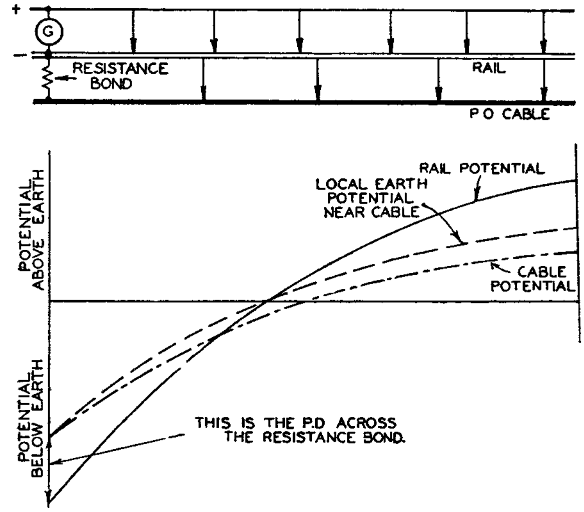

FIG. **5**.—UNIFORMLY DISTRIBUTED LOAD. P.O. CABLE BONDED TO RAIL THROUGH A RESISTOR.

cable carries less current than in Fig. **4** and, in general, no corrosion would occur, but adjustment of the value of the resistance bond is necessary to meet changes in the loading on the system. A further alternative is illustrated in Fig. **6** in which the P.O. cable is interrupted by insulating gaps in three places, each gap being shunted by a resistance adjusted so that during normal conditions the P.D. between each cable section and local earth is zero at the end nearer the station. The effect is to reduce the current carried by the cable sheath still further than in Fig. **5**, whilst still eliminating all discharge areas. The average P.D. between each cable length and local earth is, however, much reduced. This is an advantage since

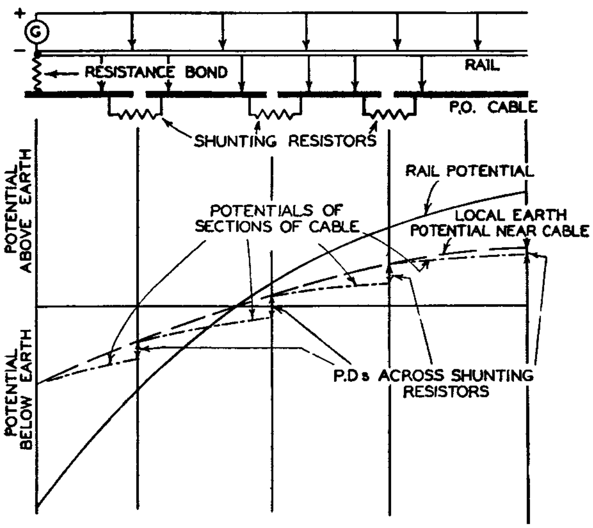

FIG. **6**.—UNIFORMLY DISTRIBUTED LOAD. GAPS IN P.O. CABLE SHUNTED BY RESISTORS.

in certain soils a high negative P.D. to earth can lead to corrosion. For a given tramway load this arrangement is very nearly perfect, but tramway loads vary over the 24 hours and during light load some stations may be shut down. Such variations in operating conditions call for the use of pilot wires and recording voltmeters, and even the adjustment of the resistance bonds from time to time. Fig. **7** shows the cross-section of a tramway route and a P.O. cable in earthenware duct crossing under the track. The cable is separated from the general network by insulating gaps at manholes on each side of the road, and the potential it takes up is a rough mean of the potentials of the different portions of ground which it traverses.

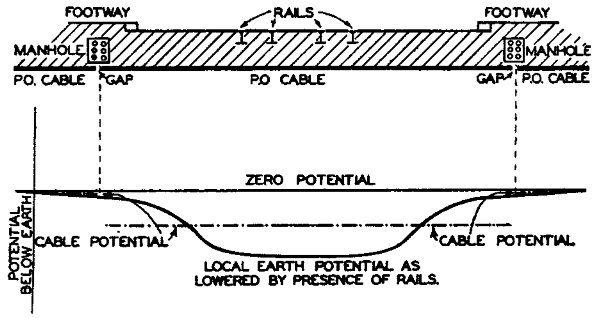

FIG. **7**.—CROSS-SECTION OF ROAD SHOWING EFFECT OF TRAMWAY ON CABLE CROSSING UNDER TRACK.

The diagram applies to a section of the track at which current is returning from the ground to the rail, and here the isolated length of cable will be negative to local earth at both ends but positive to local earth elsewhere. Owing to its short length it has a comparatively high resistance to local earth, and any current flow from the cable will be so small as to involve little risk.

If the gaps were short-circuited the cable sheath would assume a potential approaching that of the cable network as a whole, i.e., of the general mass of the earth (zero potential) and a considerable flow of current from the cable sheath to local ground would occur beneath the track—especially when the dip in the duct was full of water.

The effect of the variation in distance between the cable in the footway and the tram rails is illustrated

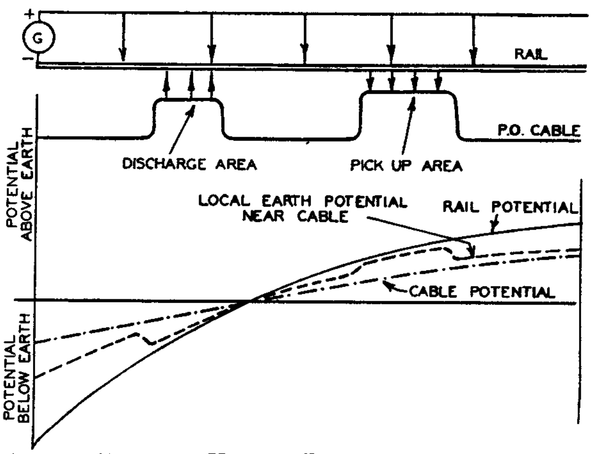

FIG. **8**.—EFFECT OF VARYING DISTANCES BETWEEN CABLE TRACK AND TRAMWAY.

in Fig. **8**. Such conditions arise where the carriageway narrows in certain places. The steep voltage gradient near the rails accentuates the effect of these variations in distance.

Leakage from Supply Mains.

Fig. **9** refers to the case of a leakage on the *negative main* of a three-wire system. The neutral of the

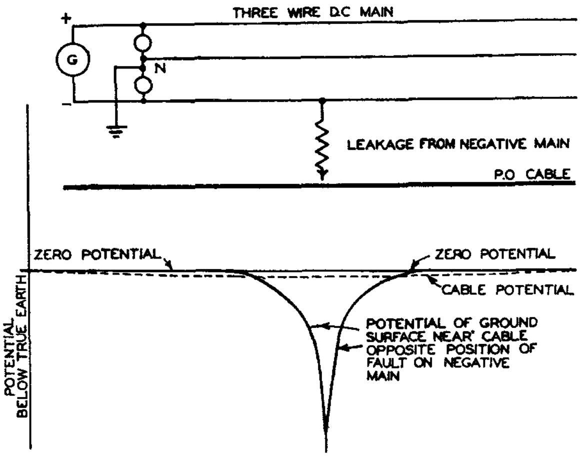

Fig. **9**.—Leakage from Negative Main of 3-wire System.

system is earthed and the P.O. cable network assumes a potential closely approaching that of the general mass of the earth (zero potential). Current, therefore, which is picked up from the earth drains back to the fault on the negative main from any point on the P.O. cable system near to it, and thereby causes concentrated, intense corrosion. The conditions are almost as though there were a direct bond between the P.O. cable network and the neutral main of the three-wire system elsewhere than at the fault.

The local depression of the ground potential in the immediate neighbourhood of a fault on a negative main will result in a flow of current from the P.O. cable to ground in this area. The P.D. measurements between a P.O. cable and earth may be quite high (possibly 50V, cable positive) close to the fault but will rapidly fall off as the distance from the fault is increased. The choice of position for the exploring earth spike is very critical as the potential gradient is so steep. The intensity of the current leaving the telephone cable sheath will be high, especially if the duct is damp, and the damage will be concentrated. This type of fault usually occurs with old mains, particularly with those insulated with bitumen and having no lead sheath.

Where, however, a fault occurs in a lead-covered impregnated paper insulated main, the leakage current initially flows from the lead sheath to the core rather than from the ground. The leakage current may soon increase, however, to the point of melting the lead sheath locally, and as the lead runs off, the current is drawn more and more from the earth. Any P.O. cable near the fault, therefore, begins to feed current into the earth and its sheath is soon damaged.

Where such a power main is in a short isolated length of iron pipe and becomes faulty, current will flow from all parts of a P.O. cable which lie near the iron pipe, and the damage will be spread over a greater length of cable : the actual perforation of the cable sheath is usually somewhat delayed.

The case of a *fault on a positive main* may be similarly studied, but the effects upon a P.O. cable are entirely different. In the vicinity of the fault, current flows into the P.O. cable and over a restricted area P.D. readings between cable and ground may be high, the ground being positive to the cable. No damage will, in ordinary circumstances, occur to the cable sheath in this area.

The current in the P.O. cable will, however, return to earth (and thence via the earth plate to the neutral of the power main) over a wide area and will not often be so concentrated at any point as to cause appreciable damage to the P.O. cable sheath. If, however, any section of the P.O. cable network passes close to the earth plates of the power system or close to any heavy iron pipe which also passes near them, the discharge of the current from the P.O. cable sheath may be relatively concentrated and in some cases be so intense as to cause local damage. It is obvious that the fault on the P.O. cable will in such circumstances be remote from the fault on the positive main and may not appear to have any connection with it.

Cyclic Variation of Resistance of Loaded Earth Electrode.

An interesting case of damage to a P.O. cable, due to leakage current to the negative conductor of a three-wire D.C. main, has actually occurred and is worthy of mention.

The two-wire service cable into a building from the negative main had been inadvertently left alive up to the service cut-outs, and these had subsequently been completely buried under a heap of rubble left after the demolition of the premises. Dust had collected in the cut-out case and moisture was finding its way in during wet weather, so that leakage occurred from earth to the live terminal. A P.O. cable in the adjacent footway broke down and, later, was found to have been perforated by concentrated electrolytic action. When the duct was being uncovered the ground was found to be hot and steaming. At this time, however, no appreciable P.D. between earth and the damaged cable sheath could be detected.

The explanation was only provided after the case had been studied further, and the chances of making a successful claim had been jeopardised. It is known from experience gained with earth plates carrying heavy currents that the flow of such currents is generally intermittent, varying from zero to full current and falling to zero again with a periodicity of some hours. The moisture in the cut-out may, therefore, be assumed to have been dried out by the heat produced at the fault to a point of complete interruption of the current, after which the slow percolation of moisture gradually re-established the circuit and the cycle was repeated. Doubtless the weather played its part and would cause the duration of the cycle to vary considerably, but the fact that the ground was still hot and steaming at a time when the leakage had ceased, no longer presented a difficulty and should not puzzle investigators in future.

A Novel Method of Surveying Boreholes

C. E. PALMER JONES†

U.D.C. 526.915

At the request of the Ministry of Fuel and Power, a method of underground surveying, using static magnetism, has been devised at short notice. The apparatus consists of a remote-indicating compass and a powerful magnet, each of which had to be designed to be inserted into a borehole only four inches in diameter. An accuracy within about two inches for distances up to the limit of 15 feet is obtainable.

The Objective.

IN December, 1949, the Post Office Engineering Research Station received an enquiry from the Ministry of Fuel and Power as to whether cable-tracing methods could be adapted, in the space of a month or so, to be usable for tracing the course of holes bored deeply in the ground.

The final objective of the Ministry is to be able to generate a continuous, copious supply of gas for use as industrial fuel by burning coal in a forced air draught where it lies in the ground. The present preliminary experiments are on a limited scale and are primarily directed to the evolution of suitable techniques of combustion control, and to economic studies. The research is being carried out at an opencast site which has been worked to the point where it is not economic to dig any further to follow the seam into the ground.

Holes four inches in diameter (after casing) were to be bored in the ground to give the effect of a U-tube with its lowest part in a coal seam. Two verticals nearly 100 ft. long were to be drilled down to intersect a hole bored almost horizontally within the coal layer, the immediate objective being to bring about accurate intersection. The scheme is illustrated in outline by Fig. 1.

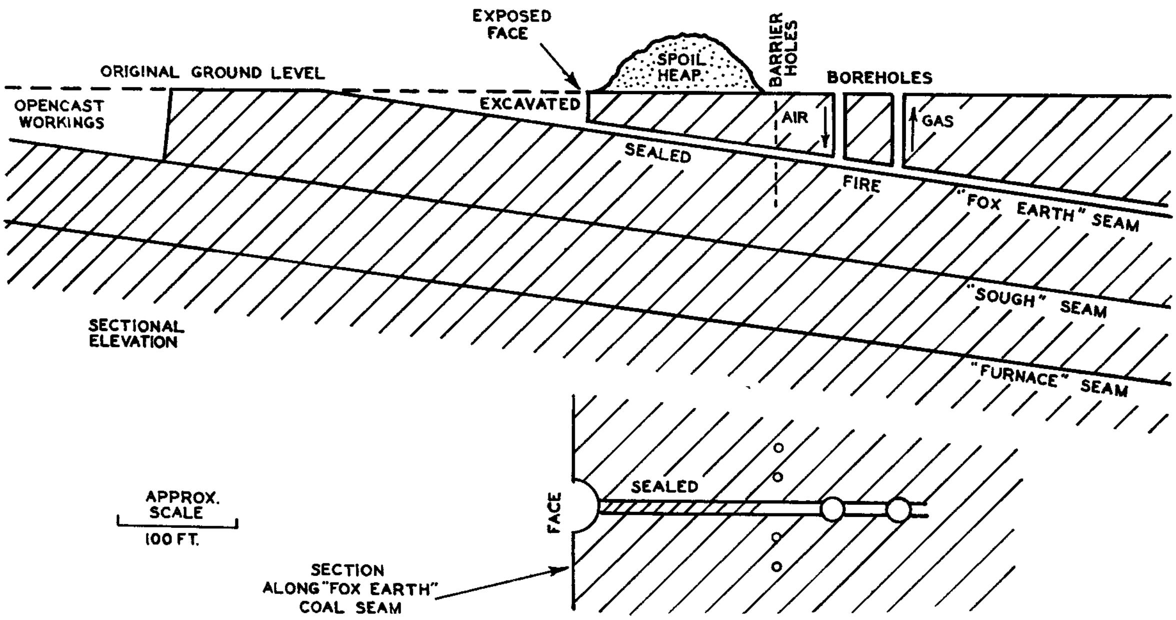

FIG. 1.—EXPLANATORY DIAGRAM OF UNDERGROUND GASIFICATION TRIALS.

The lateral hole is certain to wander in direction and depth from the course planned for it, and the vertical holes always depart to at least some slight degree from truly vertical. Thus, quite a difficult and novel problem in surveying is presented. The approach is to assess the separation between trial vertical holes and the lateral bore in order to trace its course and to deduce where to drill to make the desired intersection. The number of trial holes must be kept to a minimum and use can be made of the barrier holes put down for safety precautions in controlling the fire to be lit in the coal mass.

Choice of Method.

The known methods of finding shallow-buried cables do not lend themselves to finding the relative positions of boreholes at full depth. However, another idea occurred and, as it appeared feasible, co-operation was promised. Static magnetism with a powerful magnet would be usable, and would have a range of a few yards. The essence of the magnetic method of finding the distance between the two deep holes is to observe the effect upon a magnetic compass at the coal-seam level in the vertical hole, while a magnet is pushed into a number of successive positions in the lateral hole.

The idea of plotting magnetic fields offered accuracy of distance and direction, simplicity in operation, with cheap, robust gear and safety for personnel—

† Executive Engineer, London Telecommunications Region (formerly at Research Station).

if not for their wrist-watches! Two objections had to be considered. First, errors might arise due to magnetic minerals if such were present on the site. Second, it looked as if a large amount of effort would be necessary to carry out calibrations of the magnetic field patterns. These would have to account for the whole range of possible tilts and directions of the lateral hole in which the magnet would lie while testing.

The first objection was quickly overcome. A careful survey of the site with a prismatic compass showed that the only aberrations over a considerable area were close to the drilling rig and to a dump of steel stores. These were to be expected. Supposing there had been a minor quantity of magnetic mineral, it still might have been possible to allow for its presence, but actually mineral samples from various depths were shown to be without effect on the compass needle.

The second objection also proved not to be serious in practice. It was discovered that the magnet could be tilted several degrees from its assumed slope in the lateral hole without appreciable effect upon the reading of a compass used in the horizontal plane through the centre point of the magnetic axis of the magnet. Actual calibration work was carried out with a tilt of 15° to simulate the best forecast of field conditions at the coal mine. Again, a useful discovery was made which avoided the need for sets of calibrations for various deviations up to 20° from the expected direction (approximately E-W) of the lateral hole. Within this 40° sector at least, the average deflection, *after polarity reversal,* is always the same.

That the method would be usable had been confirmed by calculations and models to scale. These showed further that empirical calibration is very desirable.

Two alternative methods, whose merits and objections had been considered, were to use the electrical resistivity of, or the attenuation to gamma radiation offered by, the soil which intervenes between holes when distances apart are to be measured. The opportunity had been taken to make a survey of soil resistivity distribution during the preliminary visit to the site. Schemes using resistivity or any alternating electromagnetic effects suffer errors due to unpredictable reflections and variations of current distribution which occur in the skew, multi-layer system which constitutes the soil. To use radio-active isotopes as a source and a Geiger counter assembly as detector would be relatively simple, but lack of range would be a severe handicap. Only a small quantity of radio-active isotope (cobalt is preferred) can be safely handled and every foot of intervening soil reduces the count by a factor of 10^{-1}, approximately. The range of the magnetic method varies as the volume of the magnet as long as there is power available to saturate it. The sensitivity of the compass used does not affect the range, but it needs to be adequate to overcome the frictional forces in the compass so that field direction is correctly indicated.

The Requirements.

Practically all small-area geophysical surveying is based upon a selected point as origin and two natural directions, gravity and terrestrial magnetic field. For a rectangular co-ordinate system, the horizontal component of the earth's field at the origin gives Magnetic North. To this system of axes all instrumentally observed lengths and angles are referred. The P.O. technique is entirely magnetic in operation, respect having been paid to the direction of gravity in accepting the boreholes called "vertical" as truly so. At a depth of 100 ft. the out-of-vertical is not likely to exceed an inch or two, which is not enough for the assumption to produce any significant error.

The requirements in using the magnetic method are a strong enough magnet and a remote-indicating compass that will go into the four-inch holes which may well be full of water. Steel pipes casing the boreholes should be omitted in the area to be searched so as to avoid disturbance of the magnetic conditions; 10 or 12 ft. away from the magnet and compass at the nearest approaches is probably enough.

Apparatus.

To develop a suitable remote-indicating compass within the given time and size limitations was difficult, but with the assistance of a firm of experimental model engineers, production of a model designed by the P.O. specially for the purpose was achieved by mid-February, 1950, ready for use in the experiments. This "G.P.O. Remote-Indicating Compass" could not be ready for testing in January, the originally forecast month for the surveys, and therefore the possibility of realising a ready-made remote-indicating compass was earnestly explored. It was discovered that the Admiralty Compass Observatory had a fully developed instrument of considerable refinement. Nothing less than a 7-in. diameter borehole would permit its use, however, and even then quite a lot of modification would be necessary to bring the leads out at the top, to make it water-tight and capable of functioning with as long a lead as would be required for this use. The Ministry considered that the urgency justified the trouble involved and arranged to have reamers flown from Canada to widen the holes if needed. On hearing this the Admiralty Compass Observatory authorities willingly and quickly carried out the necessary alterations to suit their "A.T.M.C. Type 4" for the new project. Fig. 2 shows the complete outfit which was ready in good time. The coupling to the top was made interchangeable with the P.O. design; both were to be attached to dural tubing in 10-ft. lengths for lowering.

Before examining the details of the P.O. compass design, it may be helpful to consider what is involved in providing a magnet to produce deflections. For insertion in the lateral borehole, the complete magnet assembly is attached to the drill rods as used in boring the hole. These are 20-ft. screw-ended lengths of steel tube about 3½ in. in diameter. The magnet assembly is 20 ft. long. Externally it is a brass tube with a rounded nose at the leading end and a screwed adapter for attachment to the drill rodding at the other end. Half the length is empty and serves to isolate the magnet from the steel rods by a sufficient distance to ensure that accuracy is not

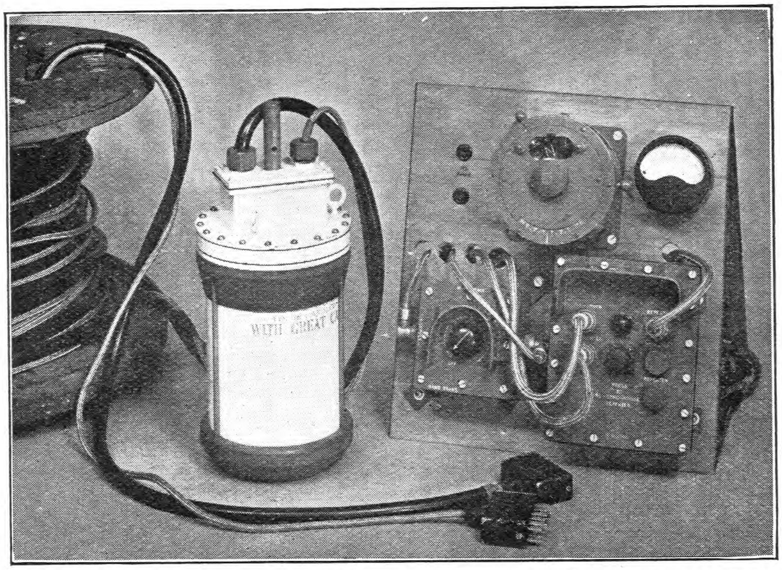

Fig. 2.—Complete Equipment of Modified Admiralty Remote-Indicating Compass.

sacrificed. Inside the leading end is a 10-ft. bar of Swedish soft iron, 2 in. in diameter, on which is wound a coil of 8,500 turns spread in four layers

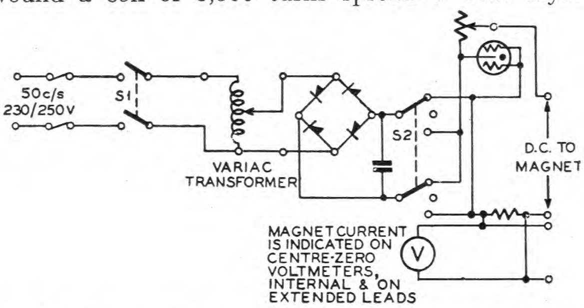

Fig. 3.—Circuit Diagram of Magnet Current Control Panel.

along the whole length of the bar. In this coil one ampere is sufficient to produce saturation flux, 300,000 maxwells at the centre of the bar, and 120V are necessary to pass this current.

The leads to the electro-magnet are fed through the hollow rods to connect up with the power panel designed to feed it and located at the entrance to the hole. The schematic diagram of the power panel which takes an input from public supply mains, or the equivalent from a petrol-electric set, is shown in Fig. **3**. It will be seen that a gas discharge tube is used to absorb the surge which might follow a sudden change of current. Another such tube is incorporated in the magnet assembly, joined in shunt with the winding. There is a quantity of rubber and sponge-rubber inside the magnet case to cushion shocks and a wax filling to prevent ingress of water. Fig. **4** is a photograph showing the magnet assembly supported on the framework used during the calibration work; the tilt is 15°, i.e., roughly the slope of the coal seam. A theodolite compass is in use for this work, because at that time neither of the special compasses had been completed. Curves are being obtained by the engineers to indicate the successive deflections of the compass to be expected as the magnet is moved along its own axis at various distances, with checks in various directions making small angles with an East-West line. These curves (Fig. **5** indicates some typical ones) form the basis of position recognition when the underground tests are in progress. It has already been mentioned that the calibration must be undertaken with the actual magnet to be used in the field work. Calculated curves or those from models of the magnet fail to take account of the exact distribution of the field pattern around the magnet arising from the particular nature of the leakage field. A very necessary precaution in carrying out any tests which involve a change of current (including changes from zero) is to saturate the magnet with one ampere in the *reverse* direction and then to bring the current through zero up to the required value. If this is overshot, the whole of the magnetising cycle must be traversed again to come up to the required adjustment.

Fig. **6** is a photograph of the G.P.O. Remote-Indicating Compass as a complete assembly, with the partly dismantled spare one alongside. It contains a magnetised needle pivoted to swing in a horizontal plane between two jewelled bearings. Light phosphor-bronze wings are carried by the needle so as to make contact, when pressed downwards, on a circular track potentiometer. Where the ends of the winding of this potentiometer come, there is a blind spot of 3° or so, but the whole instrument can be turned

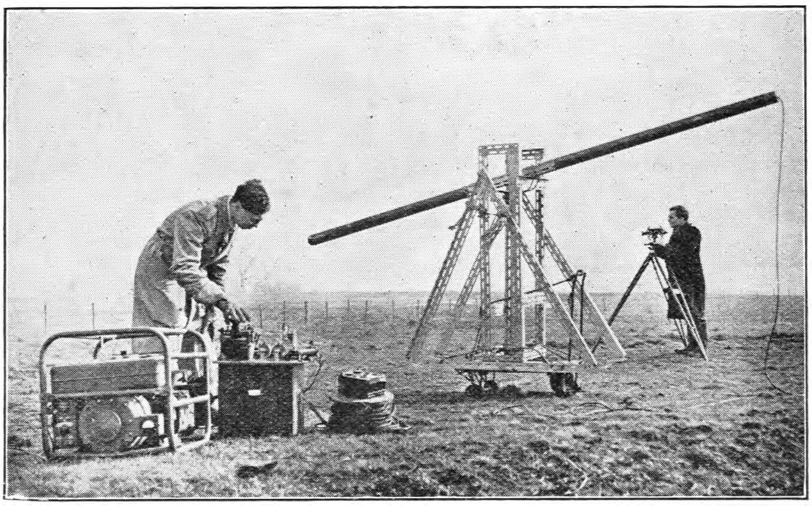

Fig. 4.—Method of Supporting Magnet Assembly during Calibration.

