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CONTENTS

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Post Office Tower, London, and the United Kingdom Network of Microwave Links

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Microwave radio links are playing an increasingly important part in the provision of additional circuits for the Post Office telephone, television and data-transmission networks. The main features of such links are reviewed and, in particular, the functions and equipment of the London Post Office Tower, which will form the terminal station for many radio-relay links, are described.

INTRODUCTION

PROVIDING a new feature on the London skyline, the Post Office Tower (Fig. 1) will be the London terminal of a nation-wide trunk network of microwave radio-relay links carrying telephone, television and data traffic.

In the period since the second world war, the Post Office has provided a national network, composed partly of underground coaxial cables and partly of microwave radio-relay links, to serve the needs of the British Broadcasting Corporation (B.B.C.) and the Independent Television Authority (I.T.A.) 405-line monochrome television services.[1] The radio component of the network provides an aggregate length of 4,000 operational video-channel miles, and its London terminal is located adjacent to, and in the shadow of, the new tower. In the same period, steady developments in microwave techniques have enabled the Post Office to introduce the microwave radio link as a practical and economic alternative to the coaxial-cable link for long-distance transmission of multi-channel telephony.[2]

Rapid expansion and reconstruction of the radio component of the network is now being carried out to provide extensive new trunk telephone-circuit capacity to meet the demands arising from the increasing use of the telephone in the United Kingdom, stimulated by the spread of subscriber trunk dialling, and to meet the requirements of the B.B.C.'s new 625-line television service. A prime example of the expansion now under way is the replacement by the Post Office Tower of the existing radio terminal in London, which has neither the communication capacity required for future needs nor an adequate height.

TRAFFIC TO BE CARRIED BY THE MICROWAVE NETWORK

By 1966 a trunk network of radio-relay links (Fig. 2), with aggregate route length of 2,000 miles and using

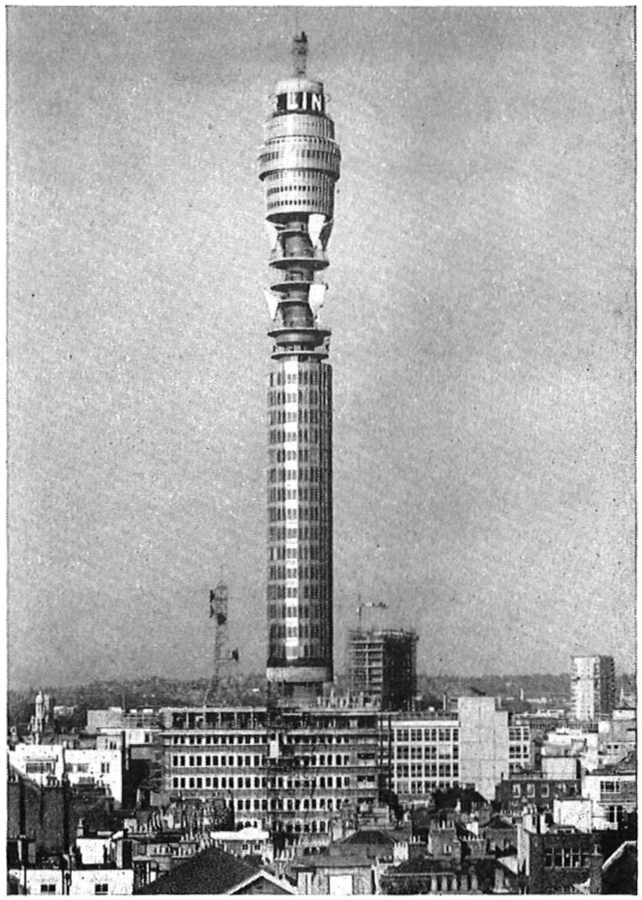


FIG. 1—THE POST OFFICE TOWER

120 stations, will join together all main centres of population in the United Kingdom. The network will by that date provide about 4,500 operational broadband-channel miles for the transmission of multi-channel telephony, of which 1,800 miles will have a capacity of 960 telephone channels per broadband channel in a frequency-division-multiplex assembly of 4 kc/s channels in the baseband* frequency spectrum 60 kc/s–4·028 Mc/s,

†Inland Radio Planning and Provision Branch, E.-in-C.'s Office.

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

A

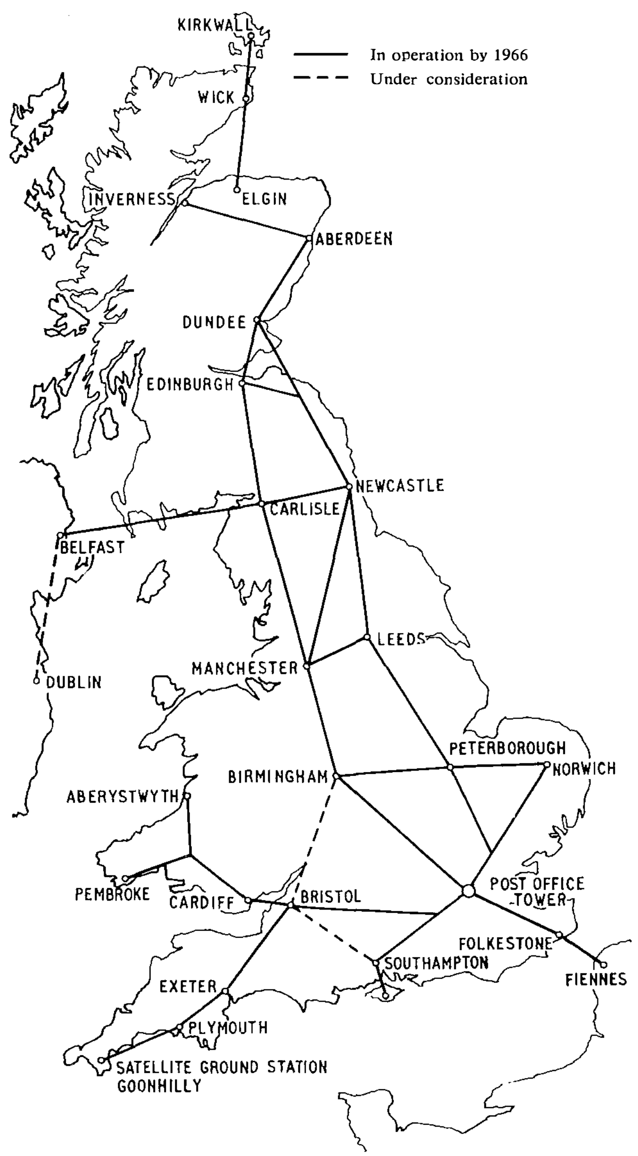
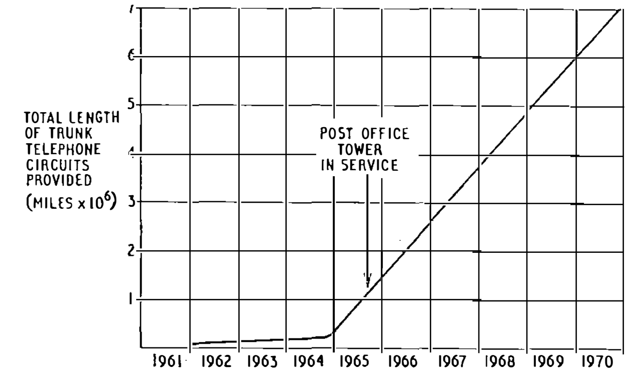


FIG. 2—POST OFFICE MICROWAVE RADIO-RELAY TRUNK NETWORK

and 1,800 miles with a capacity of 1,800 telephone channels per broadband channel (baseband frequency spectrum 312 kc/s–8·204 Mc/s). At the present time the aggregate telephone-circuit mileage carried by radio links is about 1,000,000 miles, but by the end of 1966 this will have increased to 2,500,000 and, on current estimates, should reach 7,000,000 miles by 1970 (Fig. 3).

In addition to providing for the needs of the present 405-line services, the network also provides 2,100 operational video-channel miles (vision-channel baseband frequency-spectrum 0–5·5 Mc/s) to serve the first 13 u.h.f. 625-line television broadcast transmitters, which are scheduled to be in operation by 1966. An important requirement has been the need to cater for the eventual transmission of colour signals; in the absence of international agreement on a colour system, the Post Office have specified transmission standards appropriate to the N.T.S.C.† system, which is considered to have the most stringent transmission requirements of any system that might reasonably be adopted.

†N.T.S.C.—American National Television System Committee.



The curve shows the mileage already provided and the estimated future mileage.
FIG. 3—POST OFFICE MICROWAVE RADIO-RELAY NETWORK—TRUNK TELEPHONE CIRCUIT GROWTH

The station which must cater for the greatest demand for circuits is that in the centre of London, at the focal point of important trunk telephone exchanges and the London network of television cables. By 1966 the Post Office Tower will be the terminal for 5,400 United Kingdom trunk telephone circuits and, in addition, for 23 television channels; by 1969 the trunk-telephone component will have increased to 30,000 circuits. The Tower will also be the terminal for telephone and television circuits to the continent of Europe, by way of the cross-channel radio link, and to North America, by way of the satellite ground station at Goonhilly Downs, Cornwall.

FEATURES OF MICROWAVE RADIO-RELAY LINKS AND STATIONS

General

Before giving details of the Post Office Tower it is necessary to consider the technical features and capabilities of microwave radio-relay links in general, so that the factors affecting the choice of site, the form of structure, and the radio equipment provided may be more clearly understood.

Microwave radio-relay links now in use operate in radio-frequency bands centred on 2,000, 4,000 and 6,175 Mc/s, and a further band centred on 6,760 Mc/s will shortly be brought into use; many individual broadband channels, each capable of carrying up to 1,800 speech channels or, as an alternative, one 625-line colour-television signal, can be accommodated in each band.

Microwaves, i.e. radio waves having a frequency greater than about 1,000 Mc/s, are suitable for point-to-point transmission because they can be concentrated into highly-directional beams by reasonably compact aerials (Fig. 4), and directed along substantially-straight line-of-sight paths between adjacent stations (Fig. 5).

To obtain the most efficient transmission of the radio waves, there must be certain minimum clearances between the direct line-of-sight transmission path of the microwave energy and the ground or other obstacles on or near the transmission path. To achieve this, microwave radio stations are usually sited on ground which is higher than the surrounding area, and the aerials are mounted on towers, usually of lattice steel but sometimes of reinforced concrete. Post Office links are normally planned so that the radio transmission path between

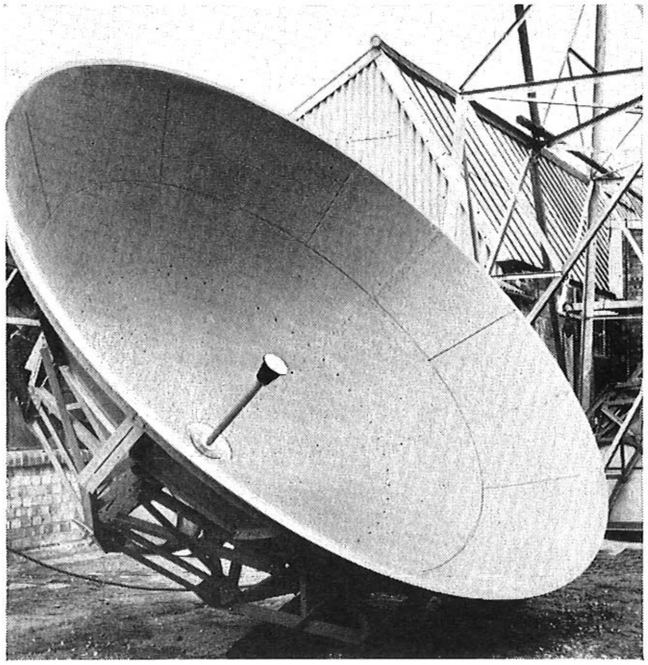
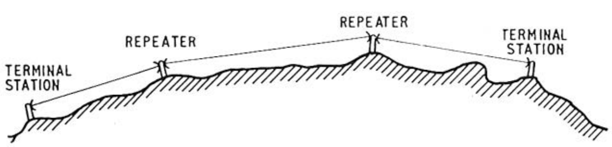


FIG. 4—PARABOLIC-DISH AERIAL



TYPICAL SPACING BETWEEN STATIONS ABOUT 30 MILES

FIG. 5—LINE-OF-SIGHT MICROWAVE SYSTEM

aerials at adjacent stations clears all features of the intervening terrain by about half the radius of the first Fresnel zone.* Moreover, as an additional precaution, this clearance is designed to occur even under adverse meteorological conditions that can occasionally arise,† making the radio path curve so that it is convex towards the earth, with a curvature one quarter of that of the earth. To provide the required quality of transmission, and in order to keep the heights of the towers within reasonable bounds, the spacing between stations is normally about 30 miles, which, in this country, leads to tower heights ranging between 50 and 300 feet, depending on the particular features of the path terrain. A typical radio station of this type, using a lattice-steel tower, is shown in Figure 6; most stations in the network have towers of this, or similar, type but reinforced-concrete towers[3] are in use at seven stations.

At stations of this kind, the microwave-radio equipment is housed in a single-story building at the foot of the tower and is connected to the aerials by means of waveguide feeders located within the structure of the tower.

The average link between main centres of telecommunication traffic in the United Kingdom is about

*The first Fresnel zone is an ellipsoid enclosing the two aerials and the path, such that the sum of the distance from any point on its surface to the two aerials is half a wavelength longer than the direct distance between the two aerials.

†On occasions such as those when the normal decrease of air temperature and/or humidity with increasing height is reversed.