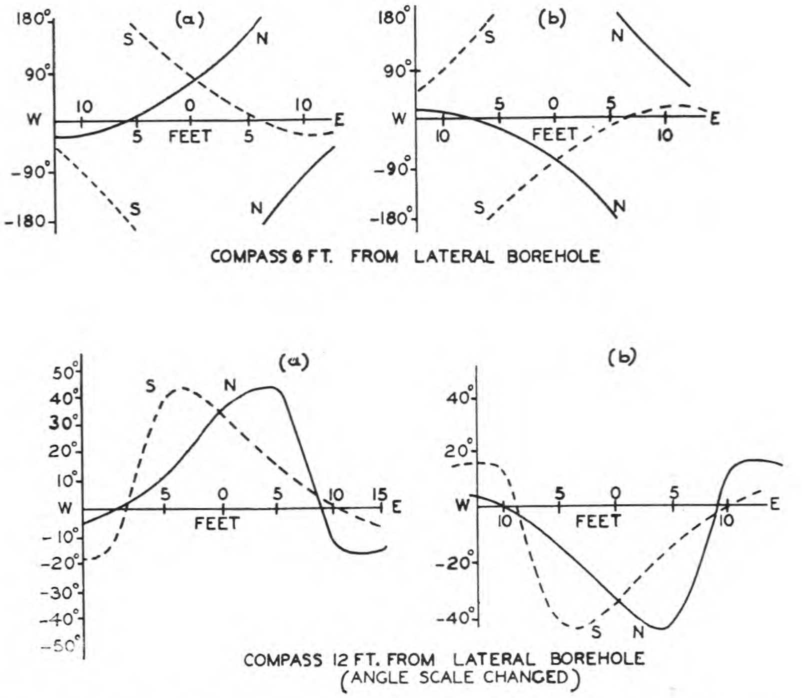

FIG. 5.—TYPICAL CURVES OF DEFLECTION *v.* LENGTH AS 10-FT. SATURATED MAGNET MOVES PAST COMPASS FROM WEST TO EAST: (*a*) WITH SOUTH POLE LEADING; (*b*) WITH NORTH POLE LEADING. CURVES S, MAGNET SOUTH OF COMPASS; CURVES N, MAGNET NORTH OF COMPASS.

Note:—These curves are shown to illustrate the forms taken by plots of Deflection *v.* Length. The full set of accurately plotted curves enables:—

1. Separating distance to be estimated roughly.
2. Sense to be decided.
3. Accurate centering of the magnet for curves of Fig. **9** to be used for precise distance determination.

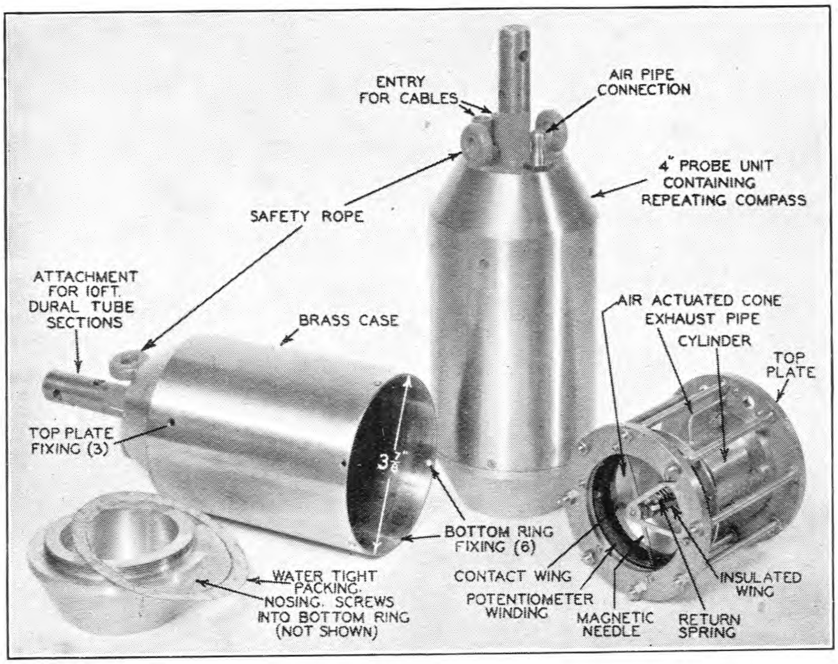

FIG. 6.—THE G.P.O. REMOTE-INDICATING COMPASS AND ITS PARTS.

by means of the supporting dural tubes to give a satisfactory starting position.

Downward pressure to clamp the magnet and establish the contact is accomplished by feeding compressed air to the unit via a pressure tube which, with the leads from the ends of the potentiometer, is led to the surface. The air forces a piston to move against a spring and in so doing brings a cone to bear down on the wings so that one of them makes contact (the other is for balance only and is insulated). Accurate balance and freedom of movement of the needle assembly are necessary and so is smooth positive motion of the piston and cone assembly. Precaution is taken against turbulence in the air surrounding the needle. A slow leak for air is provided to ensure successful repeat operations. At the surface a simple bridge circuit (Fig. **7**) is manually brought into balance so that a galvanometer deflection is reduced to zero, and then the compass indication can be read directly off the dial associated with the one knob used for balancing. Any field due to the small current used in the potentiometer is not sufficient to affect the compass needle.

The Admiralty compass is self-synchronising and the repeating compass at the surface reads continuously and directly. With a suitable repeating compass the bearing is displayed to an accuracy within 10 minutes of arc, the indication being dead-beat for small changes. A battery of 24V is needed to feed 4A continuously to the motors and the electronic control panel. In contrast, the P.O. instrument requires only a few milliamps from a 6-V battery and is far less complex in construction, but it cannot claim better than 1° accuracy.

The Survey.

The procedure in carrying out a survey is first to check up that the strength of the earth's magnetic field (horizontal component) is the same at the top and bottom of the borehole. This is done by fitting a small coil on the top of the compass casing and energising it from a battery to provide a reference field ; the compass is used in the role of magnetometer. If the strength is unchanged, it is fair assumption that the direction is also unchanged. The next step, having

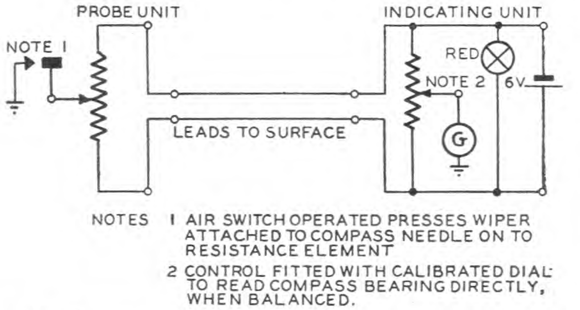

FIG. 7.—SCHEMATIC CIRCUIT OF G.P.O. REMOTE INDICATING COMPASS.

disconnected this coil, is to introduce the magnet into its borehole, after testing for polarity and applying a spot check on field strength. It is then pushed forward on rods by the drilling rig without rotating, into the lateral borehole (see Fig. **8**), until it approaches the position where it will probably begin to affect the reading of the compass waiting in the vertical hole being surveyed. Then the magnet is moved on at intervals under telephone control of the party working the compass controls, that is to say, the air control cock and the balancing knob. A curve is plotted connecting the length changes of magnet position with the angular changes of compass indication. When the magnet has passed beyond the region of effect upon the compass, its polarity is reversed and it is brought out again by stages while another plot of length against angle is made. From the symmetry of these curves (which are of the type illustrated in Fig. **5**) it is possible to guide the magnet to a position such that the compass lies on the horizontal right bisector of the magnet. The compass being at coal level at this stage, it is now moved up and down by small steps to confirm that an optimum reading exists and that, therefore, the compass and the magnet centre lie in the same

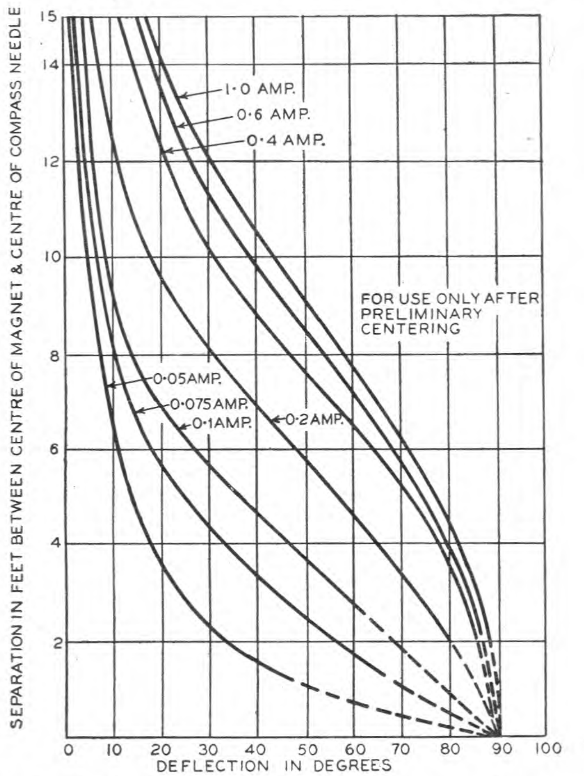

FIG. 9.—CURVES OF DISTANCE *v.* DEFLECTION AT SELECTED INTERVALS OF MAGNET CURRENT. DISTANCE MEASURED ON HORIZONTAL RIGHT BISECTOR OF MAGNET LYING E-W (MAGNETIC).

horizontal plane. Finally, a curve is plotted for the accurately centred arrangement to relate deflection against the current in the magnet winding using prearranged steps of current for which the calibrations have been previously plotted (see Fig. **9**). The distance separating the magnet and the compass can then be estimated for each of the currents, and the (weighted) average of these yields the information which has been sought. The weighting depends upon the slope of the calibration curve at the point where the reading is taken.

FIG. 8.—DRILLING RIG AT ENTRANCE TO LATERAL BOREHOLE.

Performance Details.

Using the technique described, an error of less than an inch was shown to be possible in an actual distance of over 13 ft. during rehearsals. Accuracy falls off over 15 ft. and also in the immediate vicinity of the magnet. Within a foot or so the forces acting on the compass needle pivots are undesirably great ; a smaller magnet is under trial for very close work, but the large one can be used if the higher values of current are avoided at times when the compass needle is near and not clamped.

It was actually in March before the survey was required; delays were due to various unforeseen causes, one of which was the great difficulty experienced in getting the lateral drilling reasonably straight and near the proposed position in the coal seam. The attempt which was destined to succeed was assisted by sinking the vertical holes along the track of the lateral hole so that the underground surveying could be used to keep trace of its tortuous course. Most of the vertical holes were four inches, but one was cut to eight inches in readiness to put the Admiralty compass into commission if the P.O. compass gave any trouble, but actually it did not. Due to the exigencies of their main task, the Ministry were unable to afford an opportunity to try out the larger and more refined equipment, but they have undertaken to provide an opportunity† to do so in the next phase of their experiments.

The distances actually observed were found to be 1 ft. 2 in., 3 ft. 1 in., 3 ft. 10 in. and 11 ft. 9 in. The last two proved to be out of range of some elaborate radio-active equipment tried out before the G.P.O. survey started, but it was satisfactory to note that the first two agreed with that equipment within an inch or so. If the verticals had been truly parallel to each other, the course of the lateral would have become correctly known and new verticals could have been drilled accordingly to make intersection. Actually the drilling was not quite precise, but a small explosive charge forced a clear passage between the holes.

With a jointer's tent at the top of the hole being tested, another at the entrance to the lateral hole and cover for the generator and subsidiary equipment, good weather protection was afforded and the laboratory-made gear proved quite suitable. There was some unintentional very rough handling of the magnet when and after its connector became accidentally unscrewed from the drilling rod. After first-aid repairs to the casing, connector and cabling, it continued to give good service.

† Since this article was written the opportunity has occurred (May 1950) to use the Admiralty compass in further surveys. As expected, it performed well and was very convenient to operate. While the P.O. compass is adequate and needs no enlargement of the borehole, it is clear that, had the programme delays not occurred, the Admiralty "rescue" in January would have been most effective.

Acknowledgments.

Permission to publish information contained herein is gratefully acknowledged to the Admiralty and the Ministry of Fuel and Power, as also is the hearty co-operation given by these Departments and the author's colleagues at Dollis Hill whereby this job was swiftly, resolutely and successfully tackled.

Book Review

"Vade Mecum ('The World's Radio Tubes'), 1950." P. H. Brans. P. H. Brans, Ltd., Antwerp. 508 pp. 20s.

The eighth international edition of P. H. Brans' Radio Tube Vade-Mecum, 1950, shows two major changes compared with its predecessors, in that it is now published as a single volume and the valve base data are segregated in a separate section. Otherwise previous users of this work will find the layout and classification exactly as before.

The book has for its aim the collection of the more important characteristics of all current valves produced throughout the world up to September, 1949, and includes, in addition to conventional receiving types, such items as projection tubes, accelerometers, crystal diodes and the recently introduced crystal triodes. An approximate estimate showed that the number of different types listed exceeds 10,000 and, in addition, about 1,200 different base connections are illustrated and classified.

The introduction and instructions on how to use the book are repeated in five languages, Dutch, English, French, German and Danish. The valve types are classified alphabetically and numerically in a comprehensive index that gives the following preliminary data: (*a*) manufacturer, (*b*) number of the table in which the main data are to be found, (*c*) filament voltage, (*d*) reference number of base connections and (*e*) valves having equivalent performance.

The main tabulated information is divided so that all the valves of one category are listed together in one table where they are further sub-divided according to heater or filament voltage.

The value of a valve reference book of this type is largely determined by the following four qualities: the degree to which the valve list is comprehensive, the amount of data given, the accuracy of the data and finally the facility for finding a particular item of information. In order to form an opinion on these four points, approximately 50 valve types were picked at random from current British Manufacturers' lists and consulted in the Vade Mecum. The conventional valves were all found without difficulty, but three gas-filled triodes and four types of disc-seal valve were missing. The information given was generally adequate for many purposes with, however, some important exceptions. The data on interelectrode capacitances were meagre, being confined to occasional values quoted in the remarks column, and, for some of the rectifiers, the mean anode current quoted referred only to a particular circuit without making this point clear. The data were, in general, found to be accurate and showed only minor occasional differences from the manufacturers' published information, while all the information sought was readily found once the method of classification had been mastered.

Some criticism of the presentation of the high-power valve characteristics is called for in that the relevant working conditions are not made clear. The usefulness of this section would also be enhanced by stating the type of cooling, i.e. radiation, forced-air or water cooling.

The book has, however, attempted a truly monumental task with considerable success and many workers in the sphere of telecommunications and electronics will find it a valuable and convenient reference work, particularly for those workers whose main interest lies in the servicing and installation of equipment.

K. D. B.

Power-Operated Doors

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U.D.C. 624.028.1—83

This article is about power-operated and automatic doors used for draught exclusion in buildings and particularly in postal sorting offices, but there are many applications of power operation to doors and gates, and some of these are considered briefly.

Introduction.

A GATE or a door is useless unless it is usually closed. The chief difference between them is that a gate can only prevent free passage through an opening, whereas a door has additional uses, chief among which is exclusion of draughts. Whenever a door is opened to allow a passenger to pass through, it should be closed again immediately afterwards to prevent an unauthorised person from passing through or to exclude a draught. Unfortunately, closing the door does not help the passenger on his way, and consequently doors are often left open.

The simplest solution to the problem is the self-closing door ; energy is stored in a spring when the door is pushed open and it closes automatically behind the passenger. Additional effort is needed to open the door, but the passenger does not object to this as he is saved the worry of thinking about closing it. However, this kind of door is not effective where vehicles must pass through. A vehicle cannot push its way gently enough to avoid damage to itself or the doors, or both. An ordinary door is more suitable for a vehicle, but then the driver must dismount once to open the door and a second time to close it—if he remembers. Alternatively, where there is frequent traffic, a door-keeper may be employed or the door may be left open, for if it is heavy, opening and closing by hand would be hard work.

All these difficulties can be overcome by power-operating gear for opening and closing doors or gates, and by automatic control of the operating gear in some cases.

Purposes of Power Operation.

The term "automatic doors" is sometimes used incorrectly. Power-operating gear saves the effort of opening and closing a door, and the gear may be controlled automatically, but not necessarily. An automatic door is one which opens on the approach of a passenger and closes behind him without deliberate action on his part. He is saved the trouble of thinking about opening the door and remembering to close it. Power-operated doors, on the other hand, may be controlled by some person other than the passenger. A semi-automatic door is one which requires deliberate action to open *or* close it, but which performs the other function automatically.

Besides saving labour and thought, power-operated doors may be employed as safety devices as the following examples illustrate :—

Lifts.—Time is saved in preparing to enter or leave the car. The attendant, on car switch lifts, and the passenger on automatic lifts, is saved the effort of opening and closing both landing and car gates. On automatic lifts the passengers are protected from the danger of opening the car gate while the lift is in motion.

Underground Railway power doors save the passengers the effort of opening and closing doors, and protect them from draughts and from the danger of stepping out of the train when it is in motion. The station staff are saved the trouble of checking that the doors are closed and time is saved in ensuring that all is safe before the train leaves the station. The guard has complete control.

Buses.—A door can be provided to protect the passengers from draughts and the dangers of mounting or alighting while the bus is in motion, without giving the conductor additional work in opening and closing the door at halts.

Shops.—The customer is welcomed automatically, and if he leaves carrying parcels he is saved some inconvenience.

Warehouse Gates must be controlled to prevent theft. With power gear for the gates, the gatekeeper can give close supervision to the traffic without delaying it, without effort, and with only momentary interruption of other work.

Aircraft Hangar Doors may be so large and heavy that a man could not move them without power gear to assist him.

Sorting Office Doors.

An important link in the chain of transport of mails is the transfer of bags of mail between sorting offices and railway station platforms or vehicle-loading bays. At major sorting offices, where cost and space permit, bag conveyors are installed for this purpose, but at many offices it is necessary to carry the bags on some form of truck. Consequently, at busy offices there is a continual traffic of trucks into and out of the sorting office and, unless special arrangements are made to prevent draughts from the doorways, great discomfort may be caused to the staff working in the office, not only directly from the draught but indirectly from reduction in room temperature.

The usual arrangement for reduction of draughts in Post Offices, as in other large buildings, is to provide self-closing doors. These are effective when used by pedestrians as the effort required to push the door open, though not excessive, is sufficient to ensure that it will not be held open longer than necessary. To improve draught reduction, two doors are often fitted with a short lobby between them. The pedestrian pushes one door open and that closes behind him before he has time to reach the second door and open that. Thus, the lobby provides a partial air lock to prevent through draughts. The only reasonable way to pass through such doors with a hand cart or an electric truck is to fix the doors open, thereby vitiating the draught-excluding system. But if the doors are power operated, they can be equally efficient for pedestrians or trucks.

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Power Operation of Doors

The door itself may be of the sliding or the swing type, or may perhaps rotate: The design selected depends primarily on the location and purpose, but is affected to some degree by the power-operating gear. Six driving linkages are shown in outline in Fig. **1**. The

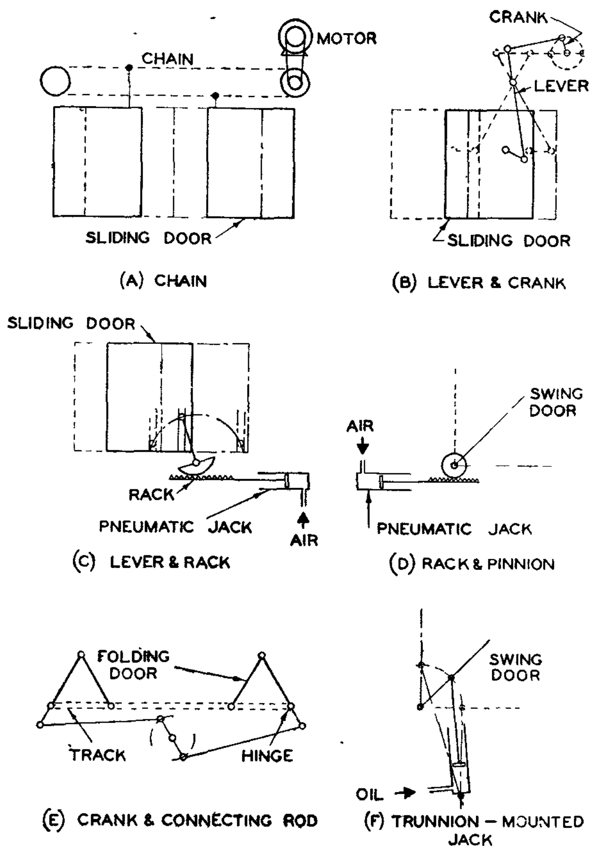

Fig. 1.—Driving Linkages for Power-Operated Doors.

overhead chain drive shown at (*A*) is suitable for large sliding doors or gates. A single door may be driven or bi-parting doors, as illustrated.

The linkage for a sliding door, shown at (*B*), is commonly used on lifts but is suitable only for narrow doorways, and at (*C*) is shown a similar scheme as used on the Underground Railways. Both these have the advantage that the velocity of the door at the limits of travel is zero, so that it opens and closes without slamming. Linkages (*D*) and (*F*) have been applied to swing doors, and that at (*E*) is for small folding doors as sometimes used on buses. The trunnion-mounted hydraulic jack, shown at (*F*), has the advantage of giving a maximum torque at starting to open the door and a minimum when the door is fully open so that slamming is not severe.

In most applications the driving gear should yield if the door meets resistance, but continue to move the door when the obstruction is withdrawn. Alternatively an automatic device may be provided to reopen the door if it meets resistance in closing. Some provision must be made to prevent injury to a person struck or trapped by the door, and if this device is self-resetting the door will not be left partially open after the device has operated.

This consideration makes pneumatic operation suitable, as an air receiver in the supply system allows the door to be stopped without overloading the driving motor. Pneumatic door operation is used on railway trains and buses where the air receiver may be charged from the traction motive power.

In buildings, an electric motor must usually be used to drive the operating gear, and as an air compressor is rather noisy a mechanical or hydraulic linkage may be preferable. A solenoid of the power required would be inefficient, but electro-hydraulic thrustors have been employed instead of motors. If a motor drives a mechanical linkage directly, a clutch or spring must be included to allow the door to yield without stalling the motor, but the motor must be stopped at the limits of travel, and each time it starts time is wasted in running up to full speed.

On the other hand, a hydraulic linkage can include an accumulator to keep the fluid pressure within limits, and if this accumulator is large enough it may be used to supply fluid to the system for several operations of the door. The driving motor is then used to pump up the accumulator only when the pressure reaches the lower limit, and full power is always available immediately to start driving the door open.

Sliding Doors and Gates.

The simplest mechanism is that required for a sliding door in a building. The door is hung on an overhead track and driven horizontally by a continuous chain in the manner shown in Fig. **1** (*A*), one chain sprocket wheel being driven by an electric motor through a clutch. When the motor is energised, the chain drives the door along the track until, when it is fully open, a limit switch is operated by a ramp on the door to disconnect or reverse the motor. To prevent slamming, shock absorbers and buffers are fitted at both limits of travel.

Space is not always available for a sliding door to open into, and collapsible shutter gates may then be used. These have the advantage over sliding doors that since the whole gate does not move at the driving velocity the momentum is less, so that shock absorbers are not necessary and a collision is less likely to cause damage. The method of drive is similar, but as an alternative to a clutch the gates may be allowed to stop by detaching the driven picket from the chain. The leading picket is hinged on the second picket, so that when it meets an obstruction it rises and unhooks itself from the driving chain which continues to move, leaving the gate stationary. This safety device is not self-restoring and the gates must be closed by hand to reconnect the drive.

Some power-driven sliding doors, particularly those on lifts, are made to reopen automatically should they meet an obstruction when closing. A simple control for this consists of a soft rubber nosing on the leading edge of the door, containing an electric contactor. When the rubber is compressed, the contacts are made and energise the control circuit to reverse the door.

Another refinement provided with Underground Railway doors allows them to be forced open a few inches to permit a person who has caught his arm in the door to remove it. The short movement required is controlled by a spring on the door driving lever.

Sliding doors are usually awkward to open and close by hand, so that swing doors are preferable if it is necessary to use the doors when the driving gear is out of service for maintenance.

Swing Doors.

A successful mechanical linkage for swing doors is shown in Fig. **2**. The doors themselves are of the common two-leaf pattern arranged to swing open in one direction only, and the operating gear is mounted above the door lintel. An electric motor drives a large cam through a reduction gear; the cam follower drives a lever which twists two powerful springs mounted parallel with the lintel, and these drive two operating levers which open the leaves of the door. The purpose of the springs is to prevent damage should the doors open against an obstruction. When the doors are fully open, a limit switch attached to the cam shaft stops the driving motor by switching it off and applying an electro-magnetic brake which holds the doors in the open position. After a predetermined time interval, the brake is released and the motor drives the cam a little further in the same direction to its starting position where the linkage is released. Separate spring closers of the conventional pattern close the doors.

A modern equipment is shown in Fig. **3**. This employs the type of hydraulic component developed during the war for the servo controls of aircraft. Each leaf of the door is moved by a hydraulic jack (Fig. **4**). The jack cylinder is mounted on trunnions on the door lintel, and the piston acts on the top of the door near the hinge, as shown in Fig. **1** (*F*). Referring to Fig. **3** and the hydraulic circuit diagram shown in Fig. **5**, oil under pressure is applied to the piston rod

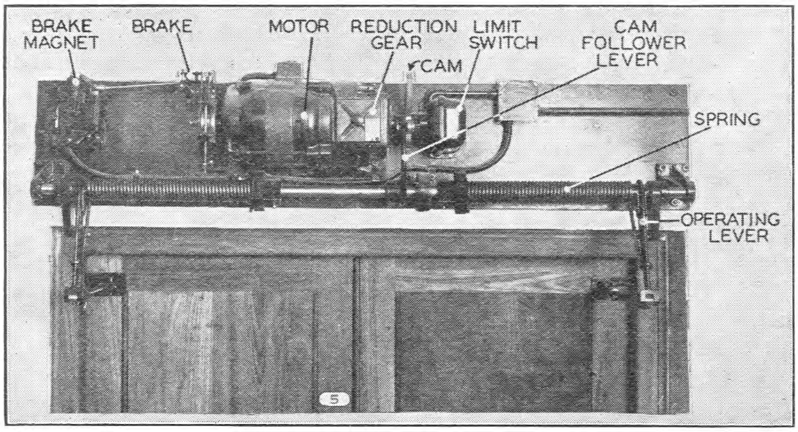

Fig. **2**.—Electro-Mechanical Opening Mechanism for Swing Doors.

Fig. **3**.—Hydraulic Power-Operated Door.

(A) Projector Lamp, (B) Oil Reservoir, (C) Pressure Switch, (D) Accumulator, (E) Rectifier for Control Valve Solenoid, (F) Control Valve, (G) Equalising Valve, (H) Jack, (J) Compressed Air for Accumulator, (K) Switch, (L) Pump, (M) Photo Cell Relay Equipment, (N) Photo-Electric Cell.

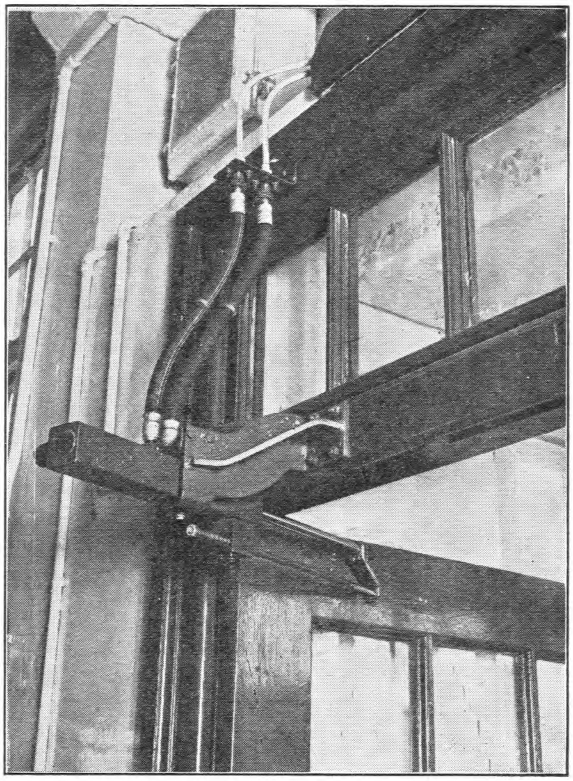

Fig. **4**.—Hydraulic Jack for opening Swing Door.

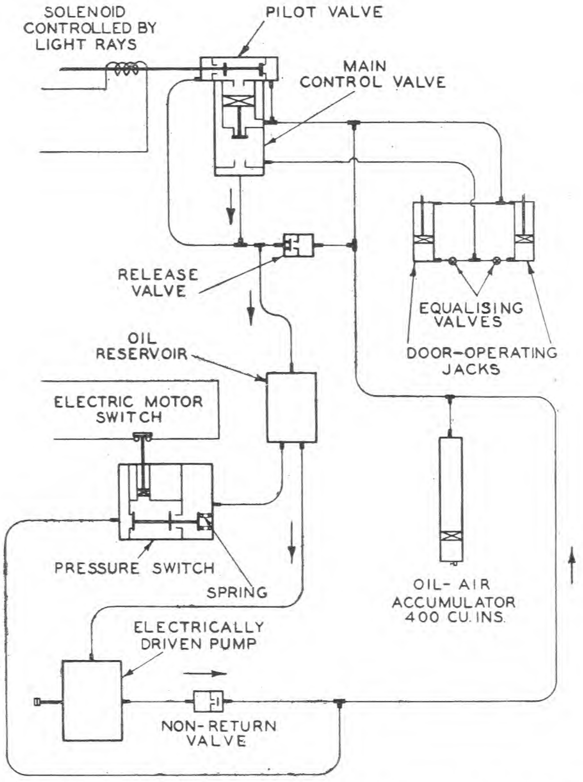

Fig. 5.—Diagram of Hydraulic Circuit for Power-Operated Door.

side of the jack pistons to hold the doors closed. To open the doors, oil under pressure is applied to the other side of the pistons as well. The opening thrust is caused by the difference in area of the two sides of the piston due to the size of the piston rod. Oil is supplied under pressure from the accumulator and is led to the jacks via the solenoid-controlled valve. Operation of this valve opens the doors immediately, even if they were closing. Each time the doors are closed, oil is discharged from the accumulator to the reservoir and the pressure in the system falls. The pressure switch is arranged to keep the oil pressure within the working limits. When the lower limit is reached, the switch operates to start an electric motor which drives the pump to re-charge the accumulator from the reservoir. When the higher pressure is reached, the switch disconnects the motor. The working pressure range is between about 350 and 250 lb. per sq. in., and the accumulator capacity is sufficient to operate the doors for 10 cycles of opening and closing. The accumulator is charged with oil against air pressure, and the lower pressure limit is set by charging the accumulator with compressed air from a cylinder. An air pressure gauge indicates the instantaneous working pressure.

When opening or closing under power, the doors can be stopped by a man without injury to himself or damage to the equipment, and if the power system is switched off the doors may be pulled or pushed open in the same way as ordinary swing doors, the jacks acting as self-closers. Equipment of this type may be applied to an existing hinged door so long as the door hinges and lintel are sufficiently strong to withstand the considerable stresses imposed by the jacks.

Methods of Control

Deliberate Control.

Remote operation is necessary whether the door is controlled by the passenger or by a doorkeeper. The passenger should be provided with a control in his pathway towards the door and at a sufficient distance from it to allow the door to open before he reaches it. The doorkeeper requires a control in the position where he is stationed to keep the doors under observation. For instance, the guard on an Underground train has his door controller in his compartment where he can reach it as he watches the passengers from his private doorway.

Push-buttons, requiring only momentary action, are suitable in conjunction with an electrical control circuit to initiate the door action. Passenger-operated doors need one control in each lane of approach and if there is no wall conveniently placed on which to mount a push-button, it may be set in the floor or a pull-switch mounted on the ceiling with a hanging chain to operate it. If the doors are not self-closing, additional controls for closing them must be placed in each lane of departure from the doorway.

The push-button contacts are made to control a self-locking relay which energises the opening gear, and in Fig. **6** are shown the control relays and contactors for a sliding shutter gate. In this example, the relay energises the driving motor contactor and limit

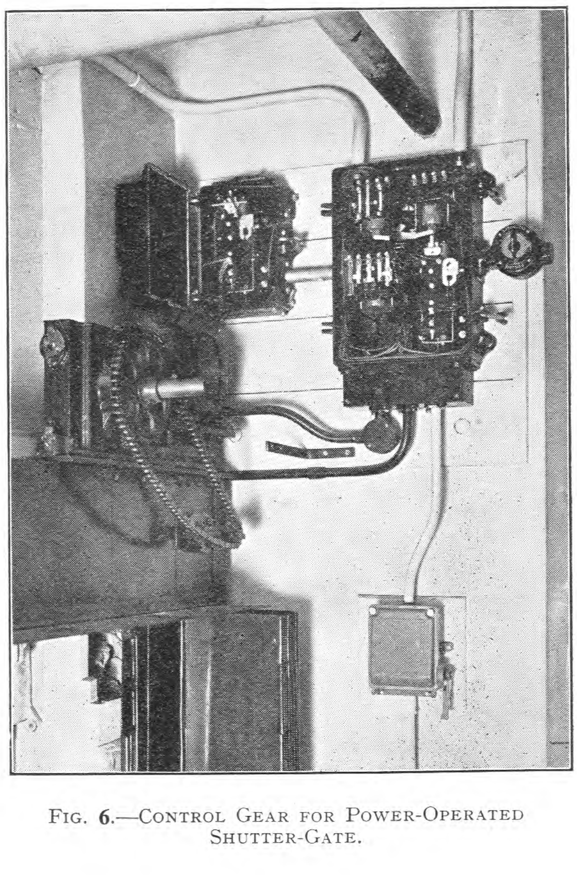

Fig. 6.—Control Gear for Power-Operated Shutter-Gate.

switches, operated by the gates, release the contactor at the limits of travel. Alternative push-button closing and automatic closing circuits are provided and one of the two eddy current time-delay relays, seen in the picture, times the interval between opening and commencement of closing of the door. There is a second timing relay because the push-button stations are at different distances from the door, and when the more distant "open" button is pressed, the door does not open until the passenger has approached nearer to it.

Push-button control circuits consume no energy when the doors are closed and are very simple to maintain. For this second reason alone, they may be preferred to the more delicate equipment required for automatic control. In general, automatic closing is better than passenger-controlled closing as the passenger may forget to press the closing button.

Automatic Control.

Photo-electric cells or vehicle-actuated pads, of the type used for traffic signals, can be used to control draught-excluding doors automatically. Pads are more robust than photo-cells and are suitable for vehicles, but for a pedestrian they are not automatic as he may step over instead of on the pad. The vehicle pad, or the light ray shining to energise the photo-cell, is placed where it must be run over or intercepted by the passenger and at a sufficient distance from the door to allow it to open in good time. Closing of the door can be controlled by another pad or light ray on the far side of the door, or by a timing relay. Thus, the maximum draught exclusion is ensured and the passengers proceed as though there were no door in the doorway.

For postal sorting offices, where traffic consists of a mixture of pedestrians and trucks, light rays are more suitable than pads, but the light ray projector must be placed where it will remain lined up on the cell, and both projector and cell must be protected from impact.

The doors shown in Fig. **3** are light-ray controlled, and a projector lamp is shown mounted on the ceiling and shining on a photo-cell which is under a glass plate in the floor. The cell is connected electrically in the grid circuit of a triode thermionic valve biased beyond its cut-off. Interception of the light ray causes the photocell resistance to rise, which neutralises the valve grid bias allowing anode current to flow. The cell relay is connected in the anode circuit, and this energises another valve circuit. The second triode, biased beyond its cut-off, has a resistance-capacitance time delay in the grid circuit. The cell relay makes a contact to neutralise the grid bias, allowing anode current to flow and energise the main relay in the anode circuit. One contact of this relay is connected in the door driving circuit and starts the doors opening. The main relay remains energised until the timing condenser has discharged through its resistance, when the valve grid cuts off the anode current and the main relay is released. Momentary interception of the light ray is sufficient to re-energise the time delay and main relay, so that a continuous stream of passengers will hold the door open indefinitely.

There is a small continuous energy consumption associated with light ray equipment, chiefly for the supply of the projector lamps, and, as these lamps are lit continuously, frequent replacements are required.

Layout of Door-Opening Equipment in Sorting Offices

Limitations of space in existing buildings usually prevent the installation of a simple system of fully automatic doors, and the best use of available equipment presents a number of problems.

Three or four seconds is needed to open an average door without unreasonable noise or shock so that an actuating light ray must be placed several yards from the door to allow approaching traffic to continue in motion after interception of the ray and while the door opens. Where mechanical vehicles and pedestrians use the door, the speed of approach will vary from about 1 m.p.h. for a man pushing a handcart to about 5 m.p.h. for an electric truck. A compromise must then be reached in siting the rays and setting the time-delay relays to allow each traffic item to pass through the doorway with the minimum delay and without holding the door open longer than necessary.

A simple layout is shown in Fig. **7**; the door leads

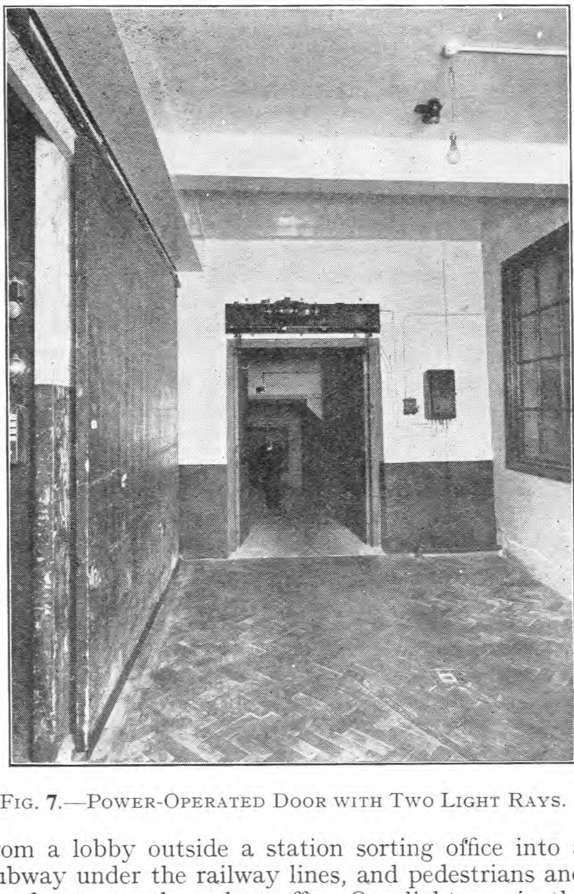

Fig. **7**.—Power-Operated Door with Two Light Rays.

from a lobby outside a station sorting office into a subway under the railway lines, and pedestrians and handcarts are the only traffic. One light ray in the lobby and another in the subway shine vertically in the track of approaching traffic, and where they may be avoided by traffic which has passed through the doorway. If the second ray is not avoided, the door is reopened just as it would normally commence to close. This difficulty may be overcome, where the approaches to a two-way doorway are narrow, by placing two light rays close together and arranging their relay circuits so that if light ray A, farthest from the door, is intercepted first the door opens, but if light ray B, nearer the door, is intercepted first it cuts A out of circuit for long enough to allow the passenger to intercept A without opening the door.

Referring again to Fig. **3**, the ray in the foreground is in the sorting office and liable to be intercepted by traffic which may pass across the doorway without intending to pass through; thus, the door may be opened unnecessarily. This can be prevented only by placing a barrier on each side of the ray so that it can be intercepted only by traffic approaching directly towards the door. Such a barrier would restrict manœuvring space in the sorting office, and for this reason push-button control is sometimes preferred. A truck leaving the sorting office may commence its journey from a point near the door, in which case operation of a push-button at that point would not delay the driver. But a push-button has the disadvantage that it can make no allowance for the length of a vehicle; the associated timing relay for closing the door times from the instant that the button is released by the passenger's hand or foot, whereas with a light ray the timing relay times from the instant that the ray is released by the back of the vehicle. Thus, with a light ray the time that the door is held open is automatically adjusted to the length and speed of the vehicle, and this is of some importance where an electric tractor towing several trailers uses the same door as individual pedestrians.

With the photo-electric cell placed under a glass plate in the floor, as shown in Figs. **3** and **7**, the light ray may be obscured by a piece of litter, accumulated dust or even by scratches on the glass, and the door will open and stay open incorrectly unless the glass plate is kept clear and clean, and replaced at regular intervals.

A more satisfactory layout would have separate power doors, one for an entrance and one for an exit, controlled by horizontal light rays, as shown in Fig. **8**. Such an arrangement, however, uses more space and does not completely exclude draughts from the office. For complete draught exclusion, it would be necessary to have each lobby with a door at each end arranged so that one is closed when the other is open. The lobby must be long enough to accommodate the largest vehicle and also to allow it to remain in motion while one door closes before the other opens. The minimum lobby length to permit a tractor and trailer measuring 17 ft. overall to travel through at three miles per hour uninterrupted would be 43 ft. and the controlling light ray would be 13 ft. away outside the door, so that the overall length of the whole arrangement would be 69 ft. At very few offices could so much space be made available.

Where there is a short corridor on each side of the door and one-way traffic is arranged, as in Fig. **8**, the light rays may be placed horizontally. This ensures that the passenger cannot fail to intercept the ray and the photo-electric cell is less likely to become obscured. The ray must shine at a low level, so that it will be intercepted by the wheels of a truck which might otherwise pass under it. In this position the projector lamps and photo-cells will be reached easily for maintenance, but must be protected from impact and from rain water if placed in the open.

Fig. **9** shows two power doors with a lobby between them. A long bridge happens to be placed outside the sorting office door with the lobby on it, but the doorway is not wide enough to allow traffic to pass in both

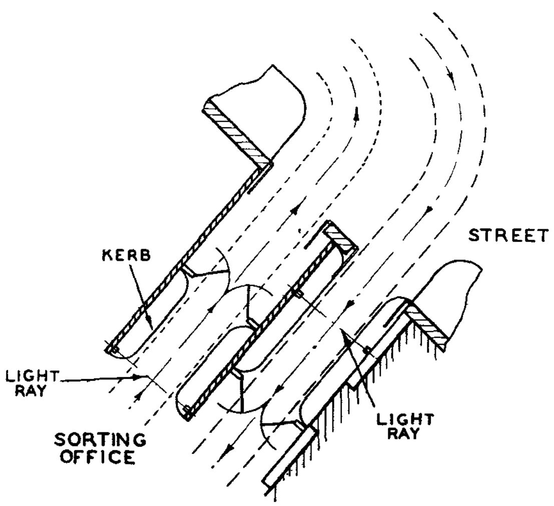

FIG. **8**.—A LAYOUT OF POWER-OPERATED DOORS WITH SEPARATE DOORS FOR EACH DIRECTION OF TRAFFIC.

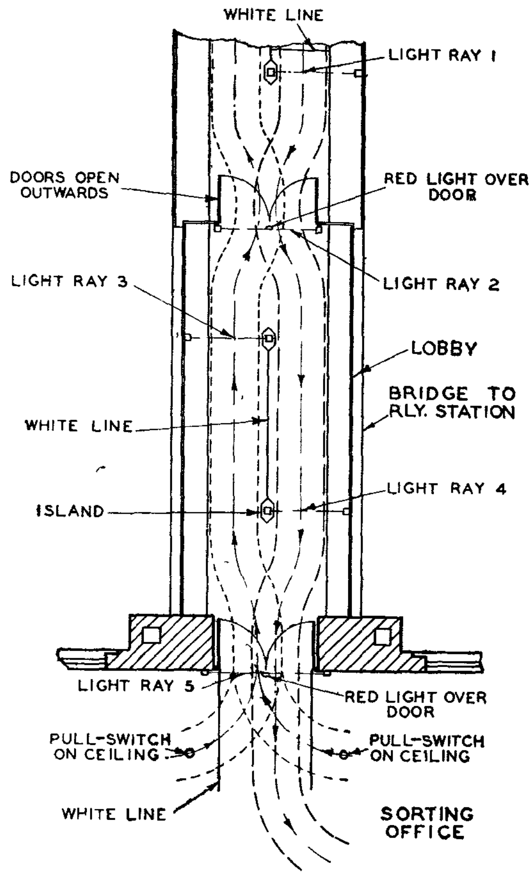

FIG. **9**.—A LAYOUT OF POWER-OPERATED DOORS WITH AN AIR-LOCK.

directions at once. Separate exit and entrance lobbies could not be provided, therefore, and incoming and outgoing traffic must take turns through the one lobby. This makes a signalling system necessary to indicate to outgoing traffic when incoming traffic is approaching in the lobby and vice versa. The red lights shown in the drawing over each doorway give these signals and are controlled automatically by the photo-cells. Five rays and photo-cells and two pull switches control the doors, pull switches being chosen instead of light rays in the office for the reason mentioned earlier. For incoming traffic, light rays 1 and 4 open the outer and inner doors respectively, and light ray 3 opens the outer door for outgoing traffic. Rays 2 and 5 are to prevent the doors from closing on a vehicle delayed for any reason in the doorway and to ensure that the door closes as soon as the vehicle is clear of the ray. Both doors open outwards only, in order that winds shall tend to keep them closed.

Post Office Installations

The first installation was made at Redhill Station Sorting Office in 1935, and the whole equipment remains in service at the present time. It consists of driving gear, as shown in Fig. **2**, for two double-swing doors controlled by light rays, and one of these doors with its projector lamps is shown in Fig. **7**. The other door is similar and leads from the sorting office on the right into the lobby from which the photograph was taken. The postman seen in the picture is approaching from the railway subway and entering the lobby. On the left may be seen an entrance to a lift to the station platform and a manually operated sliding door for closing it. When the sliding door is closed the automatic doors are effective in excluding draughts from the sorting office, but when the lift is in use the lobby no longer provides an air lock. Also the traffic lanes between the three doorways overlap so that sometimes one of the light rays in the lobby is intercepted by traffic which does not intend to pass through the associated door which is then opened unnecessarily. In spite of these difficulties, the installation has given useful service for many years.

In 1939 and 1940 several installations were made using hydraulic equipment of an unusual pattern for swing doors. Each door leaf was mounted on pivot hinges in the lintel and floor, and the lower pivot was attached to a rectangular vane below the floor, enclosed in a chamber shaped as a segment of a cylinder. Oil under pressure was introduced into the chamber on one side of the vane to revolve it in the chamber and so open the door. Many faults occurred, chief among which was leakage of the operating oil, due to the difficulty of providing an adequate seal between the edges of the vane and the inner surface of the chamber. Due to difficulty in obtaining spare parts during the war, the equipment was taken out of service, but one at Birmingham H.P.O. has since been restored and the associated light ray equipment has been modified to permit interruption of the light rays by traffic from either direction without incorrect opening of the doors.

In 1949, two new installations were made at Leicester and Woking Station Sorting Offices using hydraulic equipment especially developed from the type of equipment used for aircraft servo-mechanisms. Fig. **3** shows the Leicester door which is described earlier, and the Woking equipment is similar but push-button controlled.

An automatic sliding door was installed at Reading H.P.O. in 1937, and in 1949 a pair of sliding shutter gates was added. Fig. **6** shows the driving and control gear for these gates, which are used in conjunction with the older door by electric trucks and trailers travelling between the H.P.O. and the railway station.

All recent installations are for single doors excluding lobbies as, in most cases, space would not permit a more elaborate arrangement, but proposals for new installations include the schemes shown in Figs. **8** and **9**.

Conclusion.

Power-operating gear for a sorting office door makes it possible to move mail-laden trolleys and electric trucks through the doorway without delay, inconvenience to the postal staff or damage to the door and while restricting draughts through the doorway to the minimum. Clear space is necessary on each side of the door, and for complete draught exclusion a long lobby with doors at each end is essential. Separate entrance and exit doorways are desirable to allow a free flow of traffic and permit the use of simple control equipment.

Book Review

"Telecommunications and Equipment in Germany During the Period 1939-1945." (British Intelligence Objectives Sub-Committee Surveys Report No. 29.) His Majesty's Stationery Office, 1950. 55 pp. 1s. 8d. (post free).

This survey has been prepared by a number of expert officers of the Engineering Department of the Post Office from studies of the mass of British, Combined and Joint Intelligence Objective Reports and Field Intelligence Agency reports which have already been published separately by H.M.S.O.

Lists of these reports are included in the survey which has therefore an important value for permanent reference.

The report itself includes sections on Research, Transmission, Exchange Equipment, Telegraphs, Subscribers' Apparatus, Power and Radio and these make easy and interesting reading. Where appropriate, comparisons of policy and techniques with British practice are made, including some interesting comments on subscriber-dialling. Although there are many items and advances mentioned which obviously warrant study in detail, it seems clear that war-time difficulties of dispersal and shortages of materials and manpower caused telecommunication development on the whole to mark time and lose ground relatively to the Allies.

Published at a nominal price, this report is in general a valuable contribution to the literature and history of the telecommunications industry and in particular a useful bibliography of papers describing German war-time techniques and developments.

L. H. H.

Edinburgh Conversion from Non-Director to Director

W. V. McWALTER†

U.D.C. 621.395.34

Over a period of approximately 12 years, the Edinburgh telephone system is to be completely converted from non-director to director working. An auto-to-auto transfer of this magnitude raises many complex problems since disturbance to subscribers must be kept to a minimum over the whole of the period. This article outlines the conversion plans and exchange programme involved and gives details of the first stage which has been completed by the opening of the George Street, 7,000-line director exchange.

Introduction.

AT 1.15 p.m. on 25th March, 1950, a 7,000-line director exchange (George Street) was cut into the Edinburgh local telephone network, and with it came the introduction of director code dialling by non-director subscribers. This was a key point in the first conversion in the country of a complete non-director area to director working.

In 1945, the area was served by 13 exchanges, using a linked numbering scheme within the five-digit range, and had a working multiple of 42,400. Development figures for 1955 required a multiple of 63,700. With accommodation and spare numbers seriously inadequate, discussions, which had been interrupted by the war, were resumed as a matter of extreme urgency. Within a few weeks plans were prepared and approved in principle for the complete conversion, over a period of approximately 12 years, from Siemens 16 (S.16) to director equipment.

THE CONVERSION PLAN.

The plan was based on the principle that subscribers should have the simplest possible inter-dialling arrangement and should not be inconvenienced by more than one number change throughout the whole of the conversion period. It provided for the adoption of a scheme which entailed only one arbitrary code (21). This would be used by all director subscribers when dialling a five-digit (non-director) number and, along with the first digit of the five-digit number, would form the routing code from the director exchange to the 2nd selector in the S.16 network. For calls that would be routed via the S.16 main exchange, the last routing digit, being the first of the five-digit number, would be repeated into the 1st selector of the S.16 main exchange. All S.16 subscribers would dial either the five-digit number, or the director code and four-digit number shown in the directory.

The agreed scheme required the provision of director type dial number plates on all dials in the area. It also required that the route of the numerical equivalent of the director codes used should be free in the S.16 network so that the 3rd selector level chosen by the first three letters of the director exchange name could be routed to 1st numerical selectors in the director exchange.

Fortunately, Post Office accommodation in George Street, in close proximity to the main exchange, could be made available for equipment. During the war, the floor had been reinforced to make the basement an air raid shelter for the exchange staff and therefore had the strength necessary for automatic exchange equipment. While the premises were not ideal for the purpose it was decided to install a director exchange to the maximum capacity of the ground floor and to use this, by transferring subscribers from the existing system to clear essential space in the S.16 main exchange and to free the numerical equivalent of the director codes of the most urgently required director exchanges.

The number of 10 ft. 6 in. equipment racks that could be installed on the ground floor of the George Street building was decided, and from this the size of the director multiple that could be provided was determined. It was estimated that 7,000 multiple and the necessary calling and intermediate equipment could be accommodated. When the capacity of the accommodation with the clear height necessary for equipment had been decided, ways and means of providing power, intermediate distribution frames and all other miscellaneous requirements were devised.

In addition to the accommodation problem in the main exchange area, several satellite exchanges were nearing exhaustion. A review of the satellite areas adjoining the main area indicated the need for additional exchanges to reduce each exchange area to within the 10,000 multiple capacity of a director exchange. Three additional exchanges appeared to be necessary and the areas concerned are shown in Fig. 1 as F, D, and P, superimposed on the 1945 exchange area map. This proposal entailed three new buildings, but the prospect of obtaining these was so poor that it was decided two must suffice for a number of years, the third to be built later. Names for the two new exchanges were chosen (Dean and Fountainbridge), and the areas they would serve were defined. Both would take in parts of the existing main exchange area.