FIG. 6—TYPICAL POST OFFICE MICROWAVE RADIO STATION

100 miles long and requires up to three intermediate relay stations; greater distances are spanned by connecting individual links in tandem, either at the baseband or at the intermediate frequency.

The London Station (Post Office Tower)

The danger of obstruction of radio paths by tall buildings poses special problems in cities such as London and Birmingham, where traffic requirements and economics indicate that the radio station should be at the traffic centre itself, rather than on the outskirts with cable connexion to the centre as is the case for all other city or town stations in the United Kingdom.

The site chosen for the London station is adjacent to the Museum telephone exchange in Howland Street; here, there is no convenient hill on which to site the station and, also, there is a continuing growth in the number of high buildings in the London area as a whole. To make reasonably certain that the microwave paths to adjacent stations would not be obstructed by such buildings, it was necessary to build a tower of exceptional height that would support the aerials at up to 450 ft above ground. To keep the length of the waveguide feeders connecting the aerials to the radio equipment as short as possible, and hence the loss of microwave power to an acceptably small value, it was decided to house the microwave equipment inside the tower itself, just below the aerials. This in turn meant that lifts and welfare accommodation had to be provided for the maintenance staff, as well as emergency stairs to meet fire regulations. The tower is planned to accommodate equipment to provide up to 150,000 telephone circuits and 40 television circuits simultaneously; this equipment imposes a considerable power-supply load and presents a difficult cabling problem. A large dissipation of energy as heat is also involved, requiring a substantial ventilation plant.

Since the tower would have a commanding view over London, a decision was taken to provide facilities for the general public at the very top. These comprise a rotating restaurant and associated kitchens, cocktail lounge, tea bar and observation galleries. A tower fulfilling these needs had to be provided to stand on the relatively small piece of land available, and the Ministry of Public Buildings and Works undertook its design and provision.[4] The result is the now familiar reinforced-concrete tower, which is shown in schematic form in Fig. 7.

MICROWAVE-RADIO EQUIPMENT

Modern microwave transmission techniques and equipment typical of those to be used in the Post Office Tower can best be illustrated by reference to the schematic diagrams of Fig. 8(*a*)—(*d*). These show a microwave link, spanning about 60 miles by means of a single intermediate repeater station, for the provision of up to eight bothway broadband channels, each for 1,800 telephone circuits or one 625-line television signal, in a frequency band centred on 6,175 Mc/s.

There are a number of bands of radio frequencies available by international and national agreement for Post Office microwave links; these bands, given in the table, have a total bandwidth of 3,200 Mc/s, and the way in which radio carrier frequencies are arranged in the 500 Mc/s-wide band centred on 6,175 Mc/s, which is typical, is shown in Fig. 8(*e*). The band is subdivided into two adjacent blocks of 250 Mc/s, and each block contains eight radio-frequency channels with carriers spaced about 30 Mc/s apart; at any one station all transmit channels are allocated to one block and all

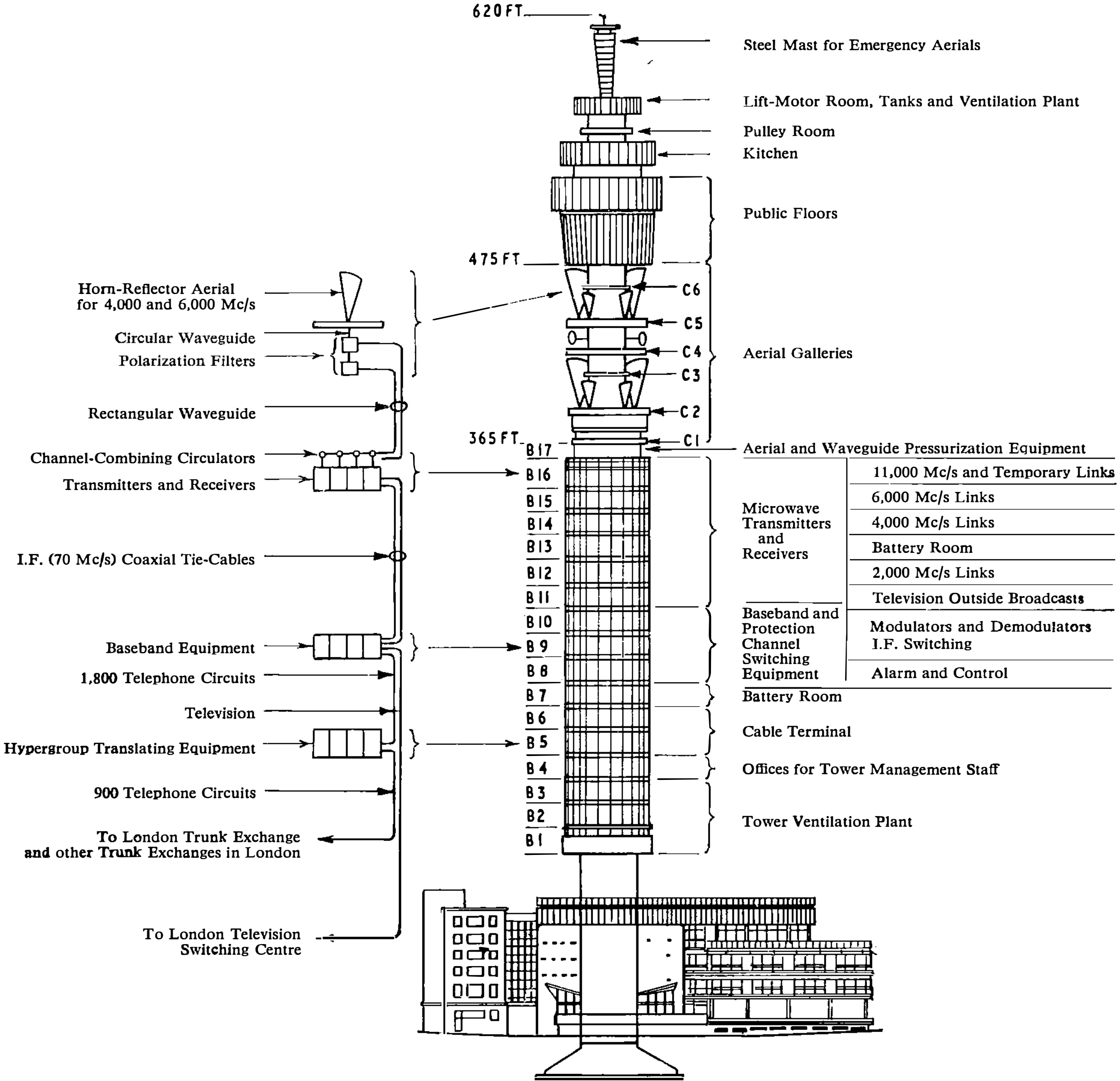
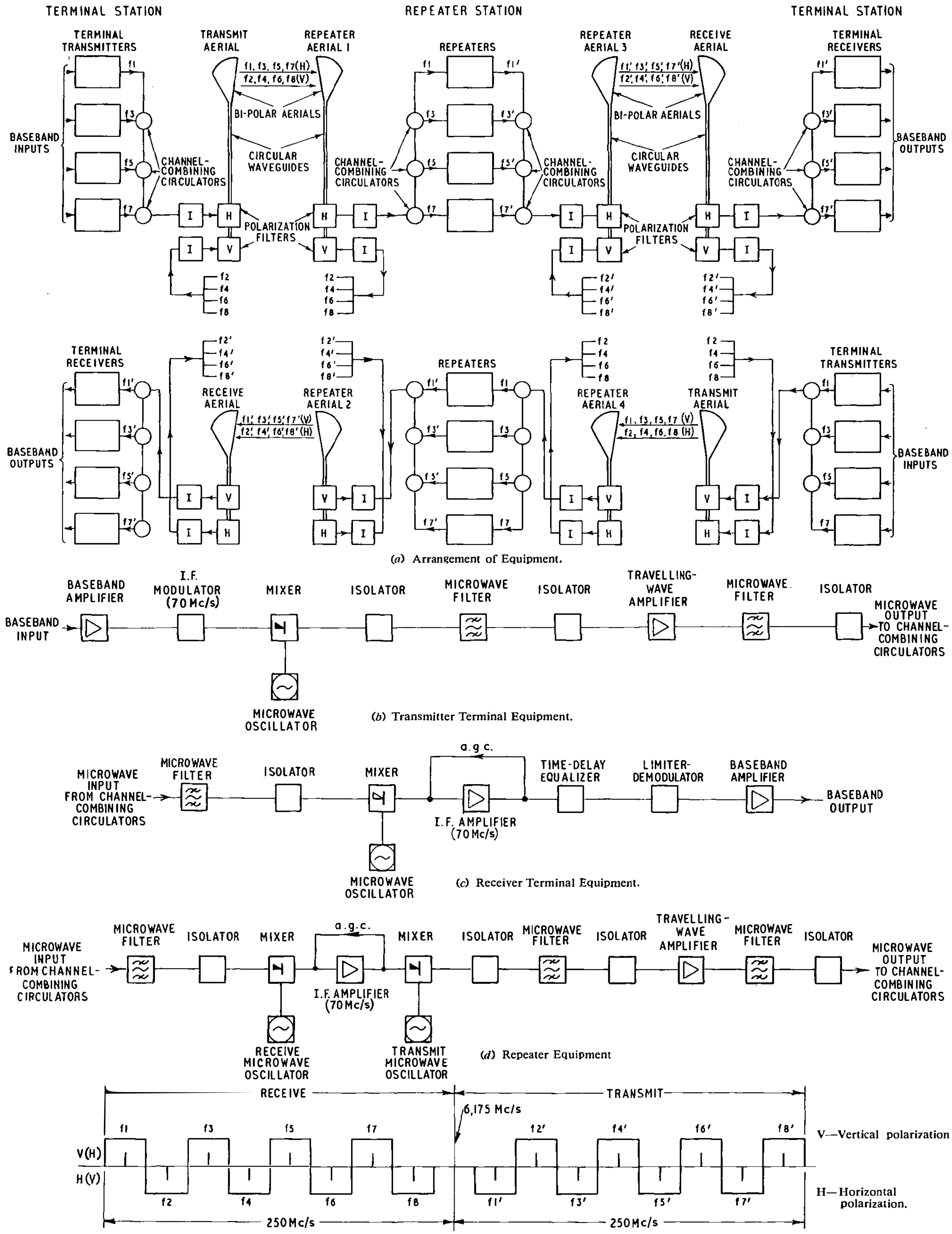


FIG. 7—UTILIZATION OF POST OFFICE TOWER



(*a*) Arrangement of Equipment.

(*b*) Transmitter Terminal Equipment.

(*c*) Receiver Terminal Equipment.

(*d*) Repeater Equipment

(*e*) Radio Channel Frequency Assignment at Repeater Station.

FIG. 8—MULTI-BROADBAND-CHANNEL MICROWAVE LINK

Radio-Frequency Bands Available for United Kingdom Microwave Links

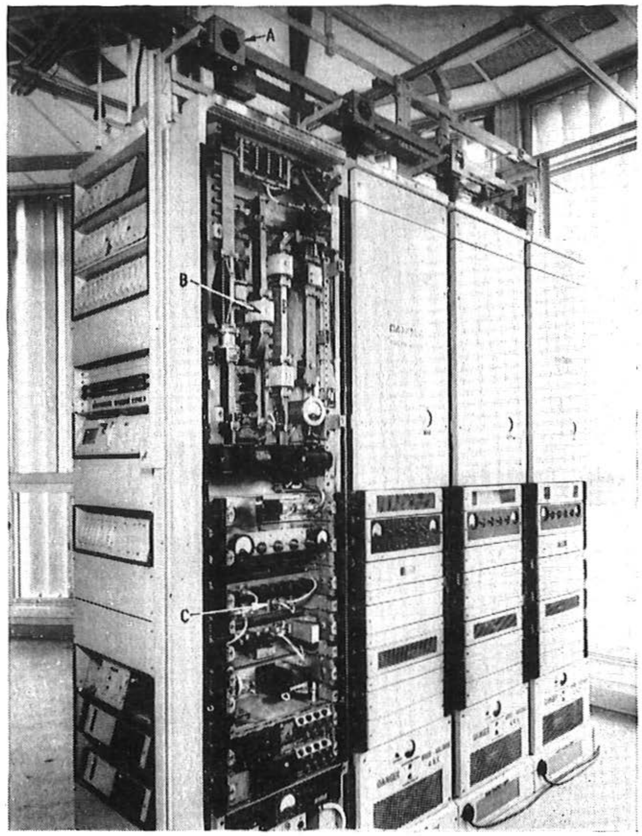
Band Centre (Mc/s)	Bandwidth (Mc/s)	Channel Spacing (Mc/s)	Number of Bothway Broadband Channels	Projected Use
1,800	200	30	2	Spur route
2,100	400	30	6	Main route
4,000	400	30	6	Main route
6,175	500	30	8	Main route
6,760	700	20 40	16 } Alternative 8 } proposals	Main route
11,190	1,000	40	12	Spur/main route

receive channels to the other. To enable channel signals to be more easily separated, adjacent channels are given orthogonal polarization, so that the minimum spacing between the channels of the same polarization is about 60 Mc/s. Because of the highly-directional properties of the aerials used it is possible to use the same set of frequencies, independently, for transmission in four different directions from each radio-relay station.

The baseband input signal, after suitable pre-emphasis, frequency-modulates an oscillator having a mean centre-frequency of 70 Mc/s—the intermediate frequency (i.f.)—producing an intermediate signal having a spectral range of 55-85 Mc/s. The modulator has a voltage/frequency transfer function which is highly linear so as to avoid production of intermodulation noise in telephony systems and distortion of television signals. After amplification the i.f. signal is applied, together with a signal from a microwave oscillator, to a balanced crystal-diode mixer; one microwave sideband of the mixer output is selected by the r.f. filter shown and amplified by a travelling-wave amplifier (t.w.a.) to a power level of 5 watts. In the arrangement shown for the terminal stations in Fig. 8, the individual broadband outputs of eight t.w.a.s are combined into two groups (radio-frequency channels f1, f3, f5, f7 and f2, f4, f6, f8) by means of ferrite circulators (Fig. 9) and connected to a bi-polar aerial by way of a polarization filter and a circular waveguide capable of supporting orthogonally-polarized signals. Another aerial, and a similar arrangement of polarization filter and ferrite circulators, is used to receive eight individual broadband signals (radio-frequency channels f1′–f8′) from the distant repeater station. The received microwave signal in each radio-frequency channel is converted to i.f. by means of a low-noise crystal-diode mixer, amplified and translated to the baseband frequency by a highly-linear frequency-demodulator.

A typical repeater, as shown in Fig. 8(*d*), consists in essence of a terminal receiver and transmitter connected together at the intermediate frequency, the microwave oscillators being displaced in frequency from each other to produce an input–output carrier-frequency shift of 252 Mc/s.

The total transmission loss between hypothetical aerials that radiate power uniformly in all directions (isotropic aerials), 30 miles apart in free space, is 140 db. Practical microwave aerials are highly directional (± 1° to 3 db power points) and have a gain of 45 db



A.—Three-port ferrite circulator. B.—Ferrite isolator. C.—Mop-up equalizer.

FIG. 9—MICROWAVE TRANSMITTERS AND RECEIVERS ON FLOOR B15

relative to isotropic aerials. The use of such aerials results in an overall transmission loss (including losses in waveguide feeders) of about 60 db under normal propagation conditions. For all practical purposes this loss is constant over the r.f. channel bandwidth of 30 Mc/s.

The normal radio-frequency (r.f.) signal level at the input crystal-diode mixer is 10^{-6} watt, and this may fall to 10^{-9} watt during occasional periods of severe fading. It has been found convenient, in the majority of links installed in the United Kingdom, to provide most of the fixed gain and all the reserve gain to overcome the inter-station transmission loss at the intermediate frequency, although one link in operation from the Post Office Tower has repeaters in which all the amplification is carried out at radio frequency.

For satisfactory transmission of multi-channel telephony or colour television, linear distortions in those sections of the radio system carrying frequency-modulation signals must be minimized. As an example of this problem, the variation of transmission time over a 30 Mc/s channel must not exceed a few nanoseconds,* and ferrite isolators (Fig. 9) are, therefore, extensively used to reduce the level of echo signals arising from mismatches between the various microwave elements, and "mop-up" time-delay equalizers (Fig. 9) are fitted in terminal receivers.

LAYOUT OF RADIO EQUIPMENT IN THE TOWER

The Tower consists of a hollow shaft of reinforced

*nanosecond = 1×10^{-9} second.

concrete from which all the floors are cantilevered. The main structure is topped by a short steel tower which, at present, carries a storm-warning radar and meteorological instruments but is available for microwave aerials should the need arise; below this are the lift-motor and water-tank rooms and the public floors.

Aerial Galleries

The aerial galleries occupy the height range of 365–475 ft and consist of four main circular galleries (C1, C2, C4 and C5) for principal aerials, with two smaller butterfly-wing mezzanine galleries (C3 and C6) for spur-route aerials. The most striking feature of the galleries is the large horn-reflector-type aerials, two of which are used for each of the four principal routes from the Tower. While more conventional parabolic-type aerials allow for connexion to a single aerial of a number of transmitters and receivers using channel frequency assignments within a single common-carrier frequency band, the wide transmission bandwidth of the horn-type aerial allows for simultaneous use of channel-frequency assignments in two common-carrier frequency bands centred on 4,000 and 6,175 Mc/s; in this way a pair of such aerials will carry 20,000 telephone conversations. The directivity pattern of the horn aerial is such that this can be achieved on each of the four principal routes from the Tower, without significant crosstalk interference between routes.

A horn aerial (Fig. 10), 27 ft high, 14 ft wide and

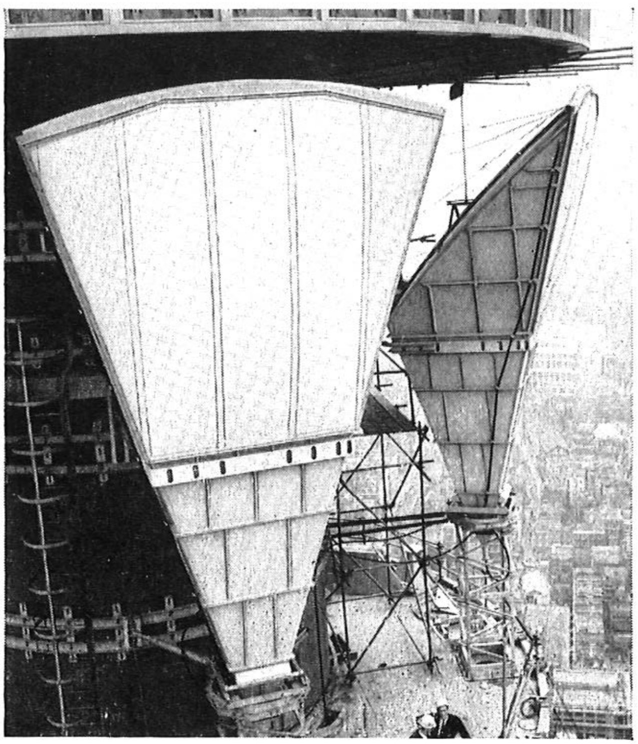


FIG. 10—HORN-REFLECTOR AERIAL BEING INSTALLED ON GALLERY C5

weighing 1 ton, consists of a parabolic reflector fed by a pyramidal horn with its axis vertical and its apex coincident with the focal point of the reflector; the radiating aperture is 140 ft^2 (gain 45 db relative to an isotropic aerial), and is closed by a Hypalon-coated terylene sheet, thus allowing the aerial and its associated waveguide to be pressurized slightly above atmospheric pressure by dry air to prevent the ingress of moisture. The pressurizing equipment is shown in Fig. 11. Because

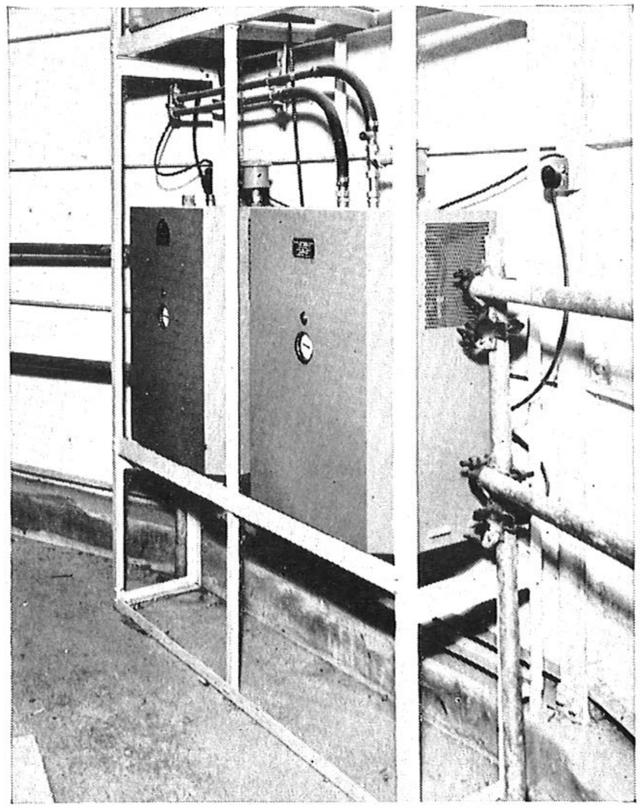


FIG. 11—AIR-PRESSURIZING EQUIPMENT ON FLOOR B17 FOR AERIAL AND WAVEGUIDES

of its gradually-tapering feed, the horn provides a superior match to the waveguide feeders and reduces echoes and losses; it has been designed to transmit and receive two signals of dominant TE_{11} mode, orthogonally polarized, when used in conjunction with low-loss circular waveguide of 3 in. diameter.

The superior qualities of the horn aerial have been an essential factor in the provision of broadband radio channels, each capable of carrying 1,800 speech channels, to the high standard of performance required. The conventional parabolic aerials of the type at present in use in the Tower galleries have so far been restricted to links carrying television or a maximum of 960 speech channels per broadband, but an improved version (e.g. as shown in Fig. 4) for single-band operation, with a performance approaching that of the horn aerial, is becoming available and will be in use by mid-1966.

The aerial galleries have capacity for about 30 aerials to serve the main routes from the Tower; in addition, a further 14 aerials may be used for spur routes and, temporary services, and be available for possible future requirements. Facilities are also available for temporary radio links for television outside broadcasts to be installed on the lowest of the aerial galleries, C1 (Fig. 12).

Aerial Feeders

Because of the importance of keeping the length of

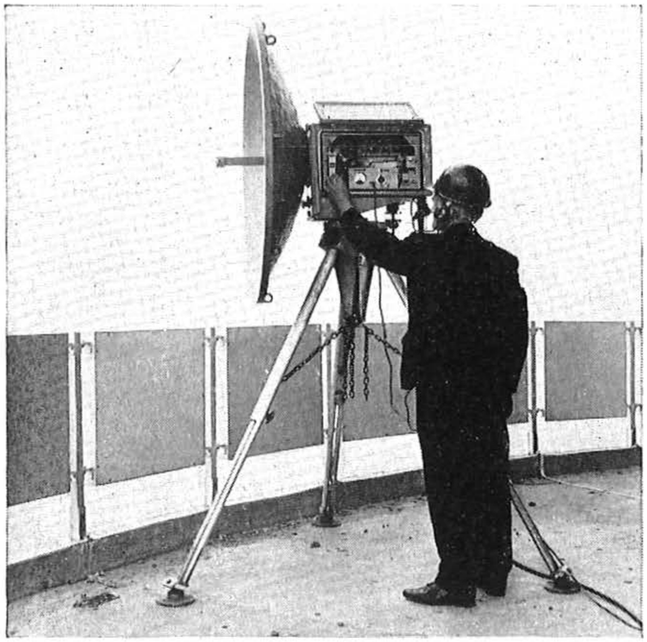


FIG. 12—TELEVISION OUTSIDE BROADCAST EQUIPMENT IN USE ON AERIAL GALLERY C1

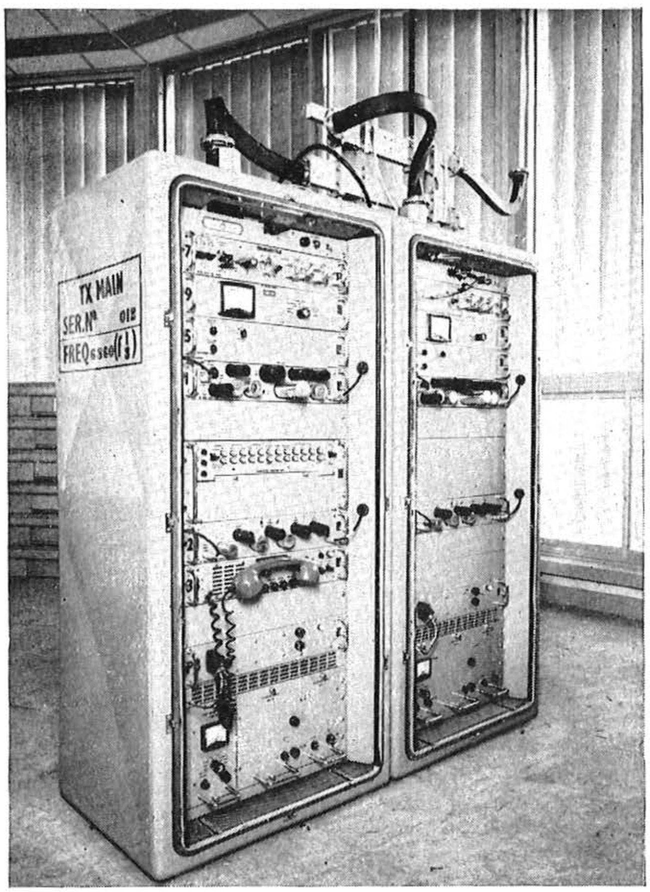


FIG. 13—TEMPORARY RADIO EQUIPMENT IN USE FOR TELEVISION LINKS TO SOUTH WALES AND ISLE OF WIGHT ON FLOOR B16

aerial waveguide-feeders as short as possible, and hence the loss of microwave power to an acceptably-low value, a special arrangement has been adopted for radio equipment in the Tower. Microwave transmitters and receivers will be separated from the associated baseband and ancillary equipment, and will be housed as near as possible to the aerials, i.e. in the top six floors of the Tower (B11–B16). Further, because the waveguide to be used for the higher-frequency bands has a higher loss per unit length than that used for the lower-frequency bands, the equipment floor nearest to the aerial galleries (B16) has been reserved for 11,000 Mc/s equipment, and the remaining floors have been allocated on a descending height and frequency basis. Space on floor B16 will also be used for radio equipment associated with temporary radio links (Fig. 13). The aerial waveguide-feeders run vertically down the outside surface of the hollow shaft that forms the central core of the Tower, and for this purpose slots large enough for the 100 or so feeders which will eventually be required are provided in the equipment floors.