Since one purpose of the 7,000-line director exchange in George Street was to free accommodation and director code levels in the existing main exchange, it followed that blocks of equipment had to be made spare and that the numbers to be transferred would have to be in numerical sequence, not chosen on a geographical basis. To meet the condition that there would be not more than one number change for each subscriber throughout the conversion period, the blocks of numbers to be transferred were divided into three groups according to geographical location and allocated numbers in the George Street director exchange which they will retain when ultimately transferred to the new exchanges, Dean, Fountainbridge and Central. The main exchange area, meantime, would take the name Central for director

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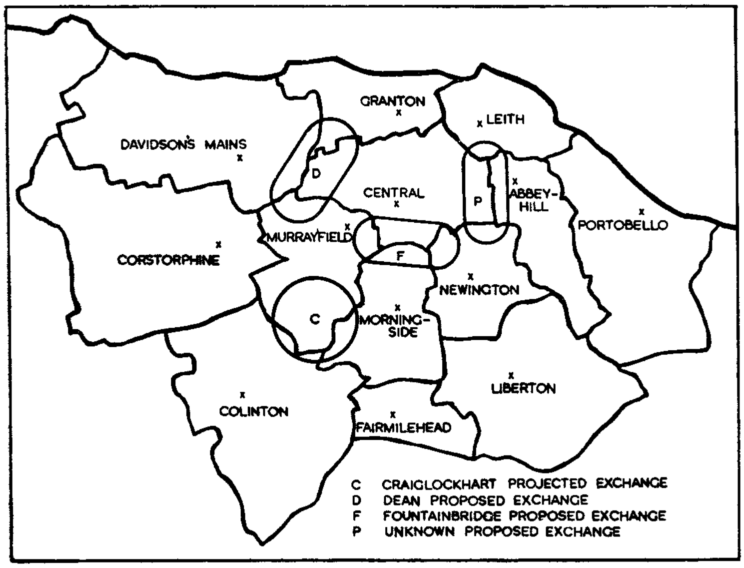

FIG. 1.—EDINBURGH MULTI-OFFICE AREA.

subscribers. The cut-in of the George Street director exchange therefore brought into use three new exchange names; CENtral, DEAn and FOUntainbridge, the latter two working as hypothetical exchanges on CENtral.

A notable point is that while it would have been very desirable in many respects to have had a new exchange in a new building, it would not have served the purpose which this three-name exchange has served, as it would have been so remote from the main exchange that it would have been necessary to transfer on a strictly geographical location basis. This would have made small groups of numbers spare, not blocks of equipment or director code levels.

While the discussions which culminated in the decision to convert to director were proceeding, plans for the installation of S.16 equipment at Craiglockhart, a new satellite exchange area, were going ahead (circle C, Fig. 1). The S.16 equipment had been manufactured before the war and stored, and the building for it had also been completed before the war. The decision to convert Edinburgh to director working, however, made it desirable to revise the plans for this particular exchange. As it was required for the spring of 1946, it was agreed that director equipment, manufactured before the war and stored in Glasgow, should be used to equip Craiglockhart as the first director exchange in Edinburgh. It was obviously impossible to introduce the agreed dialling scheme in the time available and an arbitrary two-digit code (70) was accepted as the route from S.16 to Craiglockhart director. The director installation was duly completed by the A. T. & E. Co., and the S.16 equipment which was originally intended for Craiglockhart was used to extend other S.16 exchanges in the area.

For Fairmilehead, an immediate pre-war S.16 exchange, an order for the first extension had been placed. This being a comparatively new exchange, a fair amount of spare space was available, and draft layouts showed that sufficient director equipment to replace the existing equipment and provide for the immediate future needs could be installed instead of extending the S.16 equipment. Immediate steps were therefore taken to install director equipment and again an arbitrary two-digit code (59) was accepted for routing from the S.16 network.

Further, to meet development it was necessary to equip three relief manual exchanges in the area. The names for these exchanges were chosen to have the first three letters corresponding to available numerical codes so that in the pre-director dialling period access would be by numerical code which could be changed to three-letter code dialling without any route changes.

Thus, prior to the opening of the George Street director exchange, two two-digit and three three-digit codes were in use and all were replaced by the first three letters of the exchange names simultaneously with the introduction of the new exchange. The objective dialling scheme has thus been achieved.

THE GEORGE STREET TRANSFER.

George Street Exchange.

Some 5,200 subscribers were transferred from the old main exchange to the new George Street exchange, installed by the G.E.C. Although the amount of work involved was small by comparison with many other transfer schemes which have been put through in the past, some aspects warrant special mention.

The basement of the new exchange consists of a number of small rooms, the dividing walls being also main supporting walls which could not be removed. In the largest room, which has a maximum height of 10 ft. 10 in., with only 9 ft. under beams, and is 11 ft. 9 in. wide, the subscribers' intermediate distribution frame of 37 verticals occupies the full length with a clearance of 2 ft. at one end and 4 ft. 3 in. at the other. In spite of the very restricted space, the cabling is a fine example of the art, and the installer is to be congratulated on the great ingenuity displayed.

The line side of the I.D.F. is cabled to a locally-made protector frame located in a smaller room, separated from the I.D.F. room by a passage and stairway. The protector frame is equipped with normal protectors on both sides and the line side of the protectors is cabled to the exchange side of the main distribution frame serving the S.16 main exchange, where the cabling terminates on tag blocks, 600 circuits per vertical. Between the two frames paper insulated cables, all 200-pair, were laid across a public lane, 21 ft. wide. This method was adopted to make use of the present terminations of subscribers' cables and to conserve space on the exchange side of the M.D.F.

The junction I.D.F. is located near the protector frame, while test jack frames and ringing machines are in another room in the basement. Power is supplied from the power room in the old exchange, an existing 50V supply from the main 60V plant being increased by the installation of additional machines.

Siemens 16 *Main Exchange* (*Rose Street*).

The S.16 main exchange is located on two floors of a building which was first used as a C.B. manual exchange and District Manager's office, and is now used for the joint trunk exchange and the repeater station as well as the automatic exchange. The ground floor has the necessary height for 10-ft. racks, but on the second floor there is height only for 8-ft. racks.

The building contains equipment for 13,300 lines, junctions to and from 12 satellite exchanges, and the terminal equipment for a complete group and zone network, and free space is severely limited. By rearrangement and concentration of switches, space was made available for the 400 leg-to-loop relay sets required on the junctions to director exchanges, but it was not possible to find space to install racks for loop-to-leg relay sets and incoming selectors required on junctions from director exchanges. Therefore, an alternative method of termination was devised.

In the S.16 main exchange the subscribers' 1st selector accepts loop impulses and, as 5,200 subscribers were to be transferred, a considerable amount of originating traffic would be withdrawn. An examination of the number range to be transferred and the divisions affected by the withdrawal of originating traffic indicated that the 1st selectors serving three full divisions and one partly-equipped division could be made spare, by rearrangement of subscribers in the divisions. Extensive rearrangement was necessary to make one of the divisions spare, but the others were fairly simple, rearrangement of only a small number of subscribers being involved. Subscribers not involved in the transfer to the director exchange were eliminated from these divisions by rearrangement to other divisions, so that, on the withdrawal of the main frame pegs to disconnect from the old exchange, all traffic to the 1st selectors would stop. The 1st selectors, having been connected prior to the transfer, via a line reversing relay, to the banks of 1st code selectors and modified so that metering conditions would

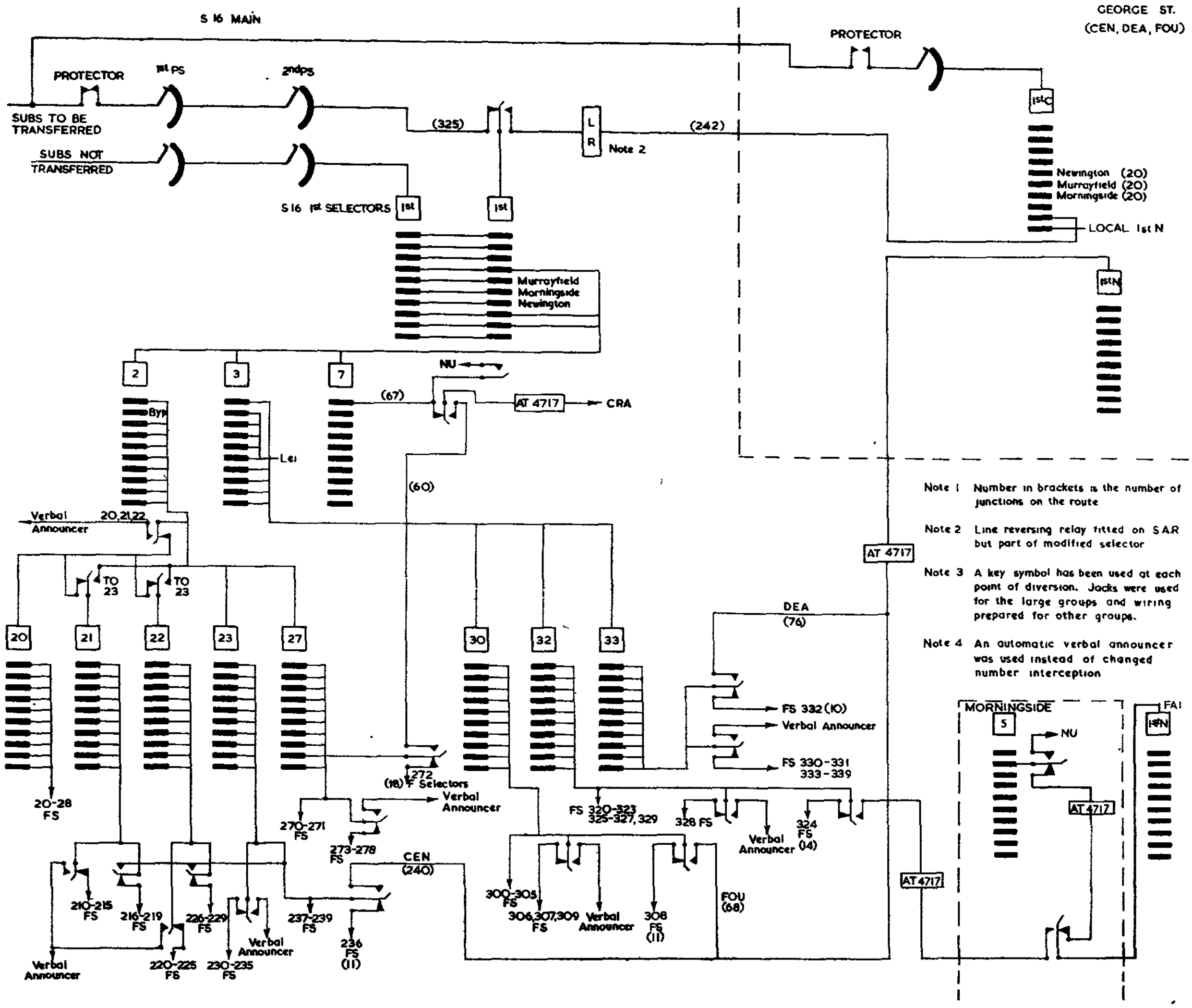

FIG. 2.—SKELETON TRUNKING DIAGRAM SHOWING DIVERSION POINTS FOR TRANSFER OF 5,200 SUBSCRIBERS FROM S.16 MAIN EXCHANGE TO GEORGE STREET DIRECTOR EXCHANGE.

operate the line reversing relay, were ready to accept traffic from the director exchange to the S.16 network. The number of selectors which were modified in this manner was 325. As a precaution against the possibility of an odd subscriber having been missed from the necessary rearrangement, all 2nd preselectors concerned were engaged as a transfer operation. Fig. 2 shows, in skeleton form, the trunking arrangements associated with the transfer, key symbols being used to indicate diversion points although keys were not actually used at all such points.

The initial digit 4, 5 or 6 of 5-digit numbers determines the destination of the call: Newington (4), Morningside (5), Murrayfield or Corstorphine via Murrayfield (6). As this initial digit is part of the routing code (21) 4, (21) 5, (21) 6, the director can route such calls to the objective exchange. Incoming selectors at these exchanges have therefore been modified to accept loop impulses and transmit back to the director a reversal, delayed to avoid metering on "busy," when the call matures. This scheme, which was proved satisfactory on a working route (Craiglockhart-Murrayfield) before the main transfer, has the advantage that it diverts traffic from the main exchange. Manual hold and other facilities provided by the loop-to-leg relay set are not required on calls from director to S.16 subscribers.

Prior to the transfer, the five 3rd selector levels which were to be used after the transfer to route calls from the S.16 network to the director exchanges were wired and equipped to carry traffic to the 500 final selector multiple concerned. Immediately after the transfer, however, they would be required to carry traffic to 10,600 director lines, CEN DEA FOU 7,000, CRA 2,400 and FAI 1,200. This called for the provision of switching facilities which could be used to expand rapidly the traffic-carrying capacity of the groups and divert the levels to the 1st numerical selectors in the director exchanges.

Level 236 presented the biggest problem, as before transfer it was routed to 11 final selectors whereas after transfer it carried 240 junctions. Level 23 was completely recabled to a new T.D.F. to provide the necessary number of groups to take the 330 switches required on that level. Additional switches were diverted from ceased levels 22 and 21. The pre-transfer grading was formed, and jumpering for the extended grading prepared, before the transfer. During the week-end immediately after the transfer, the new grading was formed.

Level 236 was recabled to a new T.D.F. and level 6 of the 3rd selectors in the 22 and 21 groups which were to be used to increase the 23 group was also wired to this T.D.F. Here jumpers were set but not connected; instead, the individual circuits were cabled to a change-over frame where each circuit was connected to two jacks. The inner springs of one set of jacks were commoned to reduce the grading to the 11 final selectors and the jacks were left without pegs. The other set of jacks was pegged and the inner springs wired to leg-to-loop relay sets connected to junctions to the director exchange. As a transfer operation pegs were inserted to cut the common from the individual circuits and pegs were withdrawn to connect to the leg-to-loop relay sets. The arrangement was complicated by the fact that levels 6, 7, 8 and 9 of the 21 and 22 groups, which were being transferred to the 23 group, had to be diverted to 236, 7, 8 and 9. Other levels were dealt with, in principle, in the same way. Fig. 3 shows, in simplified form, the trunking diagram for the Rose Street exchange on completion of the transfer.

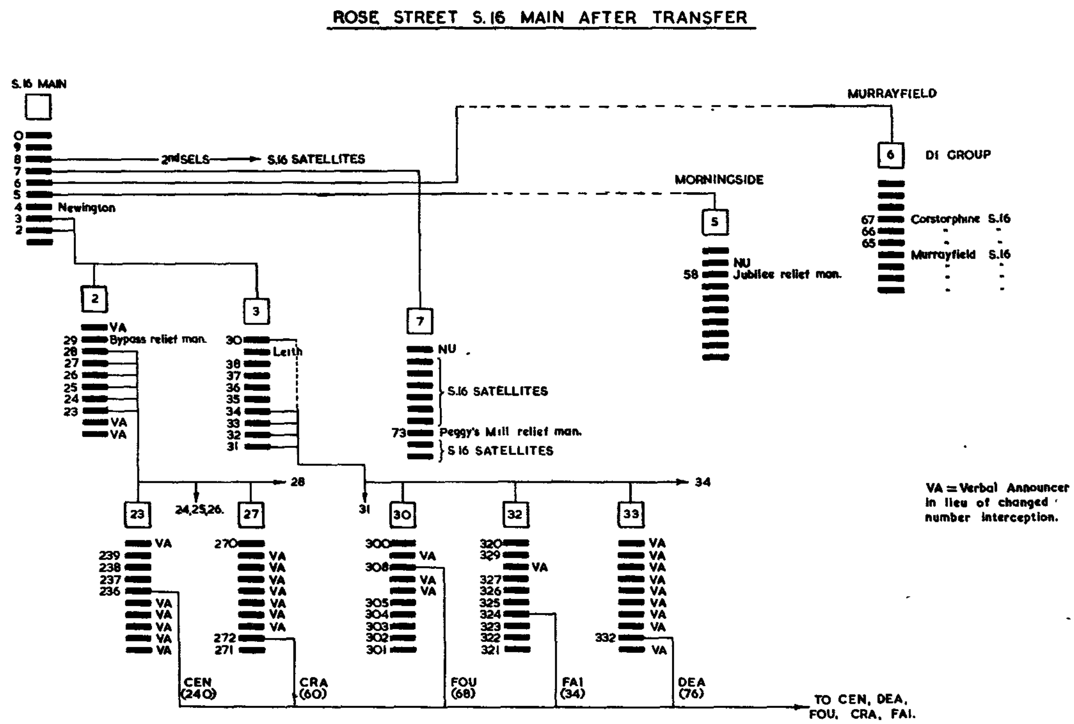

FIG. 3.—TRUNKING DIAGRAM OF ROSE STREET (S.16 MAIN) AFTER THE TRANSFER.

Changed-number Arrangements.

The lack of accommodation was responsible for the introduction of a novel " changed number " facility. Normal changed number facilities could not be provided, and for a period it was thought that " N.U. tone " was the only solution, but the suggestion was made that a verbal announcement might be the solution. This suggestion was pursued and with complete co-operation between the various branches concerned at Area, Regional and Headquarters level, an E.M.I. Tape Recorder and a Provincial Distribution Speaking Clock Amplifier were provided. A competition was run among the local telephonists to choose one with the most suitable voice to make a record to tell subscribers who dialled transferred numbers, " The number you are calling has been changed. Will you please consult the new telephone directory."

FUTURE CONVERSION PROGRAMME.

The next stage in the conversion is the provision of the first instalment of the new permanent director exchange which will replace the old S.16 main exchange in the Rose Street building. This will be a 2,100-line exchange installed in part of the space made available by the transfer of 5,200 subscribers to George Street.

The first of the new exchange buildings, and a key point in the conversion to director, is nearing completion at Fountainbridge. This will be equipped with a 7,300-line director exchange and the director area tandem exchange. More or less simultaneously with this, Abbeyhill director exchange will be installed in an extension to the existing Abbeyhill exchange building.

George Street subscribers with DEAn and FOUntainbridge numbers will be transferred to the Rose Street director and the permanent Fountainbridge exchanges respectively, Rose Street director taking the name DEAn temporarily. All the remaining Fountainbridge area subscribers from the S.16 main and adjacent satellites will go to establish, in its permanent form, the Fountainbridge exchange. Abbeyhill may be ready for service about the same time as Fountainbridge permanent exchange and will probably be converted at the same time. The subscribers in the next 2,300 S.16 multiple to be cleared will be divided on a geographical basis and transferred to director equipment in Rose Street and George Street.

As the third additional exchange, in the central area, will be required in the near future (the name WAVerley has been chosen), and it has been agreed that the name CENtral will be changed when the third new building is ready (name not yet decided), it is probable that George Street will continue as a three-name exchange until the Dean permanent exchange is ready for service. The use of the name WAVerley and the name to replace CENtral will avoid the use of CENtral for new subscribers and those converted on future transfers.

Following the recovery of the 2,300-line S.16 main exchange, an additional 2,400-line director equipment will be installed in the Rose Street building, making a total of 4,500, and when this is ready for service it is hoped that Dean permanent exchange will also be available. All the Dean subscribers will then be transferred to the new Dean exchange, leaving the whole of the 4,500 director multiple in Rose Street to accommodate the next group of S.16 main exchange subscribers to be converted. At this stage, the Rose Street equipment will take the exchange name WAVerley.

With a 7,000-line director exchange in George Street, and a 4,500-line director exchange in Rose Street, all the S.16 subscribers' equipment on the ground floor at Rose Street will be recovered, thus making space available for the extension of the Rose Street (WAV) director equipment to cater for the conversion of the remaining S.16 main exchange subscribers and those that may still be connected to the relief manual exchange serving the central area.

When the third new building is provided in the area marked P (Fig. 1) and the equipment is ready for service, subscribers will be transferred from the George Street exchange. The equipment installed in George Street will then be recovered.

Fig. 4 shows in block schematic form the various stages in the conversion of the Central area. The plan is subject to revision if the building or equipment programme is not maintained or the forecast development alters.

The 1945 multi-exchange area will be extended, during the conversion period, to include Musselburgh, an exchange area adjoining Portobello. This precludes the use of the name Murrayfield shown on the exchange area map, but as Murrayfield is only a Departmental name at present, subscribers having Edinburgh numbers, no serious controversy should arise on this point. Another name has been suggested, but alternatives are still under consideration.

Owing to an accommodation problem in the Morningside area consideration is being given to the introduction of another exchange in the area to replace the existing manual relief exchange, Jubilee, shown on the trunking diagrams.

The dialling scheme adopted imposes certain limitations on the order of conversion, requiring as it does the conversion of subscribers having numbers with the first three digits equivalent to the alphabetical code of a director exchange before that exchange can be converted. Thus, Murrayfield on level 6 must be converted before calls to Morningside and Newington can be routed via MOR (607) or NEW (639). Newington on level 4 must go before Granton, GRA (472), and Morningside on level 5 before Leith, LEI (534). When the plan was prepared this disadvantage caused no great difficulty as the conversion programme based on exhaustion of number range and availability of accommodation fitted into the scheme and no serious difficulty has yet become apparent.

Table I shows the exchanges outside the main exchange area which have still to be converted.

Conclusion.

The conversion of a complete non-director area to director working should be firmly based on a scheme which eliminates, as far as possible, the use of codes which are not shown against each subscriber's number

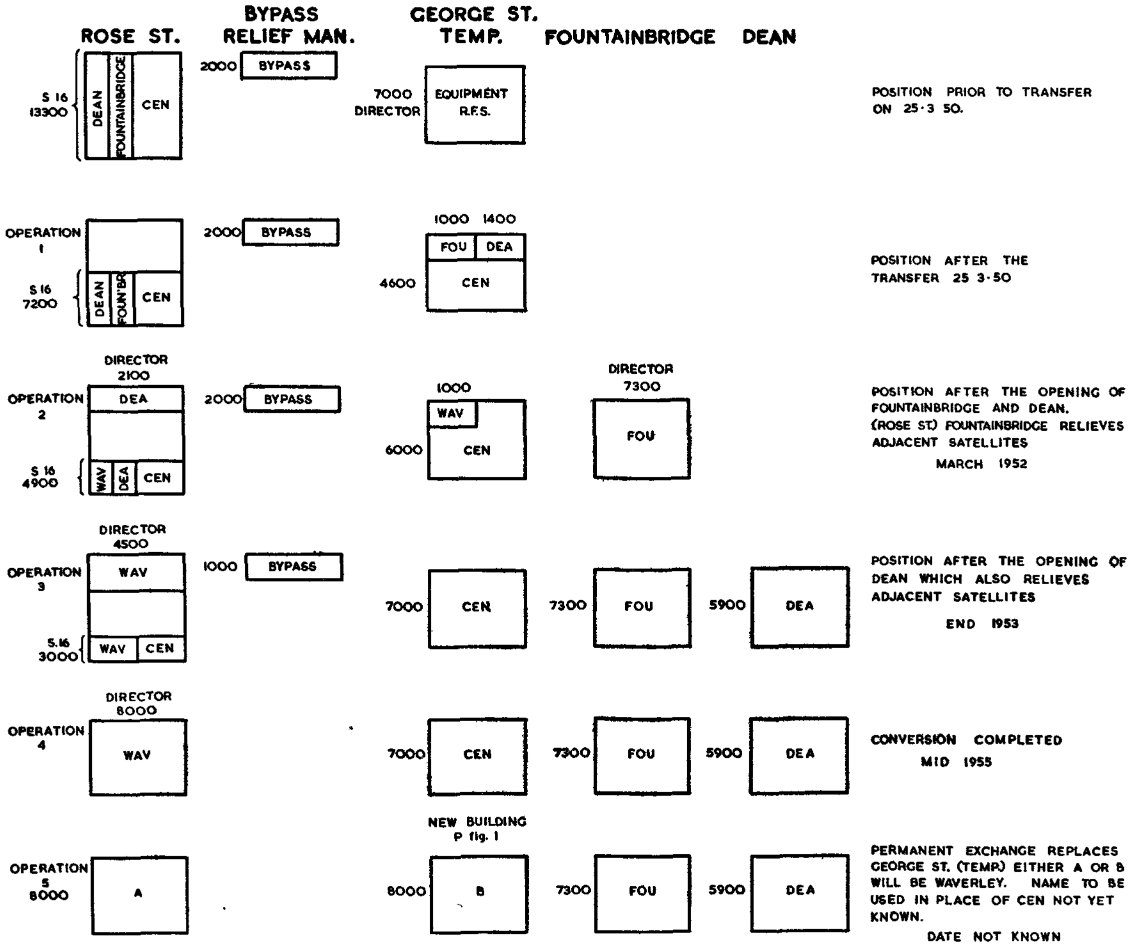

FIG. 4.—STAGES IN THE CONVERSION OF THE CENTRAL AREA TO DIRECTOR WORKING.

TABLE I.

Exchange in order of conversion	S.16 subscribers' dial	Remarks
Director Area Tandem	—	March, 1952.
Abbeyhill	ABB (222)	March, 1952.
Portobello	POR (707)	
Corstorphine	COR (207)	
Musselburgh .	"O"	As Musselburgh is excess fee from S.16 exchanges, MUS (687) will be intercepted to "O." Director exchanges dial MUS.
Ravelston . .	RAV (728)	Replace Murrayfield S.16 exchange. Alternative names under consideration.
Additional Exchange, Morningside Area	Name not chosen	If found necessary to replace Jubilee relief manual exchange.
Woodcroft Jt. Tk. .	"O"	Includes Trunk and Toll Tandem.
Davidson Mains .	DAV (328)	Opens after DEAn permanent as some 800 subs transfer from this area to Dean
Morningside	MOR (607)	
Newington	NEW (639)	
Liberton	LIB (542)	
Colinton	COL (205)	
Leith	—	Conversion completed Target Date, 1957
Granton . . .	—	Conversion completed Target Date, 1957

in the directory and there should be some obvious distinction between telephones connected to non-director exchanges and those connected to director exchanges, as it is not possible for director subscribers to have the same dialling instructions as non-director subscribers. It is also desirable to avoid having subscribers connected to non-director levels which are the numerical equivalent of director codes. It will be appreciated, however, that the availability or lack of accommodation may be a deciding factor when considering the policy to be adopted.