For parabolic aerials, single-polarization rectangular feeders are run from the aerial illuminators by way of two right-angle bends to the vertical runs, as shown in Fig. 14. For the horn aerials (Fig. 15), the twin-polarization circular waveguide drops vertically by way of ellipticity compensators to polarization filters housed in the aerial gallery immediately below. At the polarization filter, transition is made to two single-polarization rectangular feeders, and these join the vertical waveguide runs in the slots around the central core of the Tower by way of single right-angle bends. A more desirable

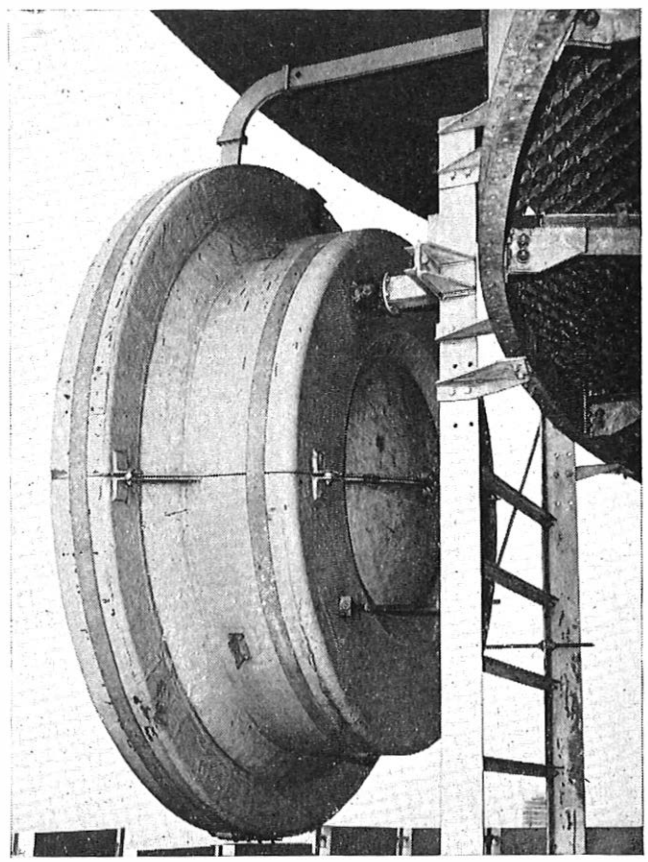
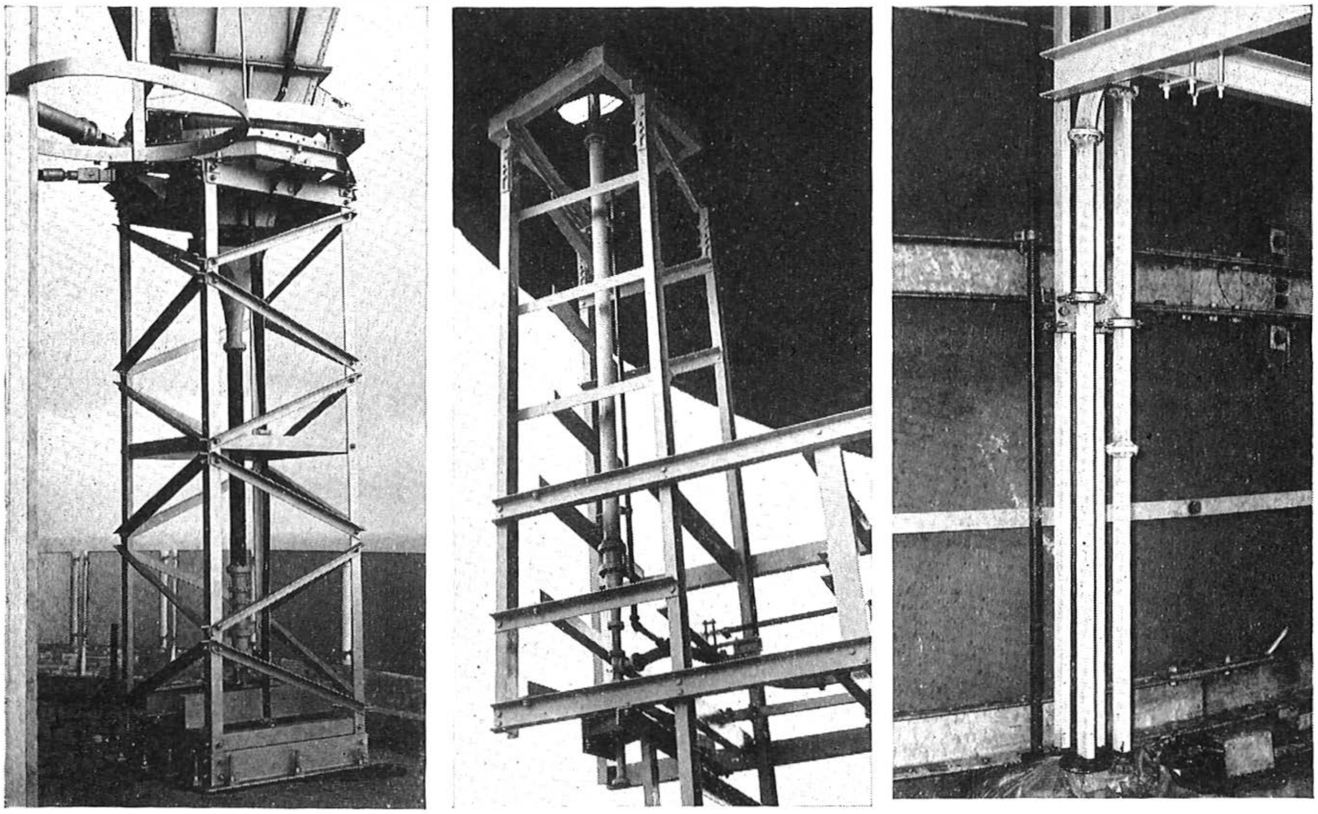


FIG. 14—PARABOLIC-DISH AERIAL SHOWING RECTANGULAR WAVE-GUIDE FEED ON AERIAL GALLERY C4



(*a*) Square-to-Circular Transition and Ellipticity Compensator.

(*b*) Polarization Filter with Circular-to-Rectangular Waveguide Transition.

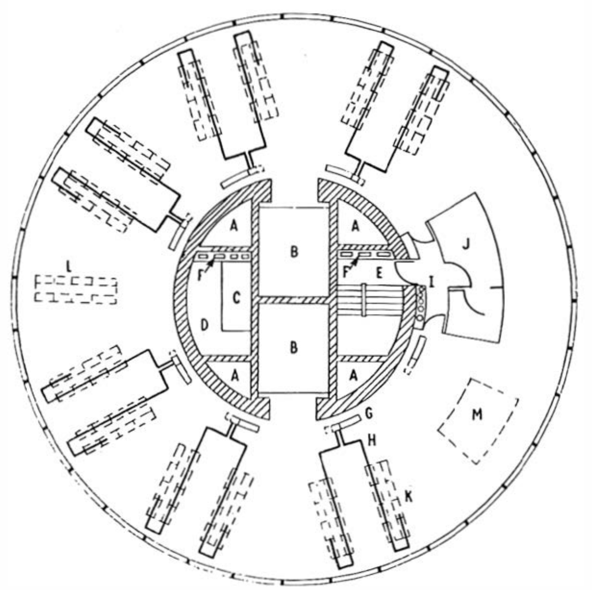
(*c*) Rectangular Waveguides on Outside Surface of Central Core of Tower.

FIG. 15—HORN-REFLECTOR AERIAL WAVEGUIDE-FEEDER ARRANGEMENT

arrangement, and the one adopted in conventional stations, would be to limit the length of higher-loss rectangular waveguide used by continuing the circular waveguide to a point as close to the microwave equipment as possible. This arrangement has been precluded in this instance by the fact that circular waveguide used for multi-frequency band working must not be bent if adequate signal quality is to be achieved, and for the physical dispositions and number of horn aerials involved this could result in up to 16 vertical waveguides running through the annular equipment space and thus be a serious limitation on the amount of equipment that could be housed on each floor.

Microwave Transmitters and Receivers

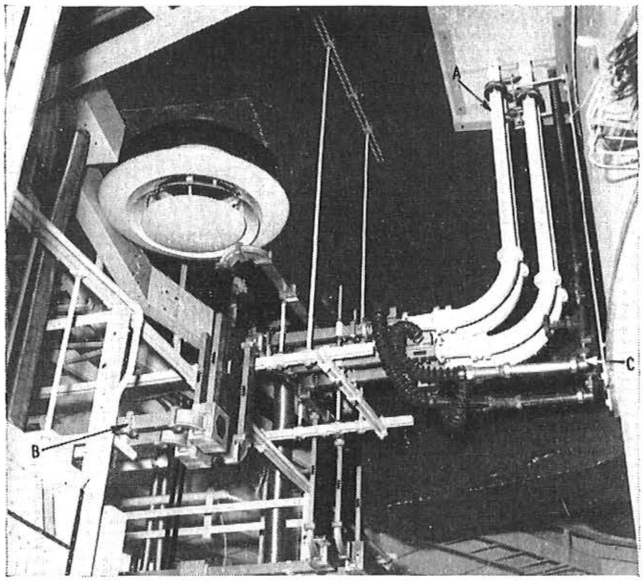
The use of rectangular waveguide, which can include a number of bends without exceeding an acceptable amount of signal distortion, facilitates the optimum arrangement of the radio equipment within the space available. The equipment is arranged in suites of 20 in. wide and 7 ft 6 in. high racks arranged radially, as shown in Fig. 16. Rectangular waveguides, each carrying up to four broadband radio signals, emerge from the slots (Fig. 17) abutting the inner core and are distributed radially to connect individual channels to the appropriate transmitters or receivers by way of ferrite circulators (Fig. 9). Fig. 17 also shows the arrangement for connecting the pressurizing equipment to the aerial waveguide feeders at the boundary point



A—Ventilation ducts. B—Lifts. C—Coaxial-cable duct. D—Working platform. E—Staircase. F—Power busbars. G—Waveguide slots. H—Waveguides. I—Service pipes J—Toilets. K—Radio-equipment racks. L—Line-termination racks. M—Test trolleys and spares.

FIG. 16—TYPICAL LAYOUT OF APPARATUS FLOOR AND CENTRAL SHAFT

between pressurized and unpressurized waveguide. Dry air (from the pressurizing equipment on floor B17)



A—Waveguide feeders from aerial galleries. B—Distribution of waveguides to microwave equipment. C—Air pipes.

FIG. 17—AERIAL WAVEGUIDE FEEDER ENTRY TO MICROWAVE EQUIPMENT, FLOOR B15, SHOWING ATTACHMENT FOR INJECTING DRY AIR

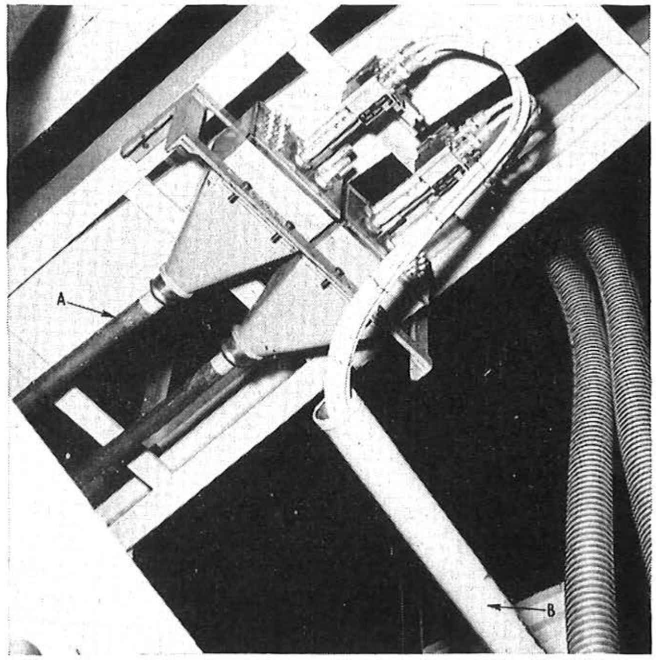
passes through the waveguide aerial feeders and polarization filter to the associated horn aerial and, thence, by way of an air connecting pipe to another horn aerial and its waveguide feeders, back to the pressurizing equipment.

Each suite contains four racks, and the layout provides a corridor for test equipment between the ends of the racks and the inner core of the tower. The space on each floor is limited to a ring of arc 320° (floor area 1,200 ft^2) by the presence of smoke barriers and access areas. Each floor will accommodate about 48 bothway transmitters and receivers of current size. The radial position of a given equipment is determined primarily by the radial position of the aerial it serves on the aerial galleries, and two waveguide slots are provided per useful quadrant of annular space; the size of slot provided is reduced for the lower floors to take account of the decreasing numbers of feeders. The equipment is laid out in pairs of parallel suites of four racks each, with a back-to-back spacing of 12 in. to allow circulation of air for convection cooling and to facilitate the waveguide connexions between back-to-back suites. A parallel, rather than a truly radial, arrangement has been chosen to enable standard right-angle waveguide bends to be used.

Baseband and Protection-Channel Switching Equipment

For reasons which have been stated, baseband modulators and demodulators are housed on floors B8–B10, and the i.f. (70 Mc/s) signal connexion to microwave transmitters and receivers is by way of composite coaxial cables, each containing four tubes of 0·174 in. outside diameter (Fig. 18), which are located in a cable space inside the central core of the Tower. A typical cable length is 100 ft and, in order to maintain the required level and quality of signal, amplifiers and time-delay equalizers are fitted to each tube, and these are mounted on the racks adjoining the microwave transmitter and receiver suites.

To achieve the high standard of reliability required for the trunk broadband microwave systems radiating from the Tower, standby or so-called "protection" broadband channels are provided that automatically switch to replace faulty working channels so that a break in transmission of only a few microseconds occurs. The protection channels will be shared between several working channels, with a consequent economy in cost of provision of circuits and in the use of the frequency spectrum. Switching is carried out at the intermediate frequency (70 Mc/s) by high-speed diode switches located at the terminal stations.



A—To baseband equipment (Floors B8–10). B—To microwave transmitters and receivers.

FIG. 18—I.F. (70 Mc/s) TIE CABLES

Each channel carries a continuity pilot signal located above the traffic-signal frequency spectrum in the baseband; should this pilot signal fall in level by 6 db, or the noise in a narrow band about the pilot frequency increase beyond a predetermined amount, immediate change-over to a protection channel is automatically carried out. A standard arrangement is to provide switching equipment which will accommodate up to six operational channels and one or two protection channels, as required. The i.f. switching equipment will be mounted on racks adjacent to those carrying the modulating and demodulating equipment, on floors B8–B10.

It is now usual to employ an auxiliary radio link, a narrow-band low-power system, sharing aerials and waveguides with the main system, for the transmission of alarms from repeaters and terminals, and for the transmission of end-to-end signals associated with automatic switching, control and supervision. In the Post Office Tower all switching and alarm indications, together with facilities for manual control of channel switching, will be concentrated on floor B8 (Fig. 19) which will be continuously staffed.

Baseband-Signal Distribution

From floors B8–B10 the basic television and frequency-

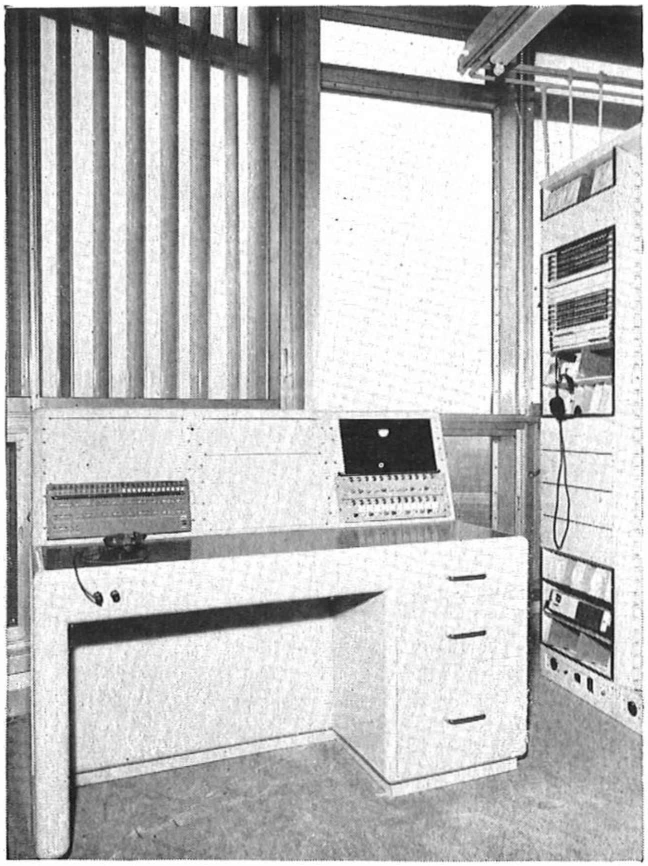


FIG. 19—ALARM AND CONTROL EQUIPMENT, FLOOR B8

division-multiplex telephony signals, which occupv a baseband frequency range up to about 8 Mc/s, are taken by further coaxial cables down the central shaft either to the adjacent building, which houses the new London Television Switching Centre and trunk telephone exchange, or to floors B5 and B6 of the Tower, which have been allocated as a cable terminal. Here, the larger assemblies of telephony channels from the radio broadbands will be broken down by hypergroup-translating equipment into units of 900 circuits for distribution to transmission terminals associated with the various London trunk-switching centres. Conversely, units of 900 incoming telephone channels will be combined into the larger units required for transmission over the radio links. Floor B4 is also allocated for this purpose, but initially will provide office accommodation for management staff.

ANCILLARY SERVICES

Floors B1–B3 house the comprehensive ventilation plant for the Tower; air is delivered at the rate of 6,000 ft^3/min to the ducts in the centre shaft at an air velocity of 3,000 ft/min and passed, via expansion chambers and silencers, to annular ceiling ducts on the equipment floors. Extraction is either direct from the equipment racks or via a second annular extraction-duct around the outside of the rooms, feeding similar large ducts in the centre shaft. The extracted hot air can be re-circulated in cold weather to maintain a reasonable temperature.

Power supplies[5] for the Tower project are provided from duplicate and independent mains connexions at 11 kV which feed a power room in the basement of the adjoining building, providing a 2,500 kVA medium voltage (415/250 volts) supply via dry-type transformers. Five automatically-started 500 kVA diesel alternators provide against failure of both mains supplies and can provide power within 30 seconds of mains failure. The equipment in the Tower requires approximately 900 kW, and this is distributed in three separate three-phase systems, two of which are regulated and provided with short-break automatic change-over between the duplicate mains sources and feed the telecommunications plant; the third is fitted with manual change-over and feeds domestic services.

In a few years it is likely that, for telecommunications equipment, including radio apparatus, valves will have been completely superseded by solid-state devices; indeed, some of the radio equipment now on order for the Tower will contain only a few valves and one travelling-wave tube. Such equipments will operate from a 24-volt d.c. supply, and floors B7 and B13 of the Tower have been allocated for batteries and associated rectifiers.

Because of the public restaurant and viewing gallery at the top of the Tower, lifts provided in the centre shaft must, apart from their use by staff and for equipment, give a rapid passenger service. Two lifts are provided, separately motored and controlled, and limited by the size of the shaft to a cage size of 6 ft 3 in. by 4 ft 6 in. This allows 15 passengers to be carried, and, to permit some of the larger units of equipment and aerial components to be hoisted, a false ceiling is fitted to each cage which, when removed, provides an internal height of 12 ft. The lifts are the fastest of their kind in Britain, with a speed of 1,000 ft/min, giving a journey time to the top of 34 seconds. Automatic control causes the car to answer all calls in the direction of travel, but this control can be over-ridden by an attendant to provide an express service to the public galleries.

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Communications for the North Sea Oil-Exploration Project

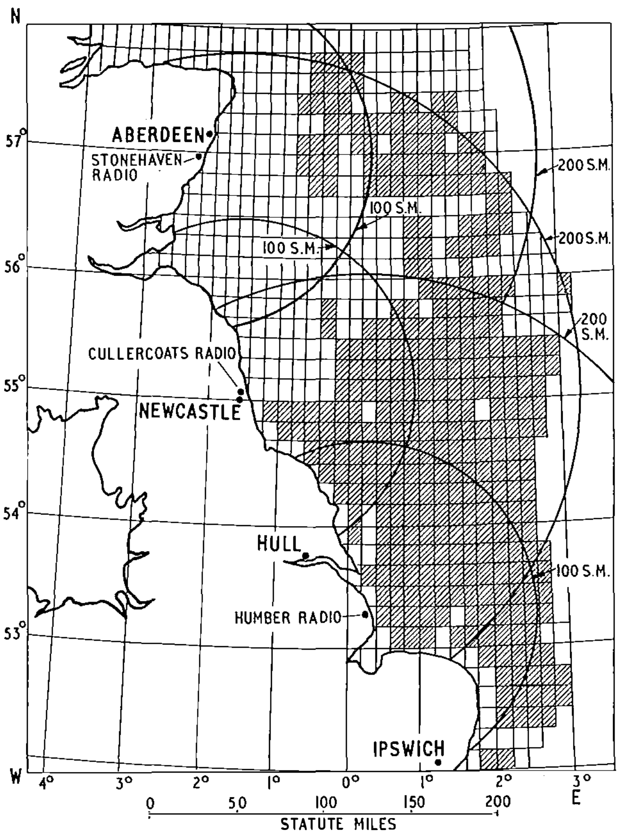
E. G. BRONSDON†

U.D.C. 621.396.93:622.242

Exploration for oil, or natural gas, under the North Sea is now in progress, and the British Post Office is providing radio-teleprinter and radio-telephone communication facilities between the sea-based drilling rigs and their shore-based offices. The radio-teleprinter system described uses established frequency-division-multiplex techniques but is novel in the conditions of use.

INTRODUCTION

It has for some time been known that an extensive search would be undertaken in the expectation of finding substantial deposits of oil or natural gas under the North Sea, but it was only as recently as the summer of 1964 that the British Post Office was approached in connexion with providing telecommunication facilities for the oil-rigs to be used in the exploration. Fig. 1 shows the permissible area of search, which is



S.M.—Statute miles

FIG. 1—AREA OF NORTH SEA SHOWING RANGES FROM THREE COAST STATIONS

divided into 10-mile square blocks, and the shaded areas have been allocated to various oil companies for exploration. It was required that communications for up to 15 rigs should be available commencing in May 1965, although within the first few months only a few rigs were likely to be in operation. The Post Office was thus faced with the problem of devising a telecommunication system of some magnitude and of providing the necessary shore-based installations, both at very short notice.

PLANNING THE PROJECT

Because the oil-rigs would change their position from time to time it was clear that radio would be the only practical communication medium. Also, established techniques and readily-available equipments would have to be used if service were to be given by May 1965.

The oil companies concerned were originally unanimous in their desire for an exclusive reliable telephone circuit between each rig and its shore-based office. Fifteen simultaneous telephone circuits require a radio-spectrum bandwidth of about 100–200 kc/s, according to the techniques employed and the frequency band used. Communication over the extreme distance (about 250 statute miles) is possible by tropospheric-scatter propagation, in the v.h.f. and u.h.f. bands, and it would have been technically feasible to provide individual telephone circuits at these frequencies. There would, however, have been many practical difficulties both on shore and on the rigs, and the use of these bands was, therefore, ruled out because of the limited time available. This left the only practical frequencies for reliable communication in the maritime band between 2 and 4 Mc/s. Below about 4 Mc/s, communication over the distances required is almost exclusively by ground-wave propagation during daylight hours, and, over sea-routes, the path attenuation is relatively low and constant in all directions. During hours of darkness, sky-wave propagation is also encountered; it can cause fading, though this can be minimized to some extent by good aerial design.

The main enemy in the chosen band is the high level of atmospheric noise; this increases at night, when interference (much of which is from sky-wave signals originating at points far outside the range of day-time reception) is at its worst. Furthermore, the North Sea is one of the most congested shipping areas in the world, and the 2–4 Mc/s band is, therefore, very extensively used for maritime communications in this area. Only two pairs of United Kingdom frequency registrations could be made exclusively available in this band for oil-rig communications, and these have allocated bandwidths totalling 24 kc/s. It would, therefore, clearly have been impossible to provide exclusive telephone circuits for more than four rigs.

In this situation the best counter is radio-telegraphy, using a protected telegraphic code and radio modulation having the smallest bandwidth possible. It was finally decided that the exclusive-channel requirement would be met by establishing a multi-channel radio-telegraph system, occupying a total bandwidth of 6 kc/s, that could provide up to 15 private teleprinter circuits between the rigs and their base-offices. In addition, three radio-telephone circuits would be provided, utilizing a total bandwidth of 18 kc/s. They would have access to the

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inland public network and be shared by all rigs. These facilities could be achieved by using one pair of registrations to provide up to 15 teleprinter circuits in one sideband of an independent-sideband (i.s.b.) transmission using narrow-band frequency-division techniques, and a telephone circuit in the other sideband. The other pair of registrations could provide two i.s.b. telephone circuits in a conventional manner.

The available frequency registrations are limited to maximum transmitter powers of 1 kW (shore-to-sea direction) or 500 watts (sea-to-shore direction). For the combined telephony-telegraphy transmission, and using the customary loading of equal peak sideband powers, only 30 watts of radio-frequency power is available for each telegraph channel. This is less, by some 15 db, than the power required to maintain reliable start-stop teleprinter communication for over 90 per cent of any one 24-hour period throughout the working area. For this reason it was necessary to use synchronous signalling and error-correcting techniques[1] over the radio path to enable the shore-transmitter powers to be kept within the prescribed limits. Transmitters capable of radiating 1 kW of peak-envelope-power (p.e.p.), and which could be installed relatively quickly, were therefore chosen. Some 250 watts would then be available for each outgoing telephone channel, and good commercial circuits could be expected at distances up to at least 250 miles during day-time. For 90 per cent of the nights the good commercial circuit range would be about 150 miles, with marginally-commercial circuits up to 200 miles. For business traffic, however, a grade of circuit sufficient for operator-to-operator working is often acceptable, and this quality could be expected up to about 250 miles for the great majority of nights.

THE RADIO-TELEGRAPH SYSTEM

Fig. 2 shows the schematic arrangement of the radio-telegraph system, which also makes provision for one radio-telephone circuit. This arrangement was operated at first only through Humber Coast Radio Station. An identical radio-telegraph installation was subsequently provided at Stonehaven Coast Radio Station and is complementary to that at Humber. Both stations operate with the same carrier-frequency registrations (3,624 kc/s shore-to-sea, and 3,324 kc/s sea-to-shore) to provide coverage of the North Sea area involved. A rig will carry its allocated radio-telegraph frequency-division channel with it if it moves outside the range of Humber to within range of Stonehaven, or vice-versa. Thus, telegraph channel frequencies being operated through Humber are interleaved with those through Stonehaven and mutual interference problems are avoided. The radio-telephone circuit is, however, unique to Humber, and the lower sideband at Stonehaven is unused, otherwise mutual interference would certainly result.