A conversion of this type is both extensive and complicated and credit is due to the Edinburgh Area staff for the very efficient way in which the conversion work has been carried through to date. Much work remains to be done, however, and no doubt other novel ideas will occur during detailed planning and contribute towards a speedy and successful completion of the whole of the complex operation now in progress.

Acknowledgments.

The author thanks his colleagues in the Telecommunications and Engineering Branches of Post Office Headquarters, Scotland, for suggestions and assistance in the preparation of this article.

A Survey of Modern Radio Valves

W. J. BRAY, M.Sc.(Eng.), A.C.G.I., D.I.C.†

Part 6(a).—Valves for Use at Frequencies Above 3,000 Mc/s

U.D.C. 621.385 : 621.396.615.14

In this concluding part of the series*, the principles of operation, methods of construction and characteristics of low-power oscillator and amplifier valves suitable for use in radio and wave-guide relay systems operating at frequencies above 3,000 Mc/s are described. The valves referred to include klystron amplifiers, travelling-wave and electron-wave amplifiers, grounded-grid triode amplifiers, klystron oscillators and continuous-wave magnetrons. The suitability of the oscillators for amplitude, frequency or pulse modulation is discussed.

Introduction.

THIS part of the survey of modern radio valves is mainly concerned with low-power valves suitable for use in single or multiple-link radio relay systems operating in the frequency bands around 4,000 and 6,000 Mc/s allocated at the Atlantic City Conference (1947) for civil communication purposes. Some consideration is also given to valves operating at frequencies of the order of 30,000 Mc/s, such as may be used in the more distant future in long-distance relay systems using waveguides.

In radio relay systems operating at frequencies above 3,000 Mc/s the aerials employed are of high gain, the links are usually less than 40 miles long and the radio paths are unobstructed. Under these conditions transmitted powers of a few watts or less are sufficient to provide the required signal-to-noise ratio. The transmitter usually consists of a low-power oscillator followed by an amplifier, since a low-power oscillator is more readily stabilised in frequency and modulated than is a high-power oscillator. Low-power oscillators are also needed for frequency changing in super-heterodyne receivers.

Although the power output required from transmitting amplifiers is only of the order of a few watts, it is desirable for the efficiency to be reasonably high, e.g. 10 per cent. or more, to reduce the power required from the high-tension supply—an important factor in systems with unattended stations. As already explained in the preceding article[1] in this series, with conventional valves of the space-charge control type the power output, efficiency and gain decrease as the frequency is increased owing to limitations imposed by (*a*) the transit time of the electrons, and (*b*) the effects of the inductance of leads to the electrodes. These limitations can be minimised by using grounded-grid triodes with very small clearances between the electrodes[2]; but for practical purposes the useful upper limit of frequency is at present about 4,000 Mc/s for amplifiers capable of about a watt output with an efficiency approaching 10 per cent.

Although some improvements in these figures can be expected it is apparent that for frequencies much above 4,000 Mc/s valves of a fundamentally different type are needed to obtain adequate gain, power output and efficiency. Fortunately, for frequencies above about 2,000 Mc/s, it is possible to use valves of the velocity-modulation (V.M.) type [3, 4, 5] as amplifiers, oscillators and frequency-multipliers, typical valves being klystrons and travelling-wave valves. In V.M. valves use is made of the fact that the electrons take an appreciable time to travel from the cathode to the collector electrode. The electron beam is first modulated in velocity by the applied radio frequency signal with the result that as the electrons move along they become bunched, i.e. the amplitude of the beam current at a given point varies at radio frequency and the electron beam is capable of delivering power to the output circuit. In addition to the V.M. valves, magnetrons are available as efficient oscillators for continuous-wave (C.W.) or pulse-modulation (P.M.) systems.

Valves may be classified under two main headings:
(i) those suitable for use as amplifiers but which may be made to oscillate by the provision of an external feed-back path; and
(ii) those with internal feed-back, or its equivalent, which are suitable for use only as oscillators.

Amplifier Valves

Velocity-modulation Klystron Amplifier.

A double-resonator klystron amplifier is shown in simplified form in Fig. 1; it consists essentially of two cavity resonators, *a* and *b*, termed the "buncher" and "catcher" respectively, which are traversed by an electron beam. Each of the resonators shown consists of a toroidal metal enclosure with two plane surfaces separated by a narrow gap (*c*, *d*) at the centre, each surface having a hole in the centre to permit the passage of the electron beam. In practice, however, the resonators may be other than toroidal, and in some valves the holes through which the electron

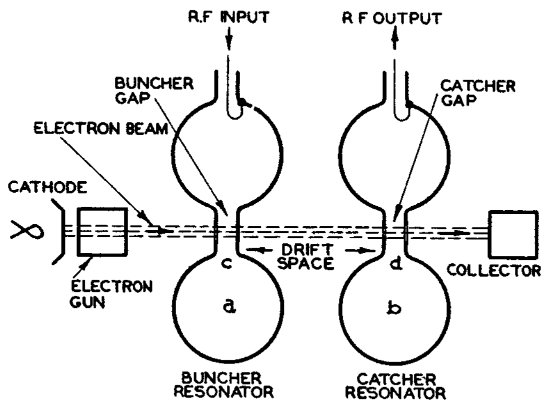

FIG. 1.—SIMPLIFIED SKETCH OF DOUBLE-RESONATOR KLYSTRON AMPLIFIER.

†Assistant Staff Engineer, Radio Experimental and Development Branch, E.-in-C's Office.

*Because of printing difficulties it has been necessary to publish Part 6 in two sections.

beam passes may be spanned by a rudimentary grid instead of being completely open. When the buncher is excited by radio frequency power fed in by means of a suitable coupling loop or probe, a relatively strong alternating electric field is set up across the narrow gap, provided the applied frequency is close to the resonance frequency of the buncher. Under these conditions the velocity of the electrons is varied by the electric field as they pass across the gap, some being accelerated when the direction of the electric field is opposite to that of the electron flow and others retarded when the field reverses. (The apparent anomaly in this statement is due to the fact that an electron has a negative charge.) Thus, some electrons leave the buncher gap with greater than average *velocity* and others with less. As the electrons pass along the space between the buncher and catcher—the " drift " space—the faster-moving electrons overtake the slower electrons and form bunches or groups with greater than average *density*, separated, of course, by comparatively empty spaces. This action is illustrated in Fig. 2 for eight equally spaced instants of

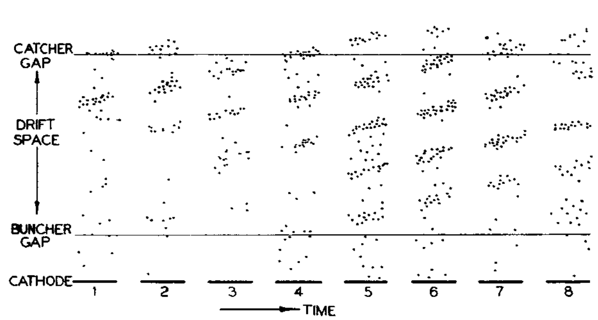

FIG. 2.—ELECTRON BUNCHING IN A KLYSTRON AMPLIFIER.

time corresponding to a total of two-and-a-half radio frequency cycles. The time of transit through the buncher gap is a small fraction, usually about one-third, of a radio frequency cycle. The time of transit through the drift space on the other hand, is much longer and may amount to several radio frequency cycles in order to obtain effective bunching. The average time spent in the drift space depends on the average velocity of the electrons and therefore on the direct accelerating potential between the cathode and the cylinder which forms the electron gun. The latter and the resonators are normally earthed and the cathode is usually held below earth potential by some 1,000 to 3,000 V.

The electron beam has thus become modulated in intensity at the applied radio frequency and the electron bunches (which correspond to a pulsating current) give rise to an alternating field between the grids or in the gaps of the output, or catcher, resonator. The phase relationship between the electron bunches and the field is dependent on the impedance of the resonator, just as the phase relationship between current and voltage in an ordinary A.C. circuit is dependent on its impedance. When maximum power is abstracted from the resonator, the direction of the field across the gaps is such as to cause the electrons to give up the maximum amount of energy, i.e., the direction of the field must be such as to cause maximum retardation of the electrons. Under suitable operating conditions more radio frequency power can be taken from the catcher resonator than is applied to the buncher, i.e., the valve functions as an amplifier. The difference between the R.F. output power and the R.F. input power comes from the power in the electron beam, i.e. the product of the beam current and the accelerating voltage ; only a fraction of the beam power is, however, abstracted at the catcher and the remainder appears as heat due to electron bombardment of the collector electrode.

The efficiency (ratio of R.F. power output to beam power) of an ideal klystron amplifier is 58 per cent. ; in practice various factors, such as damping of resonators by the inherent losses and by the beam, interception of the beam current by the grids and walls of the resonators, and the limitation of the peak R.F. voltage across the catcher gap to a value not exceeding the beam voltage, reduce the efficiency to a few per cent.

The gain of a klystron amplifier can be improved by using three resonators in cascade along the same electron beam; one advantage of this arrangement is that it can be designed to yield the maximum power output with a comparatively small drive power. With a small amount of driving power the bunching due to the first gap is relatively slight, but it excites the second resonator and this produces more velocity modulation than was produced by the first resonator, and thus enables optimum bunching to be obtained at the gap of the third, i.e. the output, resonator.

Characteristics of typical klystron amplifier.—The experimental valve VX318 developed at the Admiralty Signal and Radar Establishment, Bristol, during the war, is an example of a triple-resonator klystron amplifier ; a section of the valve is shown in Fig. **3** and an external view in Fig. **4**.

The characteristics of a typical klystron amplifier valve VX318 are as follows :

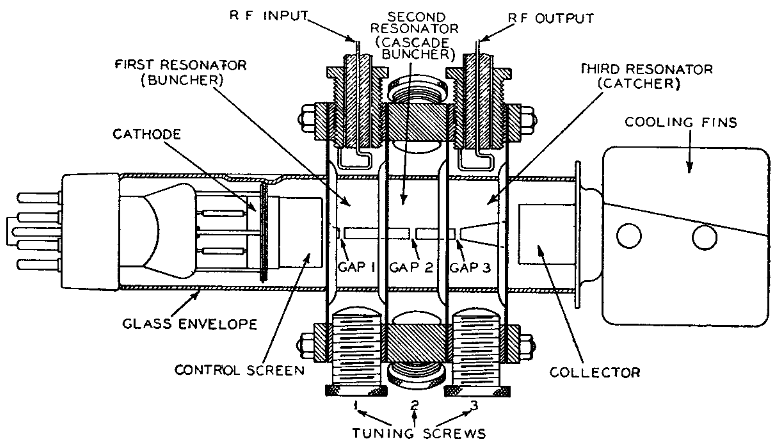

FIG. 3.—SECTION OF TRIPLE-RESONATOR KLYSTRON AMPLIFIER, VX 318.

10 to 12 db.; these low-noise valves employ a relatively small beam current (about 0·2 mA) and require a very narrow electron beam (about 1 mm. diameter) traversing a long, narrow helix. It is essential that the electrons shall travel parallel to the axis of the beam without spiralling and that interception of the beam by the helix shall be very small in order to minimise partition noise. These requirements necessitate careful design and extremely accurate mechanical construction of the electron gun, as well as a high degree of uniformity in the magnetic focusing field.

Whether these difficulties can be overcome to an extent which would permit of quantity production of low-noise travelling-wave valves and their use in radio relay systems is at present an open question.

Electron-wave Amplifiers.

An interesting new type of V.M. amplifier has recently been described by A. V. Haeff,[13] J. R. Pierce and W. B. Hebenstreit[14] and others. This amplifier is approximately equivalent to a travelling-wave amplifier in which the helix is replaced by a second electron beam, as shown in Fig. 7.

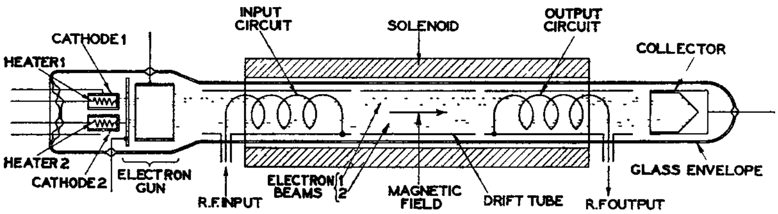

FIG. 7.—SECTION OF DOUBLE-BEAM ELECTRON-WAVE AMPLIFIER.

The two electron beams come from separate cathodes differing in potential by some 50 volts so that the beams have slightly different velocities. Both beams are velocity modulated by the R.F. input signal and pass through the same drift-tube where interaction occurs between the electrons in one beam and the electric field of the other, and vice versa. This interaction results in variation of the beam current density, i.e., in bunching; the beams are thus enabled to deliver radio frequency power to the output circuit. The input and output circuits are usually short lengths of helix, but this is not essential and resonators similar to those in klystrons can be employed. Another form of the valve exists in which a single electron beam is used, but the inner and outer portions of the beam are caused to travel at slightly different velocities by suitable adjustment of the potential of the drift-tube relative to the cathode.

Within the electron beam, gains of 80 db. or more are claimed to be possible; however, this neglects the imperfect coupling between the input and output circuits and the electron beam. In practice a net gain of 46 db. at 3,000 Mc/s has been achieved[15]; it is interesting to note that electron-wave amplification is also possible at much lower frequencies and a valve with 33 db. net gain at 255 Mc/s has been described.[14] The bandwidth limit set by the electron beam itself is of the order of 30 per cent. of the mid-band frequency, but in practice it is restricted by that of the input and output circuits. Assessments of the power output and efficiency under large signal conditions and the noise factor under small signal conditions are not available as yet, but it seems unlikely with the present form of the valve that these will be as good as in conventional travelling-wave amplifiers. However, the electron-wave valve may find applications as an amplifier of signals of medium power level, particularly when a high gain is required. Furthermore, the absence of a metallic slow-wave structure may make the valve useful for amplification of millimetric waves, since structures such as the helix or corrugated waveguide have to be made very small for such wavelengths.

Magnetron-type Travelling-wave Amplifiers.

The efficiency of conventional travelling-wave amplifiers of the Kompfner-Pierce type is generally low, being usually less than 10 per cent., whereas magnetron oscillators may have efficiencies exceeding 50 per cent. An attempt has been made by R. R. Warnecke and his associates of the Compagnie Generale de Télégraphie Sans Fil (Paris) to devise a travelling-wave amplifier,[16] which incorporates certain features of the magnetron, viz., the use of a magnetic field normal to the plane in which the electrons move, thus causing the electrons to travel, in the limit, in cycloidal paths. The resonant cavities of a magnetron are replaced by a flattened helix bent into a circle, the input and output being separated by a metallic partition. Output powers of some 50 W, overall efficiencies of 25 per cent. and gains of about 7 db. have been reported at 23 cm. wavelength (1,310 Mc/s).

Grounded-grid Triode Amplifiers.

A grounded-grid triode, BTL1553, for use at 4,000 Mc/s has been designed by J. A. Morton of the Bell Telephone Laboratories.[2] This represents an appreciable advance in the upper frequency limit for triodes, an improvement which has been obtained by:—

(*a*) reducing the grid-cathode spacing and the spacing between the turns of the grid wires,

(*b*) maintaining exact parallelism between the planes of the grid wires and the cathode,

and

(*c*) increasing the cathode emission.

The main dimensions of the BTL1553 triode are:—

Cathode-grid spacing	0·6 mil.
Grid wire thickness	0·33 mil.
Grid wire turns	1,000/in.
Grid-anode spacing	10 mils.

It will be apparent that special manufacturing techniques are needed to maintain these small spacings satisfactorily. For example, the cathode is an oxide coating on a nickel base mounted in a ceramic ring, the cathode assembly being precision-ground to a flat surface. The grid wires are wound on a molybdenum former and are tensioned to within about 50 per cent. of the breaking stress of the wire to maintain an accurately plane surface. The grid structure and the cathode assembly are spaced by a thin copper shim plate and tightly clamped together.

The characteristics of this valve when used as an amplifier with the appropriate resonators as input and output circuits, are as follows :—

Mid-band frequency	4,000 Mc/s
Bandwidth (3 db. below maximum output)	80-100 Mc/s
Gain, Class A operation	7-10 db.
Noise factor, Class A operation	14-16 db.
Gain, Class B operation	4-6 db.
Maximum R.F. output, Class B operation	0·5-1 W
Anode dissipation	6 W
Efficiency	7·5-15%

It will be observed that the characteristics of the valve make it suitable for use in both the initial and final stages of microwave repeaters, and it is understood that the valve is in production by the Western Electric Company, under the coding WE416A, for use in the New York-Chicago radio relay system.

A further development in grounded-grid triodes has been announced from the Philips Research Laboratories at Eindhoven, Holland.[17] A porous tungsten cathode (the Lemmens cathode) is used in this new triode and the active materials are inserted inside the cathode; this avoids the usual oxide coating and enables a high and uniform emission to be obtained. As a result of the very effective space-charge smoothing due to the uniform emission, the noise factor is remarkably small and a value of 7 db. at 3,000 Mc/s is claimed. Under large signal conditions a power output of 0·5 W and gain of 10 db. with a bandwidth of 50 Mc/s are obtained. The data quoted refer to early experimental samples and the valve has not yet reached the production stage.

(To be continued)

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The Institution of Post Office Electrical Engineers

London Centre

During the summer months the London Centre Committee have been active in formulating a programme of meetings and educational visits for the forthcoming Session. The number of offers of suitable papers has been rather less than that of recent years and in the interests of presenting a well-balanced programme it has been necessary in some instances to solicit papers on specific subjects.

Thanks are due not only to those authors whose papers have been accepted but also to those whose offers have, for the time being at least, had to be rejected.

Ordinary Meetings

Held at the Institution of Electrical Engineers, Savoy Place, W.C.2, commencing at 5.0 p.m.

Monday, 6th November.—" The Anglo-Continental Telephone Service." J. Rhodes, M.B.E., B.Sc., A.M.I.E.E.

Tuesday, 5th December.—" Shared Service." N. V. Knight, B.Sc., A.M.I.E.E.

Informal Meeting

Held in the Conference Room, 4th Floor, Waterloo Bridge House, S.E.1., commencing at 5.0 p.m.

Wednesday, 22nd November.—" Wage Incentive Systems." W. Hawking, T.D., A.M.I.E.E. (N.E. Region).

Arrangements are in train for a Social and Dance to be held in the Armour House Refreshment Club premises, St. Martin's le Grand, E.C.1, on Friday, November 10th, from 7.30-11.0 p.m., and in spite of the Journal printing delay it is hoped that this notification will appear in time to be of interest.

Tickets at a reasonable price will be made available in all Branches in due course and as some limitation on sales may have to be imposed early purchase is desirable.

W. H. F.

Essay Competition 1950/51

The Council offers five prizes of Three Guineas each for the five most meritorious essays submitted by members of the Engineering Department of the Post Office below the rank of Inspector. Draughtsmen, Class II, with less than five years' service on that grade, are also eligible to compete. In addition to the five prizes the Council awards a limited number of Certificates of Merit.

A prize-winner in any previous competition is not eligible to enter, but this restriction does not apply to a competitor who has been awarded a Certificate of Merit only. An essay submitted for consideration of an award in the Essay Competition and also submitted in connection with the Junior Section I.P.O.E.E. prizes, will not be eligible to receive both awards.

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

Hints on the construction of an Essay can be obtained, if desired, upon application to the Secretary at the address given below. Competitors may choose any subject relevant to current telegraph or telephone practice.

Foolscap or quarto size paper should be used, and the essay must not exceed 5,000 words. An inch margin is to be left on each page. A certificate is required to be given by each competitor, at the end of the essay, in the following terms :—

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

Name (*in Block Capitals*) ....

Signature ....

**Rank* ....

Departmental Address ....

....

Date ....

(**If a Draughtsman, Class II, state date of appointment to that grade.*)

The Essays must reach
The Secretary,
The Institution of Post Office Electrical Engineers,
G.P.O. (Alder House), London, E.C.1,
by the 31st December, 1950.

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

Special Prize of Three Guineas

In addition to the five prizes mentioned above, the Council offers a special prize of Three Guineas for the best essay on :—

" My reactions to the present Essay Competition and my suggestions for improving it."

(The restriction on previous prize-winners does not apply to this essay.)

J. READING,
Secretary.

Junior Section Notes

LIBRARY FACILITIES

Books cost money and very few people can afford to purchase all the books they would wish to have on their own bookshelves and still fewer can afford all the books necessary for reference to keep abreast of developments in the Engineering and Scientific fields. Access to libraries is, therefore, essential. The I.P.O.E.E. Library offers a comprehensive and up-to-date range of books covering Telecommunications, Engineering and allied subjects. The Institution Library is affiliated to Lewis's Scientific Library and any books requisitioned which are not held in the Institution Library are obtained, wherever possible, from Lewis's subject to their being of a character similar to those books contained in the Institution Library. Lewis's catalogue is available for loan as Book No. 931. The Library also has available for loan bound volumes of all I.P.O.E.E. printed papers, prize essays, Junior Section prize papers and unpublished papers recommended by local centres as suitable for inclusion in the library.

All these library facilities are available to a member of a recognised Junior Section on payment of only 6d. per annum.

Copies of the Catalogue and Annual Supplements are held by the local Junior Section Centre Secretaries, who also hold supplies of library requisition forms. Junior Section members requiring books should forward the requisition slips to the Librarian via their Junior Section Centre Secretary for his counter-signature.

Bishop's Stortford Centre

On the 3rd May, 1950, an inaugural meeting was held at Bishop's Stortford, with the object of forming a section to cover the Bishop's Stortford, Epping, Ware, Hertford and Saffron Walden areas.

The meeting opened with a film show, given by the Central Office of Information, and the following films were very much enjoyed :

1. This Britain, No. 22; 2. The Wonder Jet; 3. Public Opinion; 4. Wonders of the Deep; 5. In all Weathers.

After the film show the Cambridge Area Liaison Officer, Colonel T. C. Loveday, addressed the meeting, explaining in some detail the objects of the Junior Section and the advantages to be obtained by the formation of a centre at Bishop's Stortford.

As a result of this address, the meeting decided unanimously to form a centre, and approximately 30 members enrolled immediately.

The officers and committee appointed are :—

Chairman : G. T. Wyer; *Vice-Chairman :* R. A. Collins; *Secretary :* J. Poole; *Treasurer :* W. Worley; *Committee :* H. James, J. S. Rogers, G. E. Dann, R. G. Eve and F. Brackley.

The first committee meeting was held on 16th May, 1950, and the following programme was arranged for the first half of the 1950-51 Session.

September, 1950. Film Show and first Annual General Meeting. Discussion on programme for winter session.

October, 1950.—Lecture, " Astronomy," by R. C. T. Warboys. Visit to University Observatory at Cambridge.

November, 1950.—Lecture, " Faraday Building." Speaker to be announced later. Visit to Faraday Building.

December, 1950.—Lecture, " Internal Combustion Engines," by R. A. Collins.

We feel sure that a " live " centre can be maintained at Bishop's Stortford.

J. P.

Bradford Centre

The very successful 1949-50 Session closed on 7th June with the Annual General Meeting. The new officers and committee took over and work on the 1950-51 Session began. The programme will include a visit to John Players Ltd., Nottingham, a Sheffield precision tool-making factory, a broadcast quiz, inspection of the Bradford Town Hall Clock tune-playing mechanism and a " Hobbies Night "—¾ in. scale steam locomotives and " 0 " gauge electric locomotives and rolling stock will be demonstrated and a film show will follow. Papers on " Ship to Shore Radio," " Transport " and" Inter-communication Systems " will be given, and it is hoped that Mr. Harbottle, the Junior Section President, will come along and address us. The committee hope to make this programme as good as, if not better than, 1949-50, and call on all past and potential members for their vigorous support. Any suggestions for visits, offers of papers, etc., will be most welcome.

A. E.

Cambridge Centre

At the Annual General Meeting held on 18th May, 1950, the following officers were elected for the 1950-51 Session :—

Chairman : L. A. Salmon ; *Vice-Chairman :* H. W. Howarth ; *Secretary :* J. P. Wearn ; *Treasurer :* B. S. Cranfield ; *Committee :* L. R. Andrews, R. M. Jones, S. J. Davis ; *Auditors :* L. W. Pooley, N. Radford.

The following are details of the programme arranged for the first half of the session :—

September, 1950.—Visit to Vauxhall Motor Factory, Luton.

October, 1950.—Return visit to University Observatories.

November, 1950.—Lecture, " Financial System of the Post Office," by Senior Section member.

December, 1950.—Local quiz.

J. P. W.

Chichester Centre

At the Annual General Meeting held on 17th May, 1950, the following officers were elected :—

Chairman : W. C. Jackson ; *Vice-Chairman :* J. A. Harrington ; *Hon. Secretary :* R. W. Smith ; *Hon. Treasurer :* A. T. Yardley ; *Hon. Auditors :* F. S. Huggett and J. R. Gillis ; *Committee :* R. E. Jenkins, D. E. Sparkes, R. D. Barrett, B. J. Ifould, F. H. Gillespie and A. V. M. Pont.

The centre has arranged a series of five lectures for the forthcoming session and one or possibly two visits to places of interest to the members. The membership has been consistently maintained at about 42 and during the previous session more than 25 per cent. attended each lecture, although A/L, sickness and other reasons have kept a few of the regulars from attending. We are looking forward to better attendances in the forthcoming session and with a full and varied programme of lectures, we hope to have catered for the greater proportion of our members.

Darlington Centre

The Conference of Representatives of the Junior Centres in the N.E. Region held at York, 15th June, 1950, is the outstanding feature since our last notes. The proposals on the agenda as enlarged upon by the respective Centre Delegates were most convincing. There was a lively exchange of views—and with the C.R.E. (Mr. W. F. Smith) Chairman, Mr. T. E. Walker, Hon. Secretary, and Mr. A. C. Holmes, Regional Liaison Officer, to guide us—many decisions were arrived at. If these can be implemented the success of the N.E. Regional Centres is assured.