Referring to Fig. 2 it will be seen that a private v.f. telegraph circuit connects the shore-based office, for any one rig, to the coast radio station. The v.f. telegraph circuit carries 50-baud start-stop teleprinter signals in both directions, and the send-leg (shore-to-sea) signals are converted to synchronous working at the shore station in an "Autospec" terminal,[2] which employs a 10-element error-correcting code at a signalling rate of 68·5 bauds. The output from the Autospec equipment is applied to one channel input of the frequency-division multiplex (f.d.m.) transmitting equipment, which produces a corresponding frequency-modulated channel-output signal. This signal is one of 15 having nominal mean-frequencies spaced 170 c/s apart between 425 and 2,805 c/s. The frequency deviation for each channel is nominally 42·5 c/s.

The output from the f.d.m. transmitting equipment is an aggregate of up to 15 such channels, and this is applied as a nominal 0–3 kc/s baseband signal to one sideband input of the i.s.b. transmitter. The transmitter translates the baseband to the upper sideband of an

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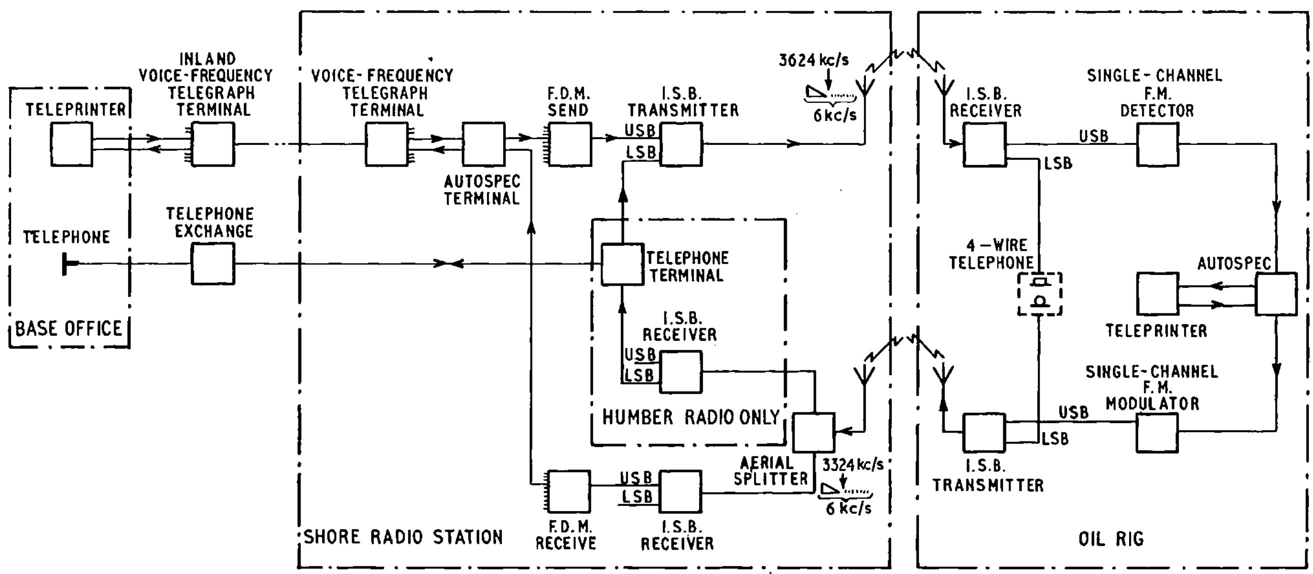


U.S.B.—Upper sideband. L.S.B.—Lower sideband.

FIG. 2—ARRANGEMENT FOR 15 TELEPRINTER CIRCUITS AND ONE TELEPHONE CIRCUIT

emission having an assigned carrier frequency of 3,624 kc/s. The carrier is suppressed to avoid interference effects that might otherwise result from a small frequency difference between the Humber and Stonehaven carriers, and that might adversely affect the performance of receivers in rigs operating in areas where approximately equal signal fields from the two shore stations would exist.

The rig receives its allocated channel via a single-channel unit, which is complementary to the coast station f.d.m. channelling equipment, and an Autospec terminal. The latter synchronizes with the received signal and converts the 68·5-baud, 10-element code, signals back to 50-baud start-stop teleprinter signals. The rig transmits a single corresponding f.m. channel in the upper sideband of an i.s.b. suppressed-carrier emission having the assigned carrier frequency of 3,324 kc/s. A number of such channels of approximately equal signal-strength (to achieve equality the rig transmitter powers are adjusted according to distance from the coast station) are received at the coast station as one sideband aggregate. After translation to baseband in the shore receiver, the aggregate is applied to the f.d.m. receiving equipment, which separates the channels. Each individual channel-output from the f.d.m. equipment is applied to an Autospec terminal which converts the received signals to 50-baud start-stop signals for onward transmission, over the receive channel of the inland v.f. telegraph circuit, to the base office.

The f.d.m. equipment chosen for this system conforms to C.C.I.R.* Report No. 199 and is suitable for radio circuits at signalling rates of up to 100 bauds. Autospec equipment automatically corrects all single-element errors and most double-element errors occurring in the radio path, and detects the great majority of multi-element errors without the use of the return path. Detected but uncorrected errors cause a special character-error symbol to be printed. Theoretically, an element error-rate of 1 in 100 will cause the error symbol to be printed once in every 80 characters, and the corresponding undetected character error-rate will be about 1 in 8,000.

It is normal practice for point-to-point radio services using i.s.b. techniques to transmit a pilot carrier at 20 db below the peak sideband power. The carrier may be used in the corresponding receivers for automatic frequency control (a.f.c.) and automatic gain control (a.g.c.) purposes. A.F.C. is normally necessary to correct for the displacement from nominal frequency values, and for random frequency variation, of the oscillators used in the transmitter and the receiver for translating baseband signals to radio frequency and back again. The acceptable residual frequency-difference between transmitted and received baseband frequencies depends upon the type of traffic used; for multi-channel telegraphy employing 170 c/s channel-spacing, which is the most stringent case, the residual error should not exceed about 12 c/s, otherwise serious telegraphic distortion will result. The f.d.m. equipments can contribute an error of about 6 c/s, leaving 6 c/s as the maximum combined error to be introduced by the transmitter and receiver oscillators.

Since suppressed-carrier working was essential in this application a.f.c. could not be used, and it was, therefore, necessary to specify a high degree of accuracy for the transmitter and receiver oscillators. Because the rigs would be operating under much more onerous conditions of temperature—humidity and vibration—than the shore stations, the majority of the residual overall tolerance was allocated to the rig equipments. The shore-equipment transmitter and receiver oscillators are, therefore, maintained stable to within about 1 in 10^8 of the nominal values, and special frequency-measuring equipment has been supplied to enable any long-term drift of the oscillators to be corrected. Normally, correction will only be necessary about every six months.

A.G.C. is derived from the aggregate sideband signal, and this is the one reason why the mean field-strengths of the individual rig telegraph transmissions have to be received at approximately equal levels. Otherwise, a rig-signal greatly in excess of others would depress the receiver gain to the disadvantage of the majority.

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

RADIO-TELEPHONE CIRCUITS

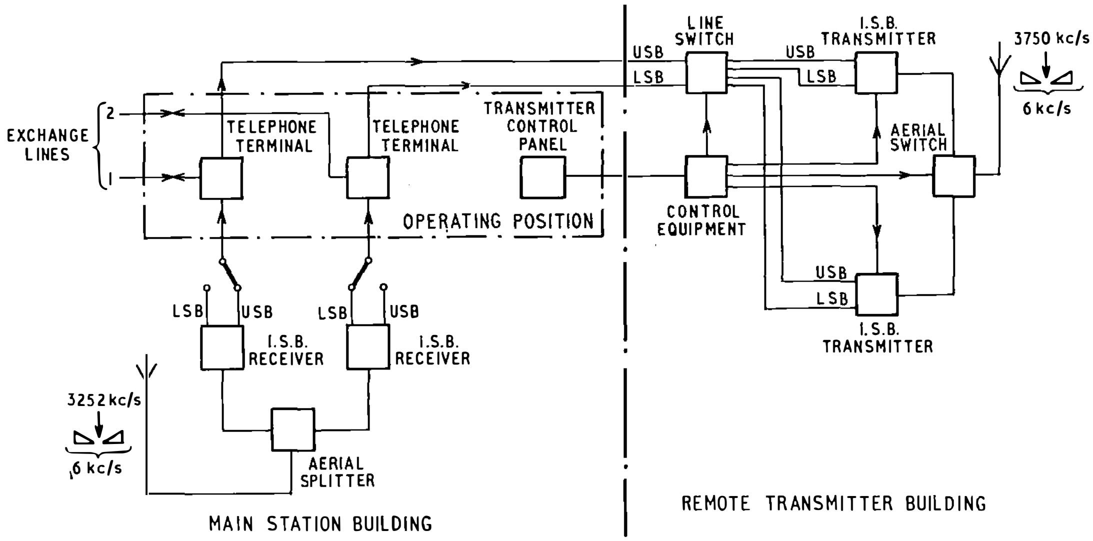
One radio-telephone circuit is provided through the lower sidebands of the Humber installation, using the 3,624 and 3,324 kc/s assignments in the arrangement shown by Fig. 2. Two more radio-telephone circuits were available by the autumn of this year through Cullercoats, using frequency assignments of 3,750 kc/s (shore-to-sea) and 3,252 kc/s (sea-to-shore). The arrangement is a conventional i.s.b. system providing one circuit in either sideband, but special problems had to be overcome for this installation.

The installations at Humber and Stonehaven were possible on existing radio-station sites and, although a new building (a standard timber U.A.X. type) had to be erected at Stonehaven, there were no particular problems with regard to the building, power supplies or control lines. At Cullercoats, however, the radio-telephone transmitters could not be accommodated on the existing station site because there is no space to erect the transmitting aerial except on land which is being eroded by the sea. The Cullercoats station is, for this reason, due to move completely within the next few years, and a new site had tentatively been chosen though negotiations for its acquisition had not commenced. These negotiations had, therefore, to be brought forward urgently to secure sufficient of the chosen site for the erection of a suitable building and aerial masts for this scheme. Negotiations for the supply of electricity to the new site had to be made at short notice, and also arrangements made for running several miles of multi-core cable between the new and existing sites for traffic and control purposes.

Fig. 3 shows the arrangement for the Cullercoats radio-telephone installation. The receivers and the telephone terminal equipment were installed on the existing main-station site; the transmitters were installed on the new site, which is about 5 miles from the main site. They are remotely-controlled from the main station in that either transmitter may be selected for service, automatically switched on, and connected to the aerial and to the telephone terminal equipment.

PERFORMANCE

So far nine companies, which will operate a total of 10 rigs between them, have contracted to use the special Post Office telecommunication facilities. Eight rigs will



U.S.B.—Upper sideband. L.S.B.—Lower sideband.

FIG. 3—ARRANGEMENT FOR TWO TELEPHONE CIRCUITS THROUGH CULLERCOATS

operate individual teleprinter circuits, and all 10 will share the use of the three telephone circuits.

In teleprinter tests with the first rig, which was then only 45 miles from Humber, its transmitter power was reduced until the received field-strength approximated to the calculated value for the full power at the extreme distance. In this condition, and with the shore channel-power also appropriately reduced, bothway teleprinter working was completely satisfactory and, on the rig, a test block of 40,000 characters was received without error. A second rig, situated about 100 miles from Humber, was subsequently brought in at approximately the same field-strength, and the teleprinter circuits have since given very reliable service.

As more rigs are brought in, and as the hours of darkness increase, it will be possible to assess fully the system performance with close channelling under noisy, fading conditions. However, the results so far accord well with expectation, and there is every reason to believe that the maximum available shore channel-power will be adequate for the extreme distance and that the performance will be satisfactory when the system is fully loaded.

The radio-telephone circuits through Humber have been consistently good so far and, compared with calls through the maritime public correspondence circuits which use double-sideband (d.s.b.) modulation, have once again demonstrated the advantage to be gained by i.s.b. modulation. For a given transmitter power an i.s.b. circuit can give at least 9 db improvement in signal-to-noise ratio compared with d.s.b. operation.

CONCLUSIONS

Although it is too early to announce unqualified success in the operation of multi-channel frequency-division radio-telegraphy in the present unusual circumstances, there is sufficient evidence to give rise to the hope that similar close-channelling techniques can be applied to long-distance ship-to-shore telegraphy in the h.f. maritime bands between 4 and 30 Mc/s. Provided that the basic requirement for a high degree of accuracy and stability of the radiated frequencies can be met, there appear to be no insuperable technical or operational problems for future applications. If such a scheme were to gain widespread acceptance, better use could be made of the maritime h.f. wideband telegraph channels, and the use of teleprinter working, perhaps with through connexion to the inland telex network, would greatly improve the efficiency of ship-to-shore communication.

ACKNOWLEDGEMENTS

The communication service for North Sea oil rigs through the Humber radio station was available within 9 months of the requirements being known. Normally the planning and installation work for such a scheme would take at least 18 months, and the achievement in this instance is a tribute to all the Post Office Departments involved.

Acknowledgement is also due to the Marconi Co., Ltd., which completed the Humber radio-telegraph terminal within 5 months of receiving the contract. This company also supplied the installations for Cullercoats and Stonehaven.

Improved Type of Corrugated Band for Twin-Band Risers

G. W. SMITH†

U.D.C. 681.187

A twin-band conveyor that sandwiches mail between a weighted upper band and the lower load-carrying band is used where steep inclines are encountered in handling mail mechanically. An improved method of weighting and corrugating the upper band is described.

WHEN it is required to carry mail on a steep-angle conveyor, i.e. at an angle greater than 30° to the horizontal, the conventional form of flat-band conveyor is not suitable because the load tends to slip back down the conveyor. To prevent this sliding action, a weighted cover band is provided. This extra band runs on top of the load-carrying band so that the articles carried are sandwiched between the two. This form of conveyor is known as a "twin-band riser." Fig. 1 shows parcels entering a twin-band riser.

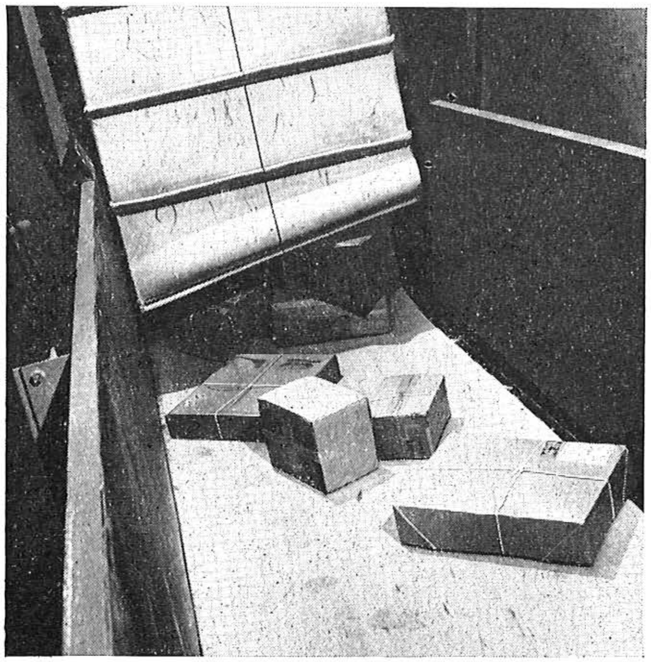


FIG. 1—PARCELS ENTERING TWIN-BAND RISER

In its original form the weighted band was provided with double pockets sewn on at intervals of 12 in. Iron bars were inserted in these pockets to obtain the necessary weight to ensure adhesion of the load on rising inclines of 45–60°. To retain the bars in position, the pockets were closed at each end by means of a screw-type fastener. Since the pockets were individually sewn on the main band, it tended to be expensive.

†Power Branch, E.-in-C.'s Office.

Difficulties were sometimes encountered because the iron bars broke free of the pockets and fouled the conveyor structure: this usually resulted in the pocket being torn from the band. Replacement of the pockets was difficult, and, hence, maintenance costs were high. Several other arrangements for retaining the iron bars have been investigated, and the following method, derived from a suggestion submitted through the official Post Office awards-suggestion scheme, has been adopted.

In this method the length of the weighted band is increased by 50 per cent and the extra length is used to form loops at 12 in. intervals. Each loop is retained by two iron bars screwed together, sandwiching the band between them as shown in Fig. 2. The loop so formed provides the necessary projection for gripping items of mail, and the air space in the middle of the loop provides shock protection between the iron bars and the items carried. Any worn portion of the band or loops is readily replaced by inserting new lengths of band over the required number of loop pitches.

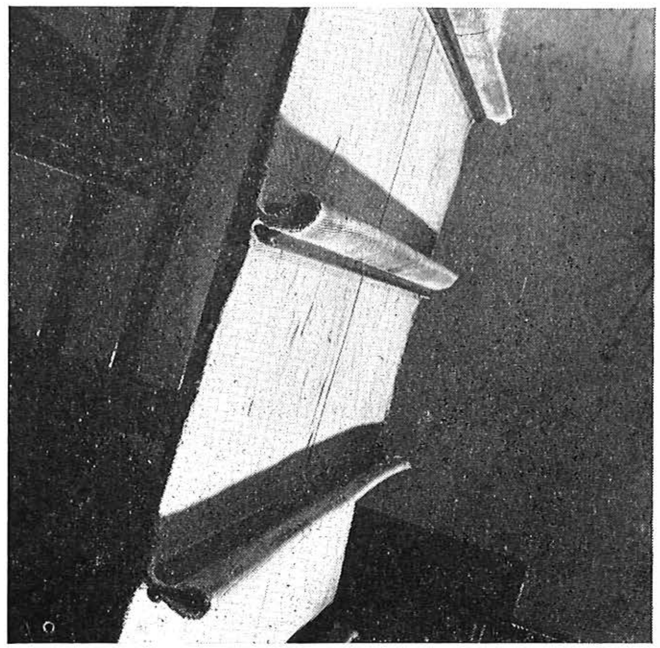


FIG. 2—METHOD OF PROVIDING LOOPS AND WEIGHTING BAND

The performance of the new weighted belt to date has been encouraging. Heavy loads can be moved with greater ease because the loops project further than the sewn pockets, and savings have been achieved both in initial cost and in maintenance.

Testing 625-Line Monochrome and Colour Television Transmission Systems

Part 2—Picture Monitoring

R. K. R. TANNER†

U.D.C. 621.397.743:621.397.621

Part 1 of this article dealt with the methods employed for the measurement of distortion and noise in 625-line monochrome and colour television systems when, in general, they are not carrying traffic. Part 2 describes the picture-monitoring equipment that enables checks to be made of systems while they are in service.

INTRODUCTION

THE tests described in Part 1 of this article are performed when the links are not carrying traffic, with the exception of those tests that may be applied as test-line signals during the field-blanking period of a composite video signal, but it is also necessary to be able to monitor the signals during transmission to check the continuity of channels and to locate sources of possible picture impairment often described in terms of the effect which the fault has on the television picture.

Several types of picture-monitoring arrangement are used by the Post Office, the type used in a given situation being selected by a suitable combination of standard units, as described below.

PICTURE-MONITORING EQUIPMENT

Video Monochrome-Picture Monitors

A precision monochrome monitor (Picture Monitor No. 5A), which has a specification similar to that used by most of the broadcasting organizations, is provided on the basis of one per test-console position (test consoles are used at Post Office network switching centres (N.C.S.s)). The salient features of this type of picture monitor are as follows.

(*i*) It is a multi-standard monitor that can be used for 405-line, 525-line (asynchronous-field) and 625-line operation, and is manually switched.

(*ii*) It has a high-quality video amplifier.

(*iii*) It has exceptionally high-quality time-bases, scanning geometry and beam focusing.

(*iv*) It uses a 14 in. cathode-ray tube.

Because the high standard of performance, particularly the picture geometry, of the monitor described above is not justified for continuity checking, a cheaper monitor (Picture Monitor No. 6A) is also provided. This monitor is mounted at a distance from the test console and is provided with automatic switching between line standards; the other main features of this monitor are as follows.

(*i*) The selected line standard (405, 525 or 625 lines) is indicated by illuminated symbols on the front panel.

(*ii*) It has a high-quality video amplifier.

(*iii*) The time bases, scanning geometry and beam focusing are designed to good-quality commercial television-receiver standards.

(*iv*) It uses a 14 in. cathode-ray tube.

(*v*) It has a compact physical design and can be mounted on a rack or a test trolley, or in a carrying case.

A novel feature of this picture monitor is the line-standard sensing circuit which automatically switches circuits within the monitor to respond to the line standard of the signal applied to its input. A simplified schematic diagram of the line-standard sensing circuit is shown in Fig. 17. When the monitor is switched on

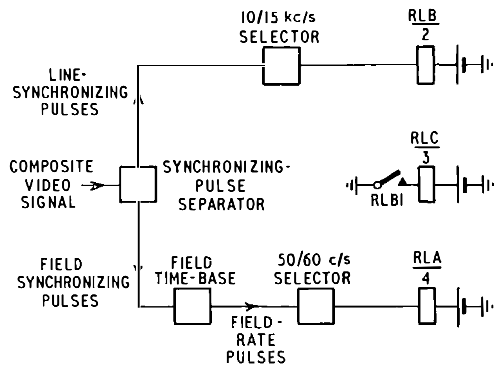


FIG. 17—SIMPLIFIED SCHEMATIC DIAGRAM OF LINE-STANDARD SENSING CIRCUIT OF A MULTI-STANDARD AUTOMATIC SWITCHING MONITOR

without a signal connected to the input, it behaves as a normal 625-line monitor, i.e. the line time-base runs at a nominal repetition rate of 15 kc/s and the field time-base runs at a nominal rate of 50 c/s. Under these conditions relay RLA is not operated but relays RLB and RLC are operated. The monitor is thus ready to receive and display 625-line pictures; this is confirmed by the 625-line indicator lamp glowing.

If 405-line signals are applied to the input of the monitor the incoming line-synchronizing pulses are fed from the synchronizing-pulse separator stage to the line-standard sensing circuit, which contains a parallel-tuned circuit that resonates to the 10·125 kc/s signals. This results in bias being applied to a valve so that relays RLB and RLC are released. Relay RLC is provided as a relief on relay RLB to isolate the contacts which switch components in the line-scanning circuits operating at high voltages. Contacts of these two relays:

(*i*) energize the 405-line indicator lamp,

(*ii*) change the nominal repetition-rate of the line time-base circuit from 15 kc/s to 10 kc/s; this is within the "pull-in" range of the line time-base multivibrator, which then synchronizes itself with the incoming signals,

(*iii*) maintain correct picture size,

(*iv*) maintain the third-harmonic tuning of the line-scanning coils and the impedance matching with the line-output transformer, and

(*v*) maintain correct picture brightness.

If 525-line, 60-field/second, signals are applied to the input of the monitor the line time-base locks to the 15·75 kc/s line-synchronizing pulses, but the parallel-tuned circuit in the line-standard sensing circuit does not

†Main Lines Development and Maintenance Branch, E.-in-C.'s Office.

B

resonate. Relays RLB and RLC operate, and the line-scanning circuits are then connected to respond correctly to 525-line (or 625-line) signals.

The field time-base locks to the 60-field/second synchronizing pulses of the incoming signal. Pulses from the field time-base are applied to the input of the line-standard sensing circuit, which contains a multivibrator that also runs at 60 c/s. The pulses from the field time-base are thus compared with the pulses produced by the multivibrator, and if they are found to have a similar repetition frequency the bias potential which normally prevents the operation of relay RLA is removed. Relay RLA therefore operates, and its contacts

(*i*) energize the 525-line indicator lamp, and

(*ii*) maintain correct picture height.

The selection is made on the field-repetition rate because of the inherent difficulty in discriminating between the line-repetition rate of 525-line signals (15·75 kc/s) and 625-line signals (15·625 kc/s). Both 405-line and 625-line systems have 50 fields/second.

Since both the precision monitor and the continuity monitor are designed to operate on 525-line asynchronous-field signals they have two common performance features that are exceptional compared with those of monitors designed to operate exclusively on conventional 405-line or 625-line signals. These features are as follows.

(*a*) Rapid line time-base fly-back time, i.e. faster than 8·5 μs. This is necessary because the period between the beginning of the line-synchronizing pulse and the end of the line-supression period is shorter in the 525-line system than it is in the other two systems. If the line time-base fly-back in the monitor has not been completed before the end of the line-suppression period in the received signal, the left-hand side of the displayed picture will be impaired. The impairment is generally termed "fold-over" of the line time-base.

(*b*) Low levels of hum-frequency induced from the power supply into the time-bases, video stages and the cathode-ray tube. This is necessary when working on asynchronous-field signals because beat frequencies are developed by the difference in frequency between the power supply and the field-repetition rate. Beat frequencies in the time-bases result in movement of the whole picture raster at the beat frequency: the effect is known as "positional error" of the raster. Asynchronous hum induced in the video stages will appear as unlocked "hum-bars" on the displayed picture, and these are subjectively more objectionable than a locked hum-bar that might otherwise be present but undetected.

Video Colour-Television Picture Monitors

Because of the compatible nature of the colour television systems used, most features in a colour-television transmission which may require to be monitored may be observed on a video monochrome picture monitor. For this reason most picture monitoring carried out by the Post Office is by means of this type of equipment because of its relative cheapness and smallness compared with video colour monitors. However, a few colour monitors are provided as a means of rapidly locating faults whose effects can only be seen by subjective observation of a colour-television picture.

Video colour picture monitors used for this purpose may be regarded as basically high-quality colour-television receivers without the r.f. stage and the r.f.-to-video translation stages.