Programme arrangements for the forthcoming session are well under way, and are being tackled with the spirit of the showman for " something bigger and better."

C. N. H.

Guildford Centre

The Centre was revived after its wartime temporary demise at a meeting held in February. Mr. Knox, Regional Liaison Officer, and Mr. Wells, Area Engineer, attended and promised their practical and moral support. Mr. C. W. Davies, Telephone Manager, was unable to be present but was later pleased to accept the Presidency.

The officers are as follows :—

Chairman : A. B. Biggs ; *Secretary :* F. Kelsey ; *Assistant Secretary :* L. G. Wallis ; *Treasurer :* F. B. Amery ; *Committee :* Messrs. S. Bush, Jamieson, Hill.

Progress in the early spring and summer was held up by the freak snowstorm which severely affected the Area and the Centre nearly became a casualty for the second time. However a programme of visits was arranged to Ford Motor Company, Dagenham; Kingston New Power Station; Friary Brewery, Guildford; Huntley & Palmers Ltd., Reading; Earley Power Station, Reading.

This Centre has always had certain misgivings about the title " Junior Section," feeling that outside bodies might easily gain the impression that we were a group of messenger boys or apprentices when they were asked for permission to visit them. These misgivings were realised when at the foot of the letter from the Ford Motor Company it was read : " We shall be pleased to have you visit us but we must emphasise that all visitors must be over 10 years of age " !

L. G. W.

Harrogate Centre

On 5th July a party of 30 went by coach to the works of the Jowett Car Company and spent a most interesting evening as guests of the Company, touring the various departments and seeing all branches of manufacture and assembly.

For the coming Winter Session a most comprehensive programme has been arranged, in addition to which it is hoped to have as usual one or two visits to engineering works or other places of interest in the district.

The remainder of the season's programme is as follows :—

1st November.—" Telephone Service in the Western Highlands and Isles of Scotland." Mr. J. P. Allen.

6th December.—" Banking Systems," also a Film Show. Mr. D. Johnson.

10th January.—" The 2,000-type Selector." Mr. H. Clough.

7th February.—" Outline of Television Reception." Mr. G. R. Bastow.

7th March.—" The Morris Minor Power Unit." Mr. W. Jibson.

J. T. W.

Leeds Centre

An attempt is being made to revive interest in this Centre which has been dormant since 1947. A new committee has been formed and it is hoped to prepare a programme for the coming winter of papers to be read and to arrange social evenings.

E. G. S.

Middlesbrough Centre

Thanks are due to the Editor and Officers of Junior Centres for the continued opportunities to read and digest articles of the activities of other Centres. The articles naturally vary in colour, no doubt because they cover from Southern England to Scotland and memberships from 70, or less, up to 2,500.

(*Continued on page* 164)

Notes and Comments

Birthday Honours

The Board of Editors offers its congratulations to the following members of the Engineering Department honoured by H.M. The King in the Birthday Honours List :—

Belfast Telephone Area	Pettigrew, J.	Technician Cl. I	British Empire Medal
Engineering Department	Nicholls, C. A. L.	Executive Engineer	Officer of the Order of the British Empire
London Telecomms. Region	Blake, H. G.	Technician Cl. I	British Empire Medal
London Telecomms. Region	Markwell, A. R.	Technician Cl. I	British Empire Medal
Shrewsbury Telephone Area	Bennett, C. F.	Mechanic-in-Charge, Gde. I	British Empire Medal
York Telephone Area	Markey, J. M.	Area Engineer	Member of the Order of the British Empire

Recent Awards

The Board of Editors has learnt with great pleasure of the honours recently conferred upon the following members of the Engineering Department :—

London Telecomms. Region	Ashton, G.	Technician Cl. IIA	Wt.Offr., Cl.II, R.A.C.	Member of the Order of the British Empire
Southampton Telephone Area	Hinton, M. R.	Technician Cl. IIA	Corporal, Royal Signals	Mentioned in Despatches

Mr. T. H. Flowers, M.B.E., B.Sc.. M.I.E.E.

The promotion of Mr. T. H. Flowers to Staff Engineer in the Research Branch marks a step not only in his own career but also in the progress of the art and science of telephone exchange systems. Himself an expert of international repute, he has

built up and is directing a team whose present efforts may well lead to remarkable changes and improvements in the practice of the art. Such work can only be fully assessed in retrospect.

Apprenticed at the Royal Arsenal, he joined the Telephone Branch of the Engineering Department as Inspector in 1926, as a well-trained engineer but with negligible experience of telecommunications. After promotion to Assistant Engineer he was posted to the Research Branch in 1930, where he advanced to Executive Engineer in 1937, and to Assistant Staff Engineer in 1943, graduating with first-class honours in 1933.

During his earlier years in the Research Branch he designed the Post Office 2 V.F. signalling system, and throughout his service in the Post Office he has been engaged on problems connected with telephone signalling and switching, or on work of an allied nature. The alternative refers in particular to special work done during the war, the quality of which has been properly recognised by the authorities concerned and for which in 1943 he was awarded the M.B.E.

Undoubtedly, chance played a large part in deciding the nature of the work first undertaken by Mr. Flowers for the Post Office. Thereafter, his innate genius for dealing with the complexity of telephone exchange problems, and his quiet but stubborn refusal to let whatever problem was presented get the better of him, have conspired to concentrate his activities on this particular field of work. Viewed broadly, the field is a large one and presents ample scope ; his friends and colleagues wish him continued success in it.

W. W.

Publication Delay

Because of a recent dispute in the printing trade the publication of this issue of the Journal has been considerably delayed and we regret any inconvenience to readers which this delay may have caused. A further result of the difficulties has been the necessity on this occasion to reduce the amount of text. While it is hoped that more favourable conditions will apply to the January, 1951, and subsequent issues, we ask for our readers' indulgence pending a return to normal conditions in the printing trade.

Regional Notes

South-Western Region

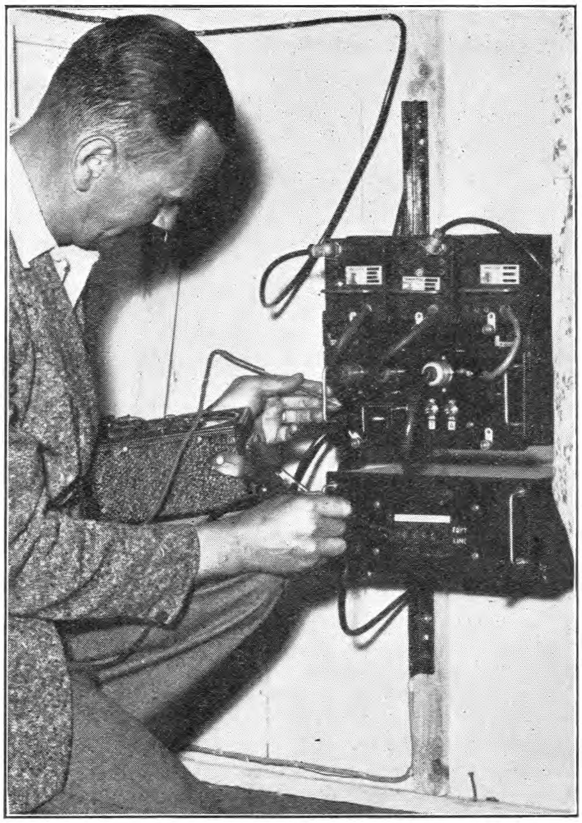
GUERNSEY-HERM RADIO LINK

An interesting installation carried out recently in the South-Western Region was the introduction of a single-channel V.H.F. radio link working from the island of Herm into the telephone network of Guernsey, Channel Islands.

Herm is a small island situated about five miles from Guernsey and eleven miles from the coast of Normandy. It has a normal population of 35, but this is greatly increased during the summer months by guests at the island's only hotel and by large numbers of day visitors who arrive from the other islands.

In January of this year urgent representations were made to Headquarters by the Guernsey Administration for the provision of communication facilities—if possible by the early part of June—and the Radio Group of the South-Western Region were asked by Headquarters to undertake the engineering, construction and installation of a radio link. The only apparatus which was readily available consisted of 12-V battery-operated mobile type equipment. It was, however, desirable to operate the circuit continuously and modifications were therefore carried out to allow A.C. mains operation, the Herm terminal working via D.C./A.C. convertors driven from the island's 200-V D.C. supply. Three power packs had to be constructed for each terminal, supplying respectively the receiver, transmitter and modulator.

Modifications to the apparatus involved the replacement of the receiver output transformer and the modulator input transformer in order to present 600 ohms to line. The conversion from D.C. operation to A.C. working also involved alteration of the bias arrangements and to the A.V.C. system.



THE TRANSMITTER AND RECEIVER UNIT AT HERM.

The receivers are crystal-controlled superheterodyne type whilst the transmitters, also crystal controlled, have output power of 7 W.

The whole of the apparatus has been built into a rack 12 in. × 12 in. × 15 in. which contains the receiver, transmitter, modulator, associated power packs and the line termination units.

The Herm terminal is installed at Foxglove Cottage, from where the 2-wire end is taken to the small magneto switchboard which at present has only two extensions. At Guernsey the apparatus is installed at Fort George radio station, the 2-wire end then being taken to the trunk positions of the States exchange. Signalling is provided by means of voice-operated relays—Unit Signalling No. 5—at either 2-wire terminal.

The aerial systems consist of dipoles with reflectors, and are connected to the equipment by co-axial cables. The two aerials at each terminal are mounted on a single 40-ft. pole.

The work of installation was carried out by Regional Headquarters' staff with assistance from the Bournemouth area. One interesting point is that the foreman in charge of the gang which performed the aerial erection last visited Herm during the recent war as a Commando sergeant—his object was looking for any radio stations which he had instructions to wreck. This temporary equipment has proved very successful and reliable since installation. It will be replaced in due course by a production model of the standard island installation, the prototype of which is under trial in the Welsh and Border Counties Region.*

Welsh and Border Counties Region

POLE DAMAGE BY LEAF-CUTTER BEE

Progress with the pole-testing programme is well advanced in this Area, but an interesting find was made in a pole on a route which had not yet been reached by the testing parties.

On report of a fault on the only circuit carried by a route of light poles, the linesman found one pole leaning over and fractured several feet above ground level. The pole was renewed the next day, and when it was allowed to fall it split along its length, revealing a number of smooth round tunnels running lengthways with the grain. The pole was an old light pole and was decayed downwards from the head for some 6 ft. The route is alongside a very quiet road and there are many birch trees near.

A solitary bee was noticed to be taking an interest in the newly erected replacing pole, and after a short time it alighted on the broken split pole lying on the ground. An attempt to catch the bee failed. Lying in the channels cut in the decayed portion of the pole were a number of cells and pieces of leaf, still green and recognisable as pieces of birch leaf.

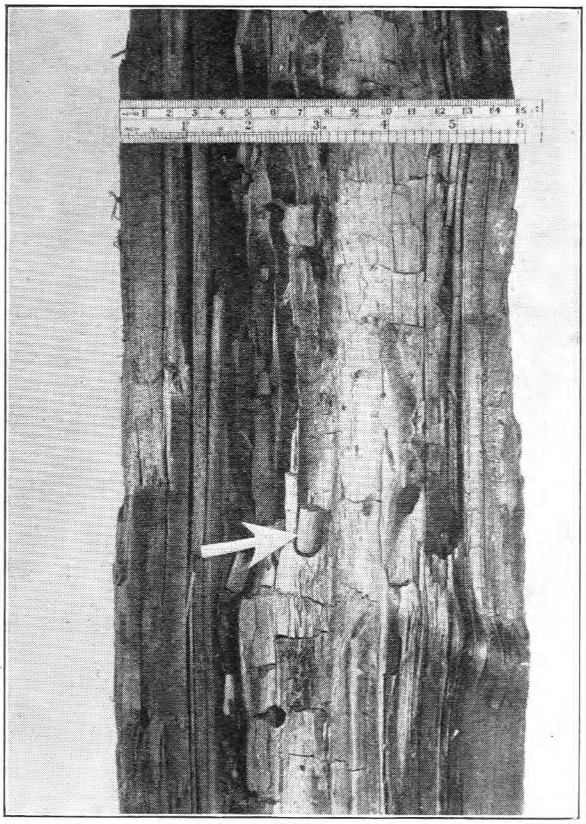
On examination of the completed cells, which are hollow, thimble-like structures, it was evident that a craftsman insect had been at work. Reference to local Field Society entomologists resulted in the work being recognised as that of the leaf-cutter bee, one of the most interesting of the solitary bees. It is of the family *Megachilidæ*, which includes the leaf-cutter and mason bees and their allies. It is familiar to many people who grow roses, on account of its habit of cutting out neat smooth-edged pieces from the leaves and petals of this plant. The cutting process is carried out with a precision which suggests the work of a machine.

The tunnelling is carried out in a decaying post or

* *P.O.E.E.J.*, Vol. 43, April 1950, p. 52.

worn-out woodwork, and the tunnels may extend considerably more than a foot.

The brood cells are made entirely of layers of excised pieces of leaves or flower petals, and are shaped like thimbles. In each cell the female places a supply of paste of pollen and honey, and lays an egg. The end of the cell is sealed by a circular piece of leaf or petal



PORTION OF DAMAGED POLE WITH CELL OF LEAF-CUTTER BEE INDICATED BY ARROW.

and this "thimble" is then the home of the grub and pupa until it is ready to emerge as a bee.

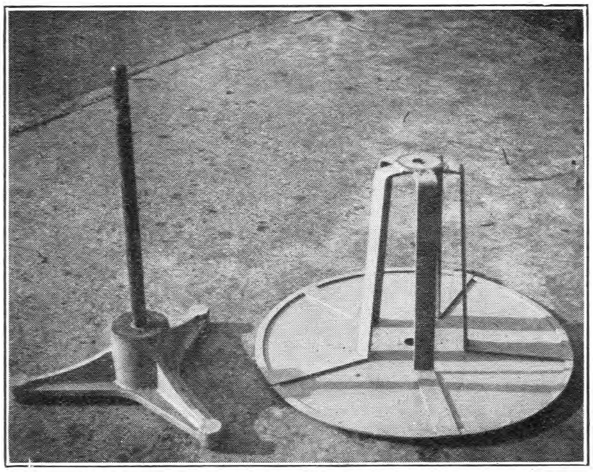
Although the bee is not large, being about the size of a small domestic bee, it is evidently a hard worker capable of weakening an already affected pole to a dangerous extent. S. H. P.

CABLE SWIFTS FOR EXCHANGE CONSTRUCTION WORKS

During the past two years a considerable amount of exchange construction work has been undertaken by departmental labour in this Region including the installation of several complete C.B.10 exchanges. The need for a cable swift, which has been felt for a number of years, was therefore increased and it was decided to manufacture a number in the Regional Workshops. The requirements of the swift to meet the conditions of exchange construction work were considered to be :—

(1) It should be sturdy so as to stand rough handling during transport.
(2) It should be suitable for holding coils of switchboard cable of various sizes.
(3) It should run freely enough for a cable to be taken off with a reasonable pull, but not to over-run.
(4) Its weight should be such that it would not drag along the floor when in use.

The first swift made had a conical centre of sheet metal which was found to be difficult to construct with facilities available. It also had a ball bearing which resulted in over-running. In the final construction



CABLE SWIFT CONSTRUCTED IN WELSH AND BORDER COUNTIES REGION.

therefore a slatted centre has been used and the ball bearing substituted by a solid thrust bearing. The base of the original model was made of angle iron welded to the central bearing support but subsequently arrangements were made for the bases to be cast by a local firm.

Reports so far received show that the swifts meet the conditions specified and are satisfactory in every way. They are proving a useful addition to the exchange construction parties' kit. S. E. N.

North-Western Region

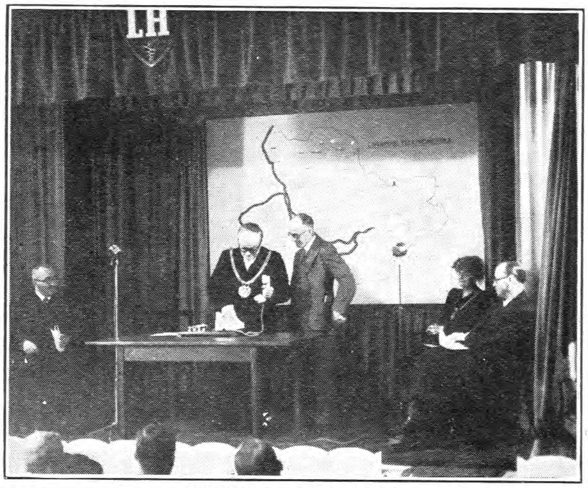
"TIM" COMES TO MERSEYSIDE

Although a speaking clock was brought into service in Lancaster House, Liverpool, in 1942 for supplying the "TIM" service for the north of the country and also to act as a reserve in the event of the failure of the London clock, the service has not been available to the Liverpool Telephone Area because of a shortage of the local supply equipment. However, some spare equipment recently became available and after it had been completely renovated and rebuilt by the local construction staff, it was decided that the Liverpool Area should enjoy the facility that they had been supplying to other Areas. It was considered that some publicity for the new facility was justified and accordingly an invitation to perform the opening ceremony was extended to and kindly accepted by the Lord Mayor of Liverpool.

The ceremony was conducted on a stage owned by members of the Lancaster House Canteen Club, and as shown in the illustration a large map of the Liverpool Telephone Area was erected at the back of the stage. Each exchange was indicated by a supervisory lamp opal underneath which was a label showing the exchange name. The director exchanges on the map, that is, those exchanges that could dial "TIM," were indicated by red opals, the remaining exchanges in the unit fee area for a "TIM" call were indicated by white opals and all other exchanges had green opals. The supervisory lamps were wired to a chromium-plated switch mounted on a polished baseboard which was placed on a table on the stage. An ivory telephone connected as an exchange line was also mounted on the baseboard. In addition, an amplifier and loudspeakers were connected to the telephone circuit.

The routing of "TIM" calls from the various director automatic exchanges to the speaking clock is via the Tandem exchange. Therefore, after the director translations for "TIM" had been completed, all that was necessary to bring the service into use was to open the tandem level to the speaking clock relay sets. The signal for this operation was also controlled by the switch mentioned above.

At the opening ceremony on Monday, 10th July, 1950, the Telephone Manager made an introductory speech and then invited the Lord Mayor to open the "TIM" service by operating the switch, followed by the dialling of "TIM" on the telephone.



INAUGURATION OF "TIM" SERVICE IN LIVERPOOL BY THE LORD MAYOR.

The Lord Mayor in his speech stated that he was considered to be a "Jonah" at these ceremonies; but in spite of this remark when he closed the switch the map became illuminated by all the supervisory lamps indicating the exchanges having access to "TIM" and his call to "TIM" was received by the audience through the loudspeakers at 11.35 a.m.

From left to right in the photograph are the Head Postmaster (Colonel R. E. Evans, C.B.E., T.D.), the Lord Mayor of Liverpool (Alderman the Rev. H. D. Longbottom), the Telephone Manager (Mr. H. C. Jones, O.B.E., M.I.E.E.), the Lady Mayoress, and the Deputy Regional Director (Mr. H. A. Ashton).

After the ceremony, the Mayoral party toured Lancaster House and were then entertained to lunch. During the lunch the Lord Mayor was presented with an album containing photographs of various items of interest in Lancaster House. Included in the album were photographs of the arrival of the Lord Mayor's party for the visit and one of him actually performing the opening ceremony as reproduced above. This rapid "developing and printing" service was carried out by the recently formed Area Camera Club.

To cater for the anticipated "TIM" traffic, 24 circuits were provided from tandem to the speaking clock equipment for calls originated by the director automatic exchanges. In addition, 8 overflow circuits from the tandem level were routed to the manual board. These were provided on a temporary basis to carry the initial "curiosity" traffic. Any calls originating on these circuits would be connected without challenge by the operator via manual circuits to the speaking clock. For calls originated by manual exchange subscribers 30 circuits were provided to the speaking clock.

For the three days following the opening of the service an average of 7,800 calls per day were made from the director exchanges and 1,945 were made from the manual exchanges. The volume of traffic was such that the tandem overflow circuits were not required, and steps were also taken to reduce the manual exchange circuits. A further safeguard taken during the initial stages was the reduction of the time pulse throw-out from 90 seconds to 36 seconds on the speaking clock relay sets. After a few days it was found that this could be restored to the normal 90 seconds. H. G. C.

London Telecommunications Region

LONDON AIRPORT P.B.X.

The telephone requirements of London Airport are at present provided by a P.M.B.X. 1A installation, but in 1952 the Airport territory is to be given the status of a public exchange and served by a non-director automatic exchange. It became apparent, however, that the Airport requirements would far exceed the capacity of a P.M.B.X. 1A equipment before the conversion to automatic working. The two obvious solutions have been either the installation of an additional P.M.B.X. 1A unit with transfer working or the complete replacement by B.E.C.B. 10 equipment. The former would be undesirable and costly from an operating point of view, while the capital cost of the latter could not be justified for so short a life. The required capacity has been obtained therefore by non-standard rearrangement of the existing P.M.B.X. 1A equipment.

In a normal fully equipped P.M.B.X. 1A installation, some 40 per cent. of the face of the switchboard is occupied by spacing strips, this being the positions where calling lamps are not required. The rearrangement adopted has aimed at making use of this space, and does not involve any departure from standard circuits.

The calling lamps are removed from their physical association with the jacks which they serve, and are concentrated in the lowest three positions which are reserved for this purpose. Strips of ten lamps for exchange lines and private wires or of 20 for extensions or spacing strips are provided in these three positions, as called for in the traffic data. Above these the multiple jacks are fitted close in formation, that is, without any spacing strips. In the present case the estimated ultimate requirements for 320 exchange lines and private wires are being provided with 23 positions. The maximum number of extensions is of the order of 1,500, equipment being provided at present for 1,200.

A small frame is fitted near the growing end of the suite, on which are terminated :—

(i) All the calling lamps.
(ii) The lamp feeds for the exchange lines and private wires, which are cabled direct from the apparatus racks.
(iii) The B line tails for the extension multiple.
(iv) Long-line relays.

Thus, any strip of lamps may be associated with any group of jacks (so far as they are strips of ten or twenty), and a calling relay may easily be jumpered into any circuit. Due to the physical size of the Airport, a larger number of relays than normal is required, and these are strip-mounted away from the racks.

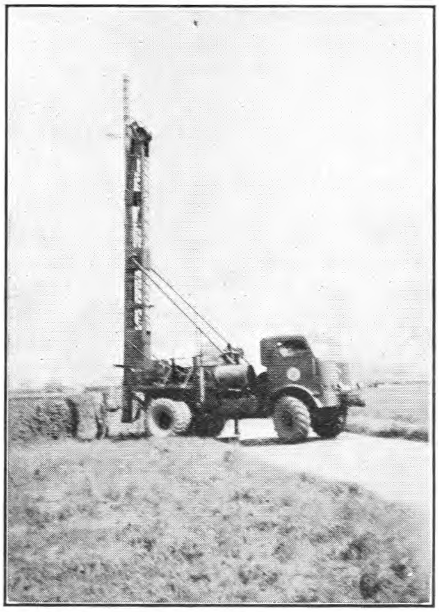
Operators identify each strip of lamps with the jacks which they serve by means of coloured markings on the stile strips, and no difficulty in operating seems to have been experienced. It should be noted that a strip of lamps is only associated with jacks which have appearance on the same panel, and only in complete strips.

The work, up to the time of writing, is still in progress, but the most difficult phase, the rearrangement of the existing suite while on traffic, has been completed with surprisingly little inconvenience to the Airport authorities. A considerable amount of work was performed at night, when the traffic was at its lowest. The multiple cabling is somewhat congested, and may give rise to maintenance troubles, but fortunately the life of the equipment is to be very short. The accommodation of the lamp cables in the suite set a problem, but these difficulties have been satisfactorily overcome. A. B. C.

Midland Region

USE OF MOBILE BORER AND POLE LIFTER

Under the programme of trunk recovery in the Birmingham Area, a large number of stout poles was included in the schedule. Where a line of poles existed in situations free from serious obstacles, use has been made of a combined borer and lifter, the property of the British Electricity Authority. It consists of a derrick and earth auger; both are mounted on a lorry chassis with a 50-h.p. power unit and operated by the lorry engine through a separate gear box. The auger can be changed according to the size of hole required and has been used on previous occasions with considerable success in the erection of poles. The derrick only has been used in recovery work, and is fitted with horizontal arms near the base to prevent poles from swinging when lifted.



POLE DRAWN JUST CLEAR OF GROUND.

The method of use is to back the vehicle up to the pole to be recovered, and make off the steel rope to the pole above the point of balance. The winch is then started and the pole is drawn vertically out of the ground. When clear of the ground the pole is lowered on to a transport vehicle, for removal to a temporary stack for ultimate disposal or re-use.

The borer and lifter which is hired by the day from the B.E.A., is capable of extracting poles up to 50 ft. long. It has been necessary to cut off the tops of poles taller than 50 ft. and also to strip poles of arms, etc., to avoid the fittings fouling the lattice of the derrick as the pole rises.

The saving in time and labour by this means can be estimated by the fact that in reasonable weather conditions and on a grass verge of moderate width, 32 stout poles have been removed and placed on the pole stack in one day. E. G. H.

Home Counties Region

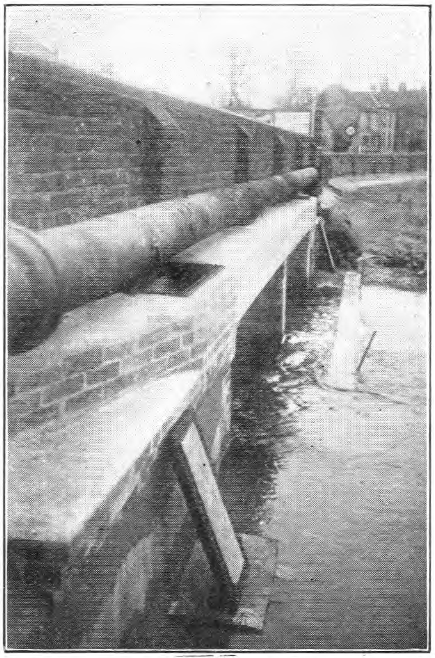
A BRIDGE-CROSSING EXPEDIENT

The metal conduits attached to the outside of Hermitage Bridge, Emsworth, carried a large number of trunk and junction circuits across an inland water creek; but salt water corrosion had disintegrated the pipes leaving only the thick socket ends supported by the cables. It was decided, therefore, to replace the conduits with a reinforced concrete trough fitted with removable covers, the trough to be carried on brickwork projections on the bridge piers. Proposals were submitted to and approved by the Highway Authority, subject to the condition that the new structure did not impair the appearance of the bridge.

Work was commenced by stripping from the cables what remained of the metal conduits; this was not difficult in the portions that had been exposed to the action of the salt water. It had been decided to extend the trough through the bridge parapet to the carriageway and cut away the steel conduits to the joint boxes at each end of the bridge. The steels were cut with an electric "Skilsaw," power being provided by an emergency charging set. After the metal conduits had been removed the cables were examined and pressure-tested.

Extensive timbering was necessary in forming the troughs, none of which was fastened to the fabric of the bridge—the whole of the moulds being carried on struts wedged between the bridge piers. To meet the Highway Authority's request for stronger reinforcement in the carriageway, $\frac{1}{2}$ in. steel plates were cut to fit over the trough leaving half the width of the trough wall for "knitting" to a final covering of reinforced concrete. As this proved successful it was decided to plate and concrete the whole of the trough instead of fitting removable covers. A small frame and cover was built into the roof of the trough for cabling purposes on each side of the creek on the outside of the bridge walls.

The waters are tidal and often in the morning the work was found festooned with seaweed and other refuse of backwater creeks.



REINFORCED CONCRETE TROUGH PROVIDED ON HERMITAGE BRIDGE, EMSWORTH.

The advantages gained by the expedient were that the bridge road surface was only disturbed at the solid ends where the trough was led into the joint boxes, the road over the bridge archways being left undisturbed. The extensive cabling operations that would have been necessary in renewing the conduits were avoided. The dimensions of the trough were made ample to cover all future cabling requirements. T. A. M.

AN UNUSUAL MOLE-DRAINING EXPERIMENT

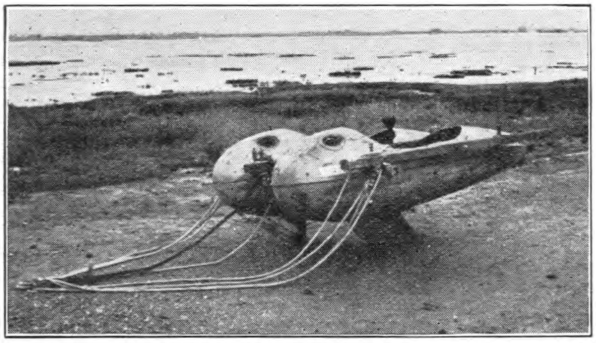
Horsey Island is situated to the North West of the town of Walton-on-the-Naze, Essex, and is separated from the mainland by Hamford Water on the North and Kirby Creek and the Wade on the South. The only approach other than by boat is across a causeway over the Wade.

This causeway is some ¾ mile in length and 6 ft. to 8 ft. in width. It is an ancient construction consisting of boulders and shingle and capable of carrying a heavy lorry. The whole causeway is covered at high tide to a depth of 6 ft. to 9 ft. when the channel is used by various craft.

The Island is farm land, there being one farmhouse and outbuildings, and when towards the end of 1949 the question of telephone installation came up for consideration problems arose.

Overhead construction was obviously unsuitable along the causeway as it would cause an obstruction to craft using the fairway. The causeway itself was unsuitable for trenching owing to its narrow width and the short periods during which it was above water and also the impossibility of reinstatement to anything like its original consolidation. It was bounded on each side, except for a few small creeks, by extensive areas of soft mud, and the possiblity of laying a cable in this by a system of mole-draining was considered.

Although this mud was much too soft for the use of normal mole-draining equipment the idea of a mole-draining raft was considered to be practicable. Thoughts turned to some old American Air Force auxiliary petrol tanks, a number of which were lying on a nearby aerodrome. Two were obtained, braced together



The Mole Draining Raft, showing Steering Tackle and Centre Plate.

with old eight-way arms and fitted with a centre plate 2 ft. 6 in. by 1 ft. 3 in. by ⅝ in., and a ¾ in. pipe was welded to the rear of the plate to take the cable but it was left without a mole, this not being necessary in the soft mud.

Steering was arranged with one centre tow rope fixed to sets of double block and tackle, one to each side, so that a towing pull could be varied and a steering effect obtained, this being necessary to keep the mole-draining raft several feet away from the causeway while working parallel with it.

The use of the causeway being limited to approximately four hours per day for normal tides and varying with low tides, it was not until February 14th, 1950, when the weather and tides proved suitable for a test, that the scheme was proved to be practicable.

In consultation with the Engineer-in-Chief's Office it was decided to use 1-pair polythene cable and also to mole-drain the parts along the approach roads on both sides of the causeway thus avoiding the use of overhead construction altogether.

Conditions again proved suitable on April 12th for work on the mudflats and two 1-pair cables were laid across the creek, one run being made in each direction. The raft was towed by a 30-cwt. W.D. type lorry running along the causeway 250 yards ahead, the cable being paid out from a second lorry running parallel with the mole-drainer raft. The steering of the raft was controlled by one man who sat on the raft and who also dealt with the removal of stray obstructions which became wedged across the blade at times.

Crossing a Small Creek. Cable can be seen entering Tube below Driver's Right arm.

Some trouble was expected from thick growths of marram grass, but surprisingly enough this did not occur as the blade cut through easily. The raft crossed the small gulleys with little difficulty, but in two creeks there was too much water for the blade to reach the bottom and the raft floated over without burying the cable in the mud and some slack had to be left to enable the cable to be buried by hand at the next spring tides.

The cable, being obtainable in half-mile lengths only, had to be jointed and this was carried out after the laying operations by polythene cable experts from the Engineer-in-Chief's Construction Branch. Two special mechanical joints were also provided between the land and submarine sections for assistance if any trouble should arise in the cable under the water and these were fitted on the cable warning beacon poles which had been erected previously.

An infinity reading with a 500-V megger was obtained on each cable after the operations, the circuit was completed and working the next afternoon, and up to the time of writing no trouble of any kind had developed.

Staff Changes

Promotions

Name	Region	Date
Deputy C.R.E. to Staff Engr.		
Moffatt, C. E.	L.T. Reg. to E.-in-C.O.	1.7.50
Asst. Staff Engr. to Staff Engr.		
Flowers, T. H.	E.-in-C.O.	1.7.50
Regl. Engr. to Deputy C.R.E.		
Stratton, J.	Mid. Reg. to L.T. Reg.	23.7.50
Exec. Engr. to Asst. Staff Engr.		
Bray, W. J.	E.-in-C.O.	5.6.50
Balcombe, J.	H.C. Reg. to E.-in-C.O.	18.6.50
Davison, G. N.	E.-in-C.O.	16.7.50
Area Engr. to Deputy T.M.		
Gill, F. W.	L.T. Reg.	18.7.50
Exec. Engr. to Principal		
Armstrong, R. G.	E.-in-C.O. to P. & A. Dept.	10.7.50
Fryer, P. W. F.	E.-in-C.O. to A. & P. R. Dept.	16.7.50
Engr. to Exec. Engr.		
Birnie, R. C.	Scot.	31.5.50
Harris, E. T. C.	E.-in-C.O.	28.5.50
Pilling, T.	E.-in-C.O.	28.5.50
Richards, D. L.	E.-in-C.O.	22.6.50
Goodwin, A. E.	E.-in-C.O.	14.7.50
Goford, R.	H.C. Reg.	14.7.50
Corke, R. L.	E.-in-C.O.	12.7.50
Jowett, J. K. S.	E.-in-C.O.	16.7.50
Davies, R. C.	E.-in-C.O.	12.7.50
Jones, D. G.	E.-in-C.O.	30.7.50
Reynolds, J.	E.-in-C.O.	1.8.50
Engr. to Sen. Sc. Offr.		
Hill, L. W.	E.-in-C.O.	19.5.50
Prob. Engr. to Engr.		
Castellano, E. J.	L.P. Reg.	1.5.50
Eley, A. C.	Mid. Reg.	6.5.50
Coustick, E. A. R.	Mid. Reg.	6.5.50
Meredith, T. E.	E.-in-C.O.	14.6.50
Mitchell, G.	E.-in-C.O.	14.6.50
Low, A. T.	E.-in-C.O.	1.6.50
Rymer, N. B.	E.-in-C.O.	14.6.50
Smith, P. E.	E.-in-C.O.	27.6.50
Abbott, P. W.	E.-in-C.O.	1.6.50
Walker, J. D.	L.T. Reg.	7.6.50
Carnson, L. B.	L.T. Reg.	1.6.50
Barker, A. J.	L.T. Reg.	28.6.50
Colyer, J. O.	L.T. Reg.	7.6.50
Seamans, K. R.	H.C. Reg.	28.6.50
Francis, R. S.	H.C. Reg.	28.6.50
Morton, J. Y.	E.-in-C.O.	17.7.50
Bennett, R. O.	E.-in-C.O.	4.7.50
Horne, F. A.	E.-in-C.O.	4.7.50
Kitchen, R. G.	E.-in-C.O.	17.7.50
Berresford, B. H.	E.-in-C.O.	1.6.50
Croft, E.	L.T. Reg.	1.7.50
Feere, S. E.	E.-in-C.O.	1.8.50

Name	Region	Date
Asst. Engr. to Engr.		
Duncan, N.	Scot. to E.-in-C.O.	20.5.50
Hulcoop, G. J.	H.C. Reg.	1.6.50
Bett, H.	H.C. Reg.	2.5.50
Piggott, T. W.	S.W. Reg.	2.5.50
Chapman, B. E. J.	L.T. Reg. to Scot.	30.5.50
Cooper, E. B.	E.-in-C.O. to L.T. Reg.	17.6.50
Mead, A. C.	L.T. Reg.	14.6.50
McEacham, J.	Scot.	14.6.50
Hills, G. W. P.	H.C. Reg. to Scot.	24.6.50
Ratcliffe, K. S.	E.-in-C.O.	14.6.50
Hales, J. R.	E.-in-C.O.	14.6.50
Beck, E. H. A.	E.-in-C.O.	14.6.50
Felton, N. F.	E.-in-C.O.	14.6.50
Nicholls, P. A.	E.-in-C.O.	14.6.50
Ashwell, J. W. G.	L.P. Reg.	14.6.50
Smith, G. H.	L.T. Reg.	1.7.50
Eustace, J.	L.T. Reg.	8.7.50
Tech. Offr. to Asst. Engr.		
Swift, F. H.	E.-in-C.O.	24.6.50
Sinclair, A. D.	E.-in-C.O.	4.7.50
Harrison, N. G.	E.-in-C.O.	5.6.50
Dean, C.	E.-in-C.O.	22.7.50
Robinson, A. J.	E.-in-C.O.	22.7.50
M.T.O. III to M.T.O. II		
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Byatt, H. A.	E.-in-C.O.	19.7.50
Hicks, A. P.	E.-in-C.O.	19.7.50

Transfers

Name	Region	Date
Exec. Engr.		
Ackroyd, J. O.	E.-in-C.O. to Admiralty	1.6.50
Engineer		
Davies, R. C.	N.W. Reg. to E.-in-C.O.	9.7.50
Asst. Engr.		
Seabrooke, G. A.	E.-in-C.O. to Inland Revenue	1.6.50
Mitchell, S. F.	E.-in-C.O. to Min. of Supply	1.6.50
Terrington, D. G.	E.-in-C.O. to Min. of Civil Aviation	1.6.50
Asst. Engr.—continued		
Franklin, L. E.	E.-in-C.O. to Mid. Reg.	1.6.50
Stollard, A. F.	E.-in-C.O. to Mid. Reg.	8.8.50
Woodford, R. A.	E.-in-C.O. to Min. of Supply	1.8.50
Gardner, D. H.	E.-in-C.O. to H.C. Reg.	14.8.50
Williams, E.	W.B.C. Reg. to S.W. Reg.	12.9.49
Lindsey, G. F.	H.C. Reg. to E.-in-C.O.	14.8.50
Asst. Exptl. Offr.		
Pidgeon, D. J.	E.-in-C.O. to Min. of Supply	3.7.50

Retirements

Name	Region	Date	Name	Region	Date
Staff Engr.			*Inspector*		
Frost, P. B.	E.-in-C.O.	30.6.50	Gosling, S. E.	L.T. Reg.	30.6.50
Asst. Engr.			Dewhurst, A. J.	L.T. Reg.	17.7.50
Mallows, E. G.	L.T. Reg.	15.6.50	Lightbown, A.	N.W. Reg.	25.7.50
Hales, G. A.	N.W. Reg.	30.6.50	Taylor, T.	N.E. Reg.	23.6.50
Thorley, C. B.	Mid. Reg.	23.6.50	Bentley, R. H.	N.E. Reg.	21.3.50
Butler, L. H.	E.-in-C.O. (Resigned)	29.5.50	Marks, J. S.	W.B.C. Reg.	29.4.50
Greenwood, G. F.	L.T. Reg.	31.7.50	Leney, H.	H.C. Reg.	31.3.50
Mitchell, E.	E.-in-C.O. (Resigned)	30.6.50	Lilleywhite, G. S.	H.C. Reg.	31.5.50
Robinson, J. G.	N.W. Reg.	26.8.50	Twort, H. S.	H.C. Reg.	6.2.50
Burgess, H. P.	L.T. Reg.	30.6.50	Hayes, R. G.	H.C. Reg.	15.3.50
Bale, W. F.	L.T. Reg.	31.7.50	Hurst, S. A.	H.C. Reg.	12.6.50
Brockwell, A. H.	L.T. Reg.	27.7.50	Gallagher, P.	N.I.Reg. (Resigned)	13.2.50
Kendall, C. A.	N.W. Reg.	31.8.50	Wonson, F. J.	S.W. Reg.	16.6.50
Swann, G. E.	L.T. Reg.	31.8.50	Wright, A. R. T.	S.W. Reg.	30.6.50
Soar, W. D.	E.-in-C.O.	31.7.50	Stewart, H.	Scot.	18.2.50
Gaukroger, W.	N.E. Reg.	14.6.50	Martin, F.	Scot.	28.4.50
Harding, C. C.	W.B.C. Reg.	20.5.50	Richards, J.	S.W. Reg. (Resigned)	28.2.50
Stead, A. D.	H.C. Reg.	16.1.50	Gosney, P. A.	L.T. Reg.	18.3.50
Grigg, C. E.	Mid. Reg.	20.8.50	Vickerage, H. B.	L.T. Reg.	11.4.50
Hicks, C. J.	L.P. Reg.	10.4.50	Glendening, C. G.	L.P. Reg.	16.1.50
Thomson, J.	Scot.	14.8.50	Sharp, A. F.	L.P. Reg.	28.3.50
Peter, D. T.	Scot.	31.7.50			
Phipps, G. R.	L.T. Reg.	31.8.50			

Deaths

Name	Region	Date	Name	Region	Date
Engineer			*Asst. Engr.—continued*		
Thompson, J. G.	N.E. Reg.	25.7.50	Gould, C. C.	W.B.C. Reg.	19.3.50
Asst. Engr.			Rogerson, T.	N.W. Reg.	8.8.50
Harrington, W. E.	L.T. Reg.	1.6.50	Randle, F.	Mid. Reg.	4.8.50
Fox, J.	N.E. Reg.	23.6.50	*Inspector*		
Nokes, H. R.	L.T. Reg.	27.7.50	Edwards, E.	Mid. Reg.	27.6.50

CLERICAL GRADES

Promotions

Name	Region	Date	Name	Region	Date
E.O. to H.E.O.			*C.O. to E.O.*		
Magness, W. H.	E.-in-C.O.	20.2.50	Crook, J.	E.-in-C.O.	4.6.50
			Wallis, W. G.	E.-in-C.O.	1.7.50

Retirements

Name	Region	Date
E.O.		
Clarke, E. V.	E.-in-C.O.	30.6.50

JUNIOR SECTION NOTES

(*Continued from page* 155)

May we appeal to all to take a lively interest in the Junior Section and their colleagues so that men become persons to each other—whatever their job is—and thus achieve the success desired. Whilst a large membership and strong financial position have been ensured by the payment of subscriptions by deduction from pay, we would like to see a larger percentage of members at the meetings in the coming winter.

Your officers are now completing the final arrangements of the programme for the forthcoming 1950-51 Session. In addition to other interesting items, we are pleased to report that three of our members have agreed to give lectures. Congratulations to those members of other Centres who have been awarded prizes in the Essay Competition. J. B.

Portsmouth Centre

We are looking forward in 1950-51 Session to another successful programme, the events planned being four film shows (sound) and the following lectures :—

(1) " Trunk Mechanisation and the Cordless Switchboard," by our Telephone Manager, Mr. H. C. Andrews.

(2) A reserved subject, to be given by our Area Engineer, Mr. R. Goford.

(3) " Sound Recording," by Mr. Baker.

Our proposed visits are as follows :—

(1) Visit to a submarine, though the Navy will not allow us to " sink."

(2) A conducted tour of an aircraft carrier.

(3) The Pirelli Cable Works, Eastleigh.

(4) British Oxygen Company.

(5) Messrs. Guinness, Park Royal.

Our membership now totals about 170, which makes an increase of about 45 members in a year. If we could get that increase at our meetings, then we should feel inclined to challenge any Section in the country.

Nevertheless we are proud to say Portsmouth Centre is very much alive and working in the right direction. W. F.

Scarborough Centre

The Annual General Meeting was held on 11th May, 1950, when a successful year's working was reviewed.

As the Chairman, Treasurer and Secretary had announced their intention of retiring after the 1949-50 Session it was the wish of the Centre that it be placed on record that the retiring officers—Messrs. F. Cowper, A. B. Clarke and P. Mitton—be accorded a hearty vote of thanks for their 13 years' continuous service as officers of the Centre. A fine example to the Institution and the Scarborough Centre in particular had been set by these officers over a long period, and the incoming officers and committee are resolved to do their best to maintain the spirit and continue the good work.

The following officers were elected for the 1950-51 Session :—

Chairman : D. S. Stephenson ; *Treasurer :* J. E. Wiseman ; *Secretary :* A. S. Bryce ; *Social Organiser :* K. Megginson ; *Committee :* A. L. Theasby, F. Cowper, G. M. Archer, P. L. Mitton, A. B. Clarke, G. Cordukes, J. Dale, H. Birch, M. Rawlinson, D. Owen, E. Horsman, B. Leadlay, D. Kynman. S. S.

Tunbridge Wells Centre

A very successful series of meetings was held during the season 1949-50. It was gratifying to see so many members at each meeting and it is hoped that the interest will be maintained during the forthcoming season. The Branch is now on a very firm basis both in membership and financially.

Our final venture of the season, a coach trip to Fulham Power Station, was one of the most interesting of our visits, our only regret being that more of our colleagues could not join us. A. E. C.

The Board of Editors is not responsible for the statements made or the opinions expressed in any of the articles in this Journal, unless such statement is made specifically by the Board.

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All communications should be addressed to the Managing Editor, *P.O.E.E. Journal*, Engineer-in-Chief's Office, Alder House, Aldersgate Street, London, E.C.1. Telephone : HEAdquarters 1234. Remittances should be made payable to " *The P.O.E.E. Journal*" and should be crossed "& Co."

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In course of preparation. Publication dates and prices to be announced later :

RADIO II — **LINE TRANSMISSION I**

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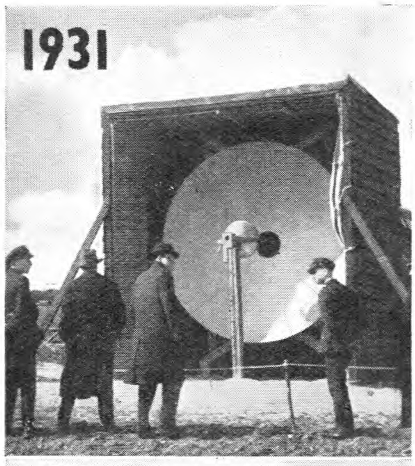
In Transmission History



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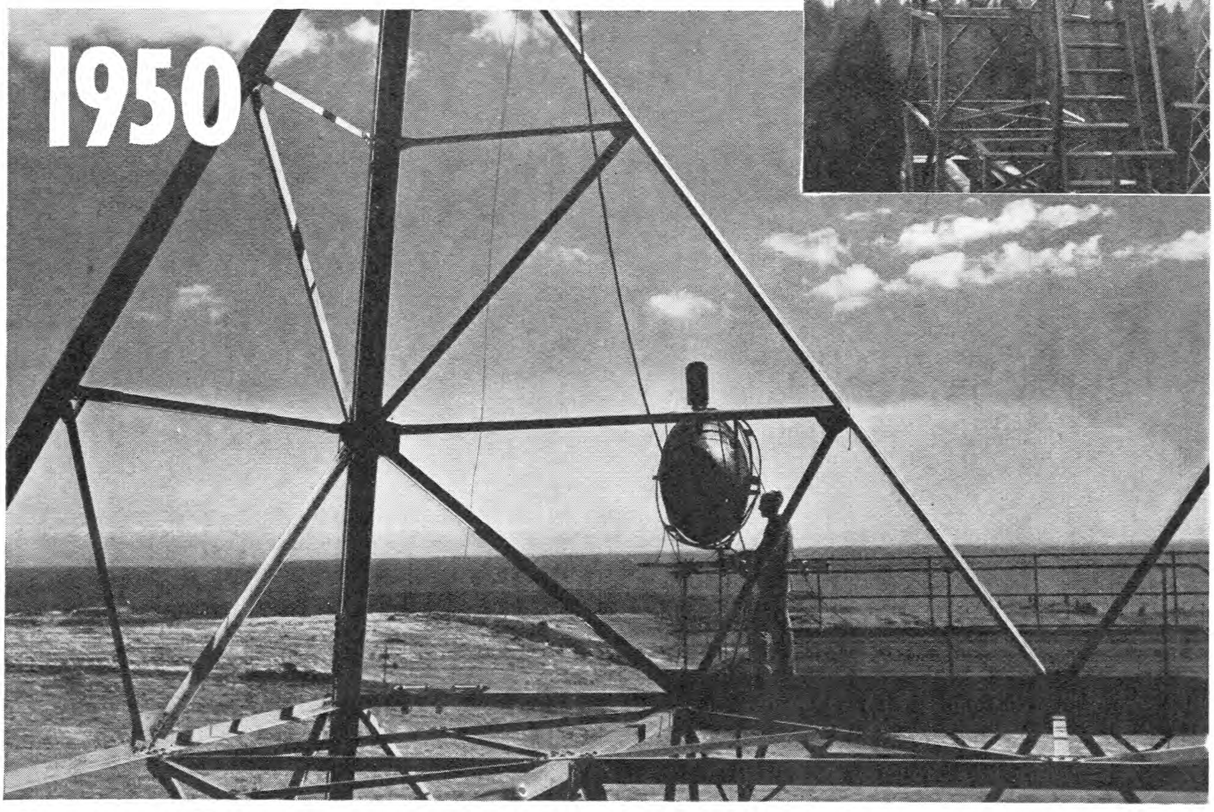

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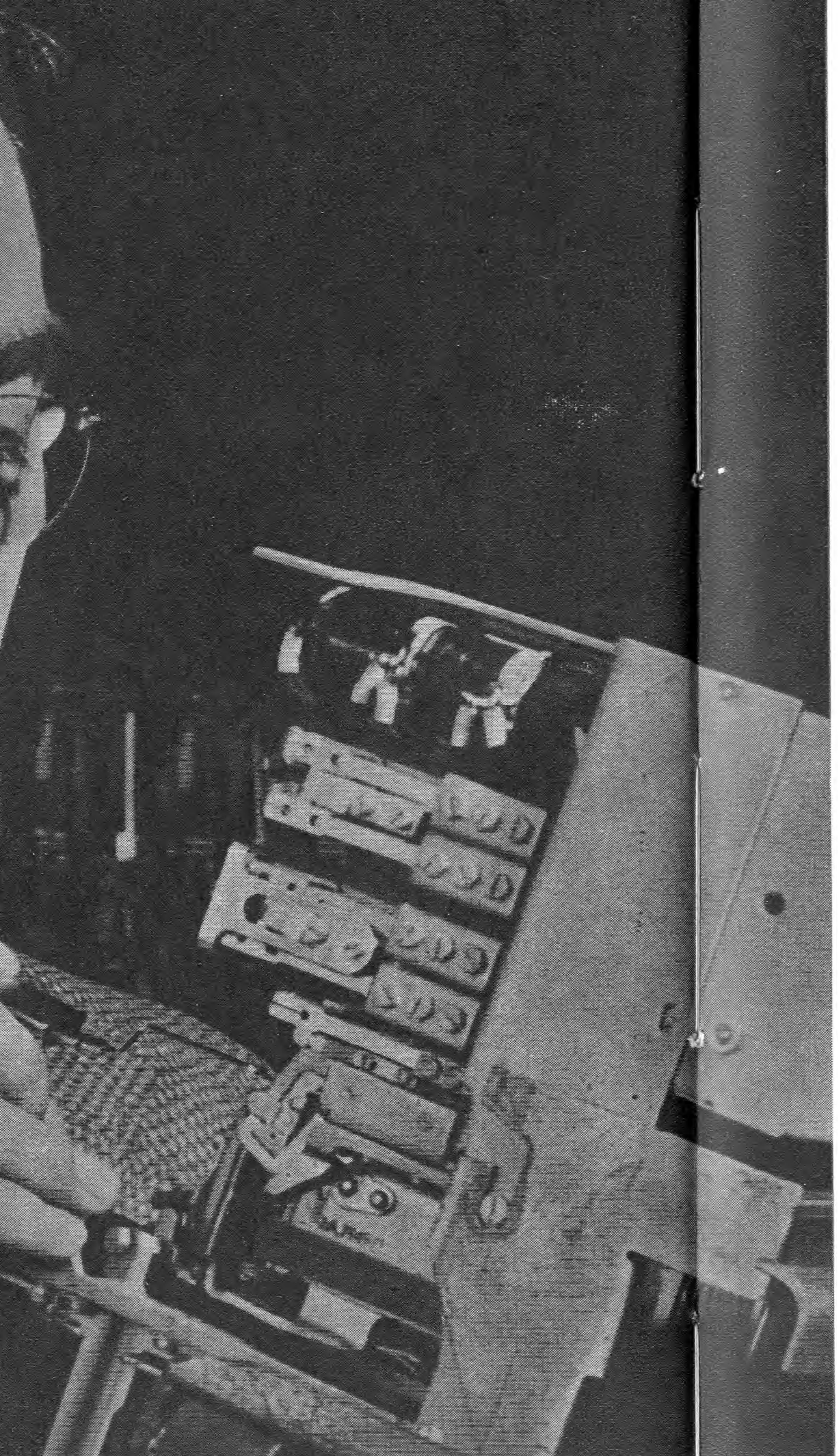

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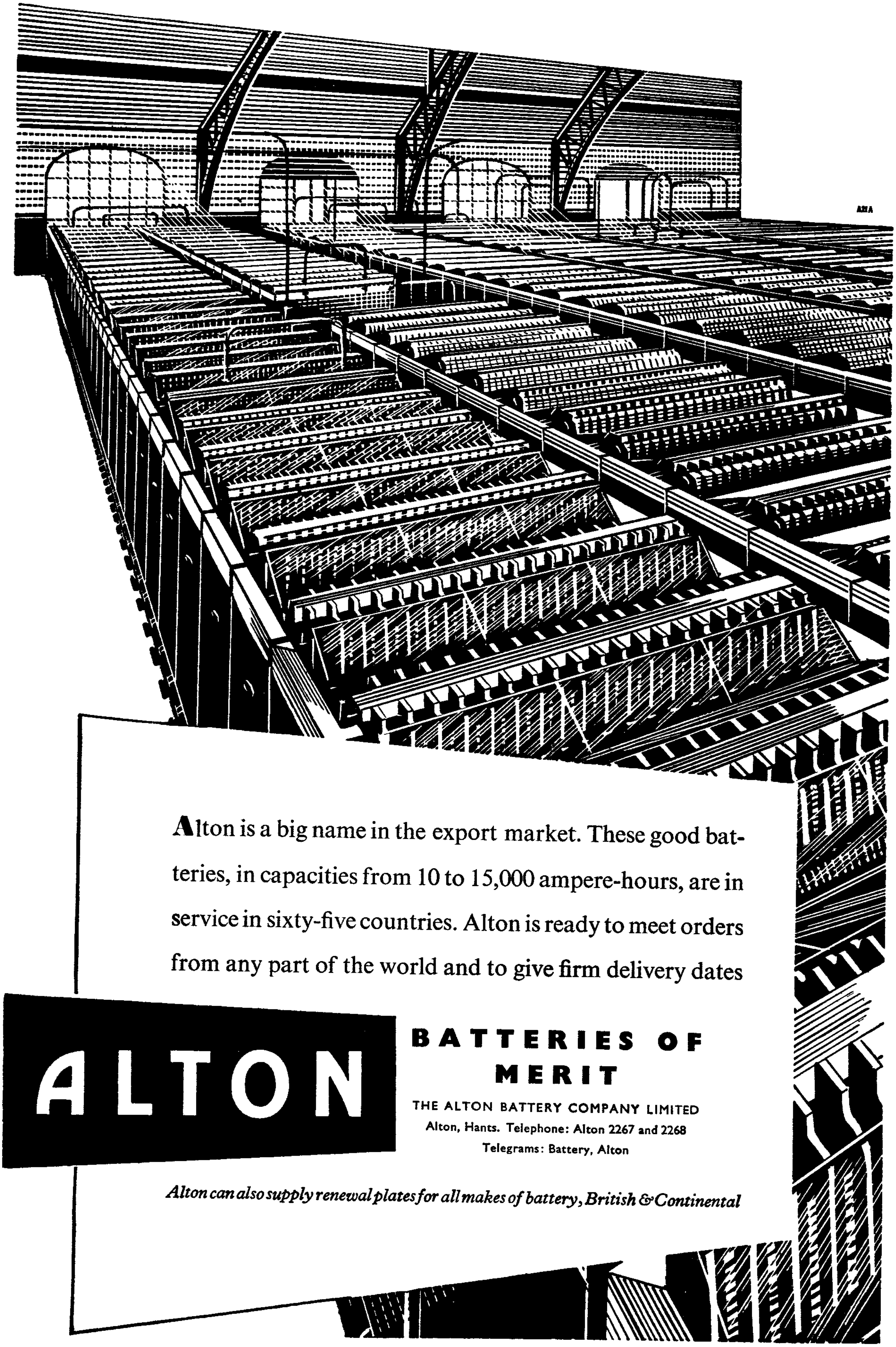
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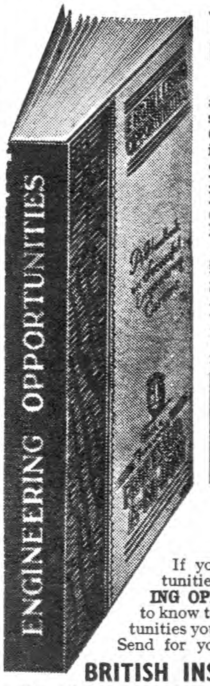

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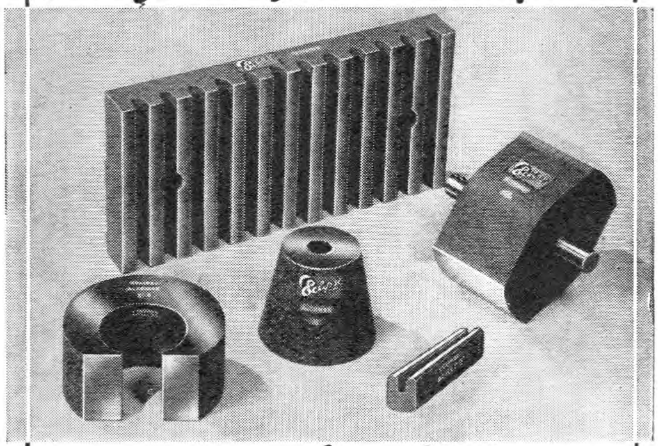

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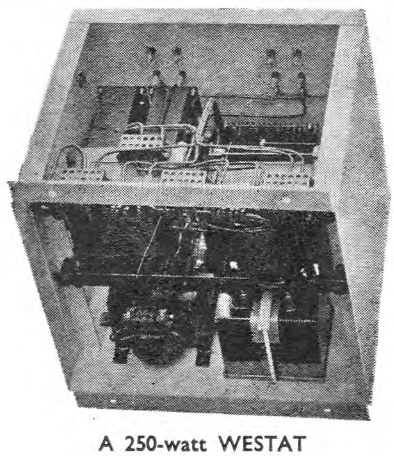

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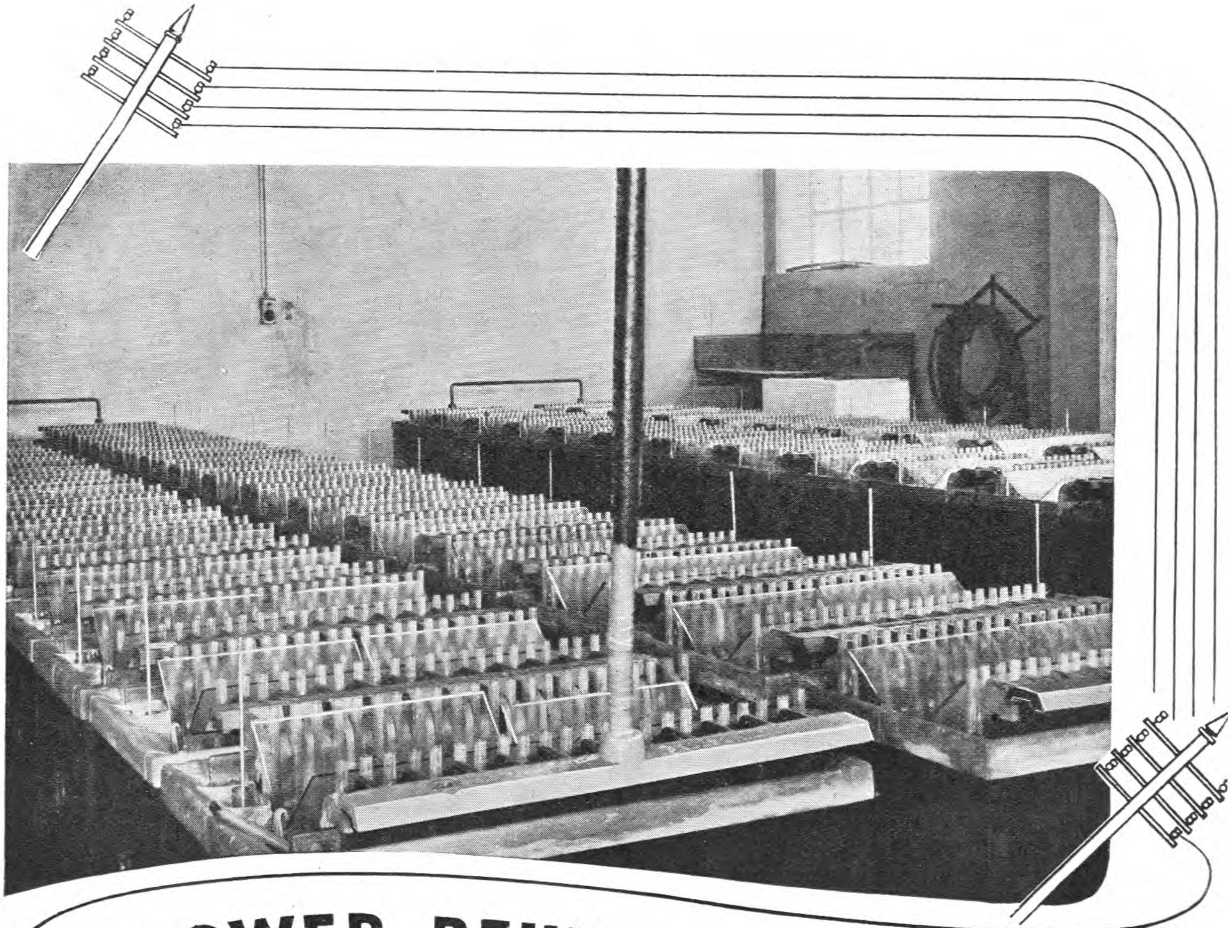

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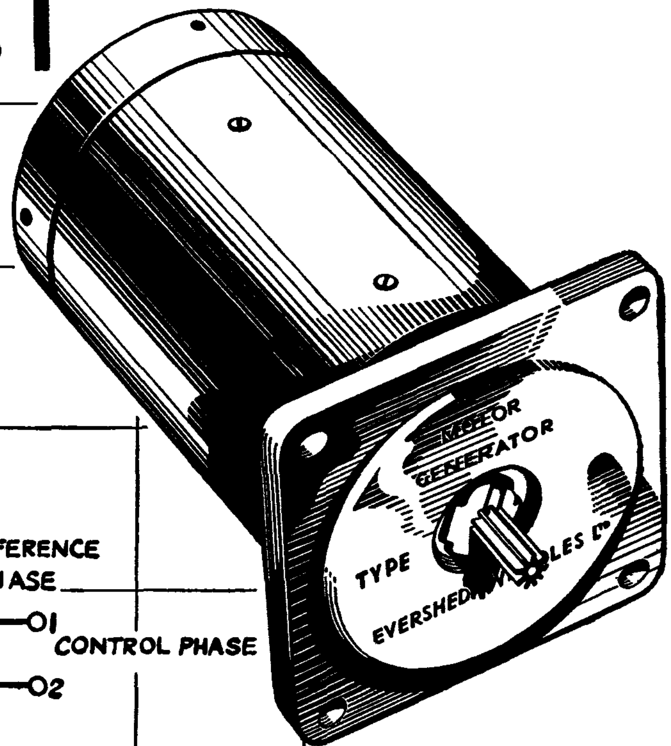

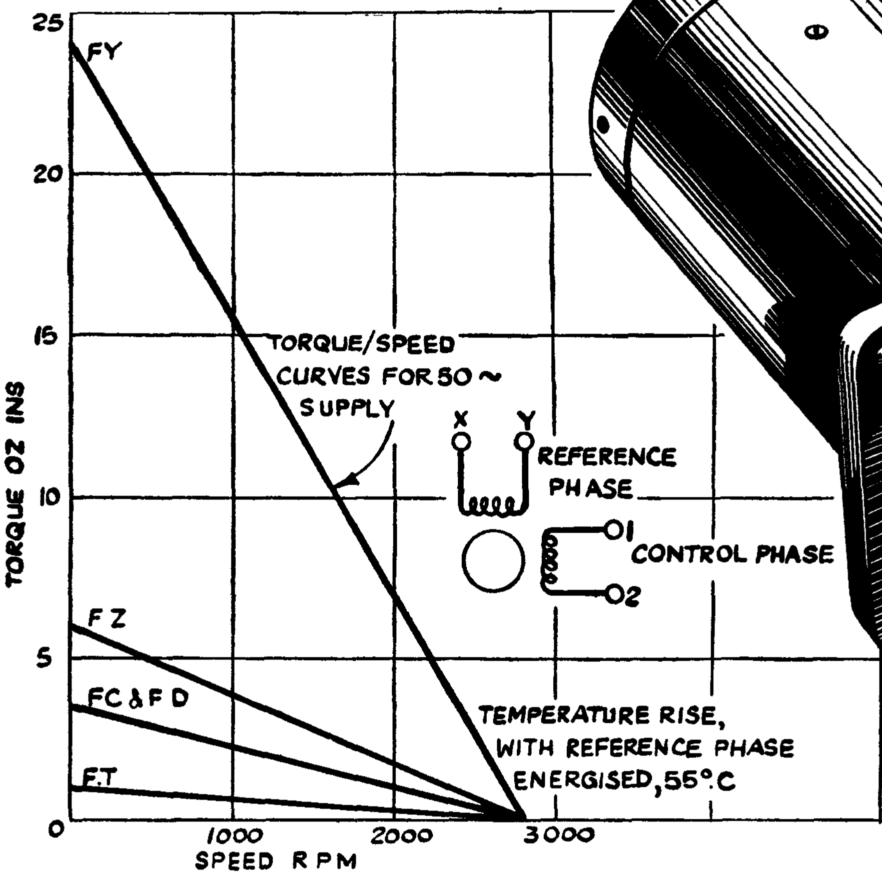

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F.D.	.2	8.6	11	2.5
F.Z.	.27	12.0	12	4.5
F.Y.	.6	35.0	35	17.0

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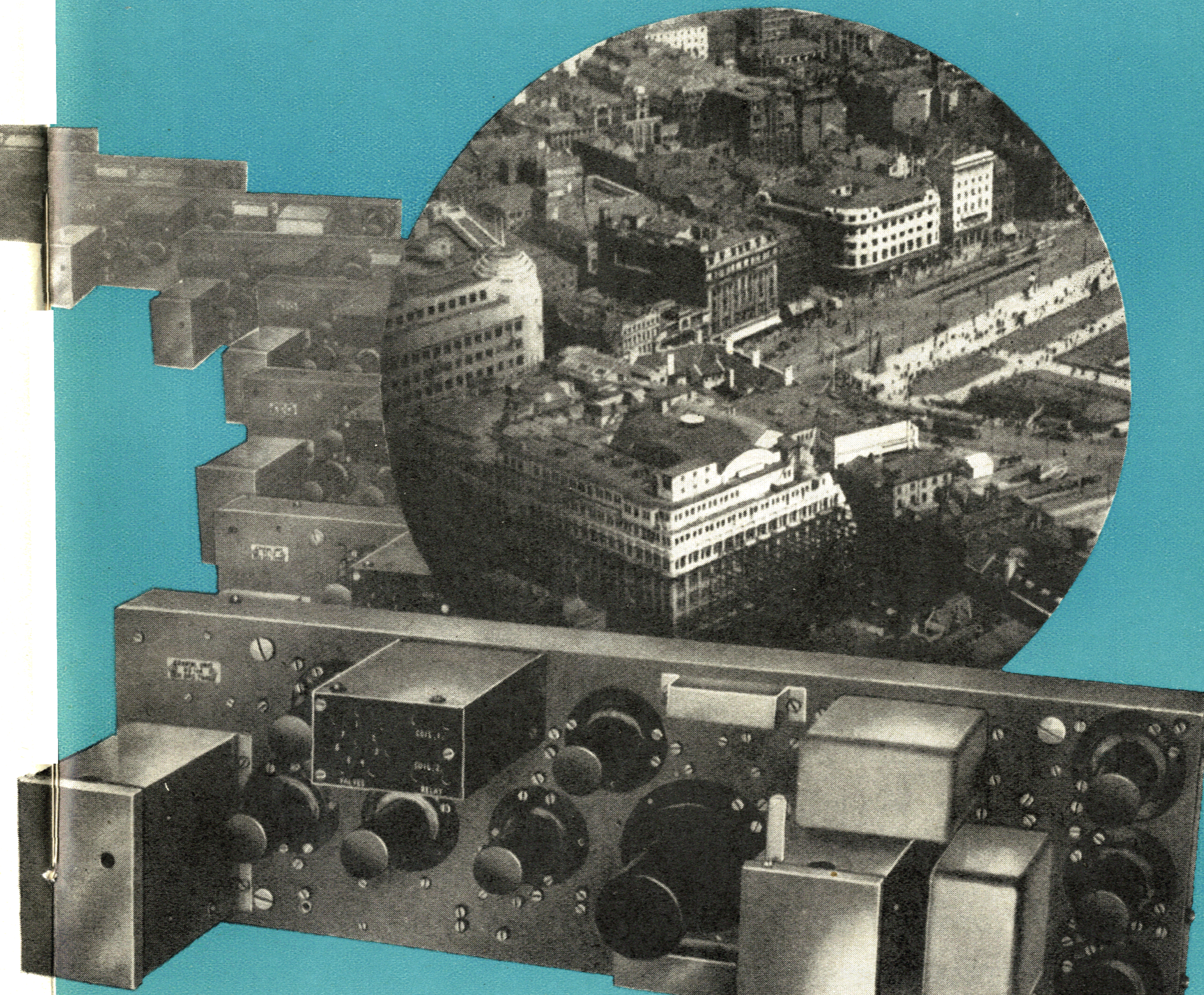

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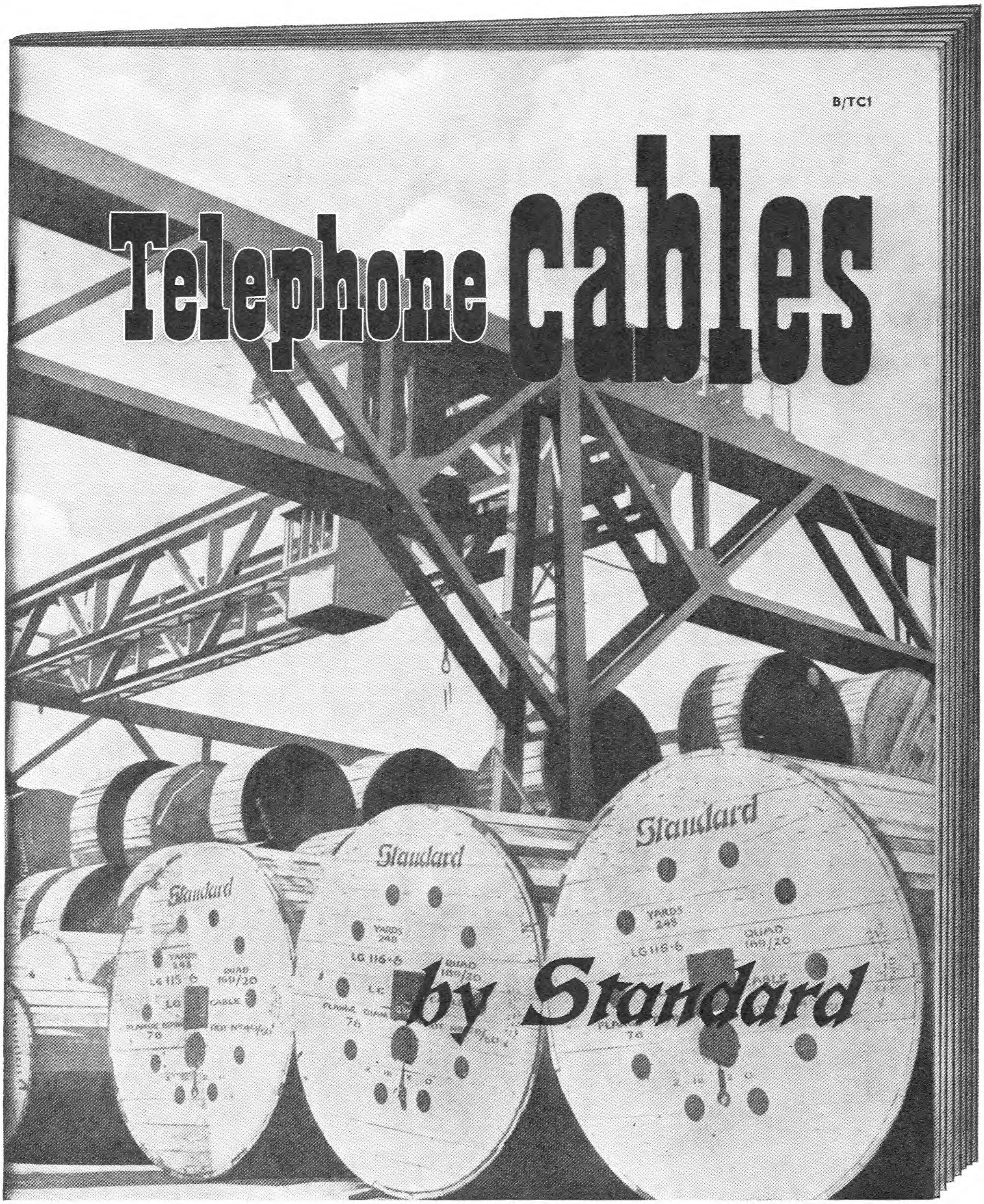
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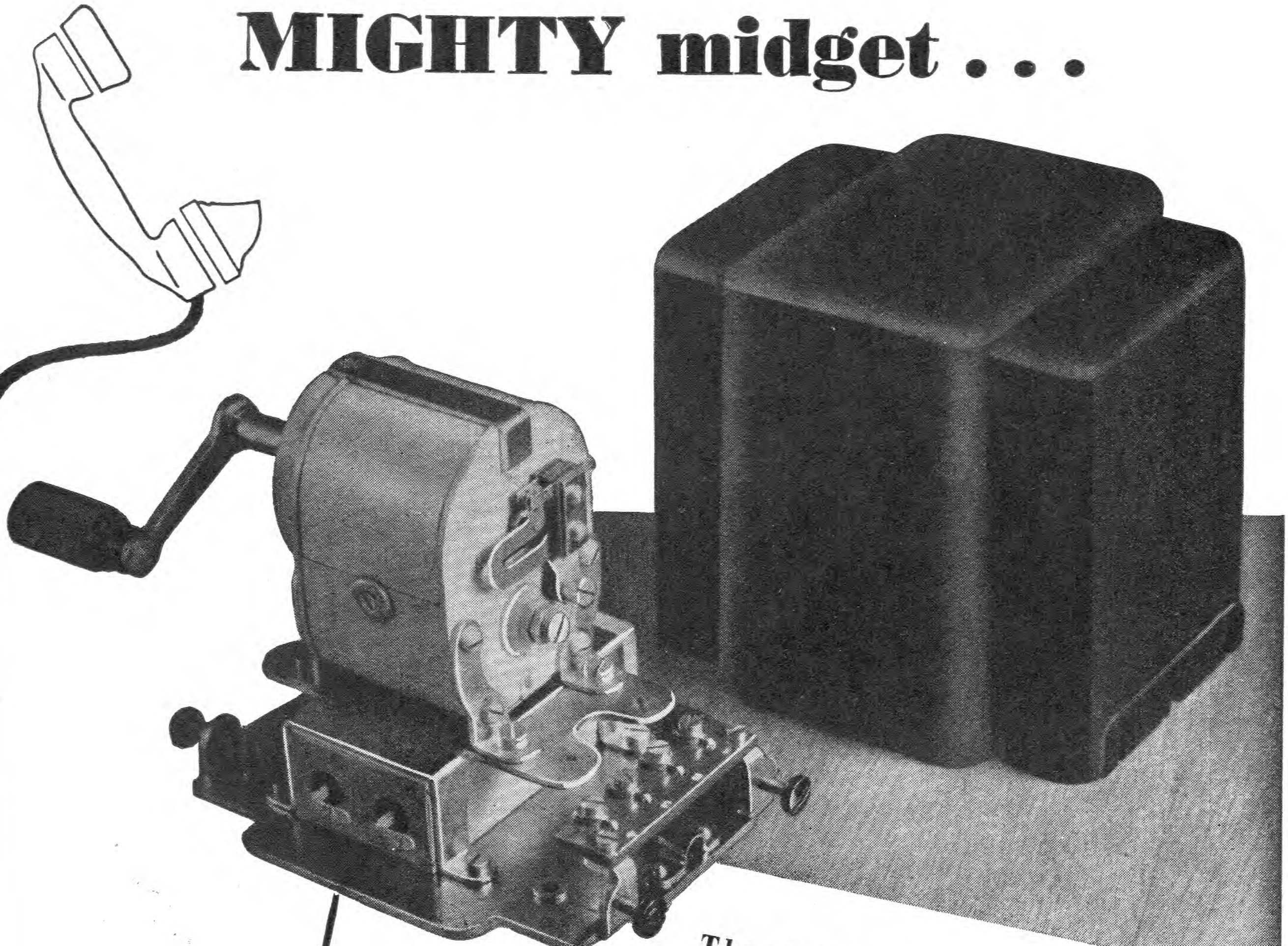

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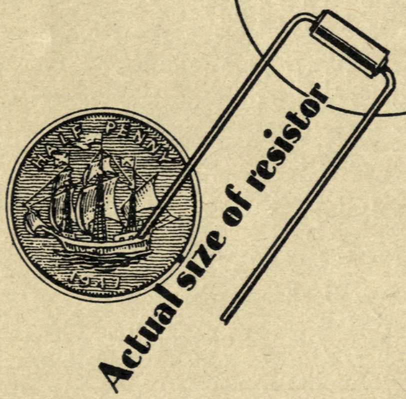

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