A simplified schematic circuit diagram of a high-quality video colour-picture monitor with a decoder for N.T.S.C.-type signals is shown in Fig. 18. The incoming video signal, comprising synchronizing and picture information, is simultaneously applied to various circuits within the equipment. The time-base synchronizing pulses perform their functions in the usual way. The reference-burst (see Fig. 1) serves to synchronize the colour sub-carrier

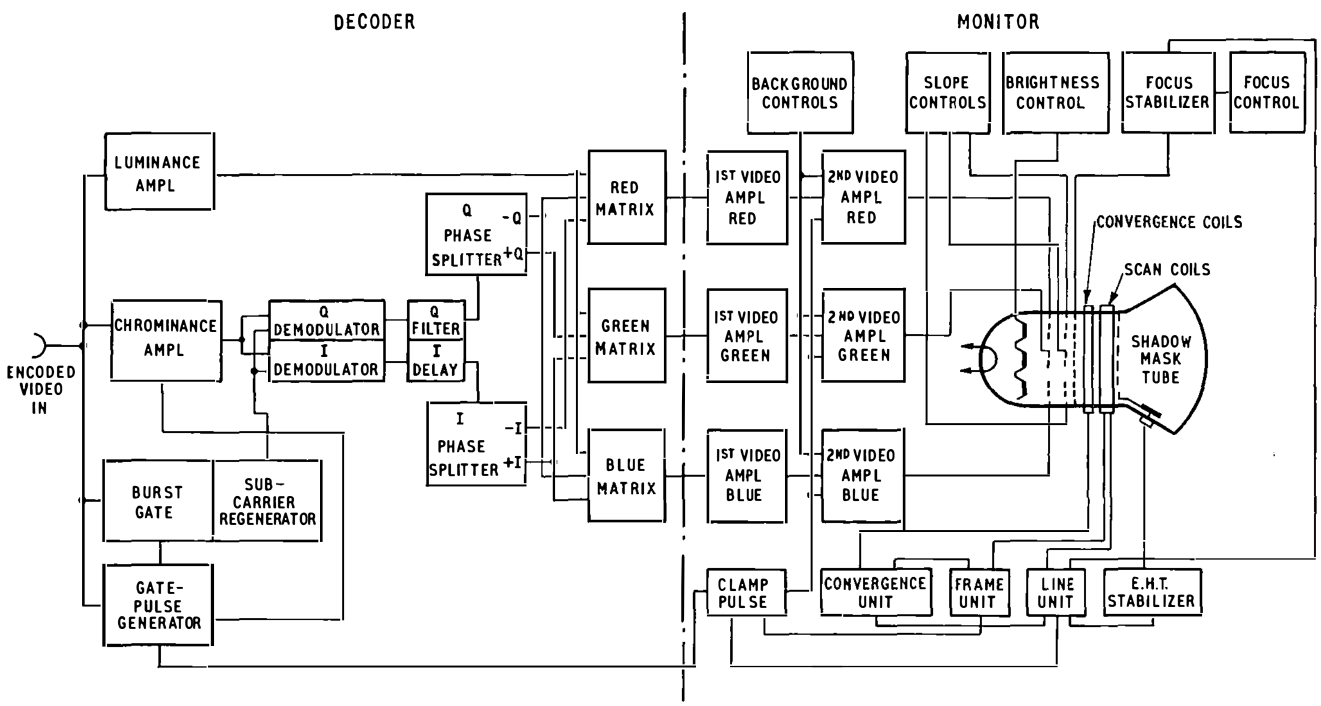


FIG. 18—SIMPLIFIED BLOCK SCHEMATIC DIAGRAM OF A VIDEO COLOUR DECODER AND MONITOR

frequency regenerator, and the picture signal is fed to demodulating and matrixing circuits in the decoder. The picture signal, E_p, may be expressed as follows:

$$E_p = E_Y' + [E_Q' \sin(\omega t + 33°) + E_I' \cos(\omega t + 33°)],$$

where luminance component

$$E_Y' = 0{\cdot}30E_R' + 0{\cdot}59E_G' + 0{\cdot}11E_B',$$

chrominance component

$$E_Q' = 0{\cdot}41\,(E_B' - E_Y') + 0{\cdot}48\,(E_R' - E_Y'),$$

chrominance component

$$E_I' = -0{\cdot}27\,(E_B' - E_Y') + 0{\cdot}74\,(E_R' - E_Y'),\ \text{and}$$

$$\omega = 2\pi \times \text{frequency of colour sub-carrier.}$$

The phase reference in the expression for E_p is that of the reference-burst plus 180°. The suffix ′ indicates that the signals have been gamma corrected.

The decoder output comprises red, green and blue signal voltages (E_R', E_G' and E_B') in the proportions necessary to reproduce the original scene on the tricolour shadow-mask tube.

Video colour-picture monitors present their own individual adjustment problems for which ancillary devices and test-waveform generators are required, as shown in Table 4.

Table 4

Test Equipment Required for Adjustment of Colour Monitors

Colloquial Description of Test	Features of Monitor Adjustment Tested	Test Equipment Required
Purity	Ensures that the electron beams from each of the three electron guns in the shadow-mask tube impinge only on their respective colour phosphor dots on the tube face.	(*a*) Generator providing synchronizing pulses, to lock monitor raster. (*b*) Demagnetizing coil, if impurity is observed.
Convergence	Ensures that the beams from each of the three electron guns in the shadow-mask tube simultaneously converge on the same triad of dots on the tube face.	Generator providing composite video signal comprising grating or dot pattern with mixed synchronizing and blanking pulses.
Grey-scale tracking	Ensures that the gain and linearity of each of the three video amplifiers feeding the three guns of the shadow-mask tube are equal.	Generator providing composite video signal comprising a "grey-scale" or staircase pattern, with at least three luminance levels between black level and white level, and mixed synchronizing and blanking pulses.
Decoder adjustment	Ensures faithful reproduction of hue and saturation of colours in the reproduced picture.	Colour-bar generator producing coded signals representing the three primary colours (red, green and blue) with their complementary colours (cyan, magneta and yellow) and black and white, complete with mixed synchronizing and blanking pulses.

Radio-Frequency Television Receiver

By associating a r.f. receiver that gives a video output with a video monochrome or colour monitor a local transmission may be checked; this arrangement provides an economical supervisory system for a N.S.C.-to-transmitter link. A suitable receiver (Receiver, Television, No. 3A) has been developed and provides the following facilities.

(*i*) It operates in v.h.f. (Bands I and III) and u.h.f. (Bands IV and V).

(*ii*) It gives the following outputs:

(*a*) 1-volt (peak-to-peak) video to drive a picture monitor,

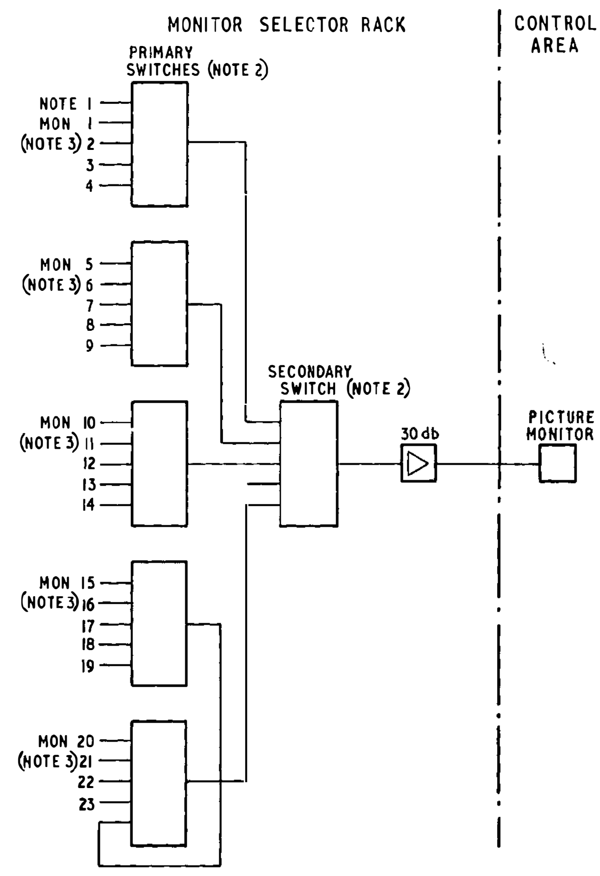
(*b*) 1-volt (peak-to-peak) video for feeding a 75-ohm unbalanced line, and

(*c*) 1 mW audio (program sound) for feeding a 600-ohm balanced line.

(*iii*) Program sound is also fed to an internal loud-speaker, which may be muted under the control of a switch.

PICTURE-MONITOR SWITCHING

Simultaneous monitoring of all video channels passing through a N.S.C. is not required; consequently, arrangements have been made which enable a picture monitor to be connected to one of a number of channels by controls mounted at a central position—on the test console at a N.S.C. The principles of the arrangements used are illustrated in Fig. 19. The channel to which a



Notes: 1. Connexion for picture-line-up generating equipment.
2. The primary and secondary switches are Switching Units No. 9A.
3. The channel monitor points (MON) are −30 db relative to signal level.

FIG. 19—PICTURE-MONITOR SWITCHING EQUIPMENT FOR LARGE STATIONS

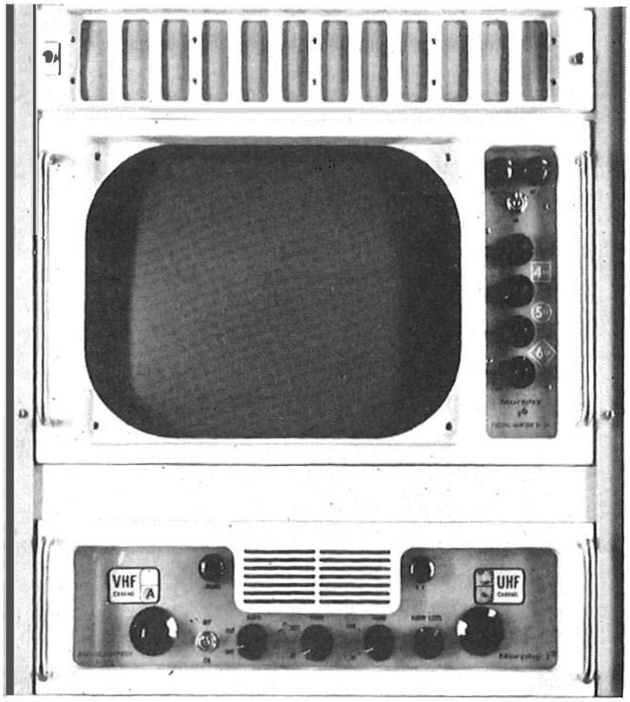


FIG. 20—COMBINED R.F. RECEIVER, VIDEO PICTURE-MONITOR AND CHANNEL INDICATOR

monitor is connected is indicated by an illuminated code on an associated display panel. A combination of picture monitor, display panel and receiver is shown in Fig. 20.

EQUIPMENT UTILIZATION

The equipment described in this article has been, or is being, designed for mounting either on racks, test consoles or test trolleys. It may also be mounted in portable or transportable cases, according to size and weight. In addition to permanently installing the equipment, it is, therefore, possible to transport and use it at outside-broadcast sites and repeater points and at permanent out-stations that do not justify having items of test equipment allocated to them individually.

CONCLUSIONS

The tests described and the equipment necessary to carry them out have been developed to measure, precisely and rapidly, distortions of 625-line monochrome and colour television signals introduced by transmission systems. Test equipment has been and is being developed to enable the Post Office to provide and maintain the television transmission network to the very high standards required.

Future development is likely to reduce the complexity, cost, bulk and weight of this highly specialized apparatus and to improve the performance and reliability, thus reducing the cost of permanent and temporary television transmission channels.

ACKNOWLEDGMENTS

The author wishes to acknowledge the basic work carried out by Dr. N. W. Lewis and other members of the British Post Office Research Station in establishing the principles of waveform testing which are now internationally accepted for testing television transmission systems.

Correction

It is regretted that an error occurred in Part 1 of this article (Vol. 58, p. 126, July 1965). The words at the bottom of the left-hand column on page 127 ". . . are known as Test Signal No. 1 and Test Signal No. 2, which are illustrated in Fig. 2 and 3, respectively;. . ." should read ". . . are known as Test Signal No. 2 and Test Signal No. 1, which are illustrated in Fig. 2 and 3, respectively;. . ."

Book Reviews

"Television Engineering Principles and Practice, Vol. 1." S. W. Amos, B.Sc., A.M.I.E.E., and D. C. Birkinshaw, M.B.E., M.A., M.I.E.E. Iliffe Books, Ltd. 301 pp. 174 ill. 45s.

This is the second enlarged edition of the first volume of a series of four, prepared by members of the B.B.C. Engineering Department primarily for training purposes within the Corporation. Its general publication makes available a good basic course covering the fundamental principles of television but concentrating on cameras and display tubes. Whereas the original text related specifically to the 405-line system, the new edition has been written in more general terms taking into account the different line standards in use throughout the world.

The greater part of the volume is devoted to a series of excellent chapters on optics and electron optics. The section on cameras and picture tubes has been brought up to date and now deals with image orthicon and vidicon tubes in more detail than before. The mathematical treatment of some of the problems associated with optics and electron optics is covered separately in appendices.

All of the text is clearly written and amply illustrated; the mathematical treatment being simple and practical does not involve a high standard of knowledge.

This volume is mainly of interest to students and those concerned with television studio equipment but contains much of general interest. R.A.D.

"Analogue Computing for Beginners." K. A. Kay. Chapman & Hall, Ltd. 164 pp. 80 ill. 25s.

This book is written in a lively and very readable style—the author does not hesitate to use expressions such as ". . . the fellow who comes to delve into the innards . . ." instead of some more conventional designation for a maintenance engineer. This breezy approach is not inconsistent with the aim of the book, which is to provide an elementary introduction to the analogue computer and some of its applications. It is aimed at computer users, and is intended to supplement the more formal instruction which they should have had. It is, therefore, essentially a practical book: it does not, for example, deal with the design of high-gain direct-coupled amplifiers, but it does discuss the ways in which their limitations can affect a computation.

It would be an ideal book to have around when first experimenting with an analogue computer: more would be gained from reading the book if the circuits described in it could be set up at the time and the results observed. When read in the abstract the reasons for some of the practical expedients which are described are sometimes difficult to follow. The diagrams are reasonably clear—once the author's self-confessed enthusiasm for inventing new symbols is accepted.

As a pure introduction to a specialized subject, new to most people, this short book has much to recommend itself.

C.A.M.

A.C. Power Supplies to Museum Telephone Exchange and the Post Office Tower

N. G. JOHNSON†

U.D.C. 621.311.62:621.395.7 + 621.396.7

The electrical power load for the combined Museum Telephone Exchange building and Post Office Tower will be almost 3½ MW. The nature of the telecommunications equipment in these buildings demands power supplies that are highly reliable, and the methods of deriving the necessary medium-voltage and high-voltage a.c. supplies and of providing stand-by supplies from engine-driven plant are described.

INTRODUCTION

IT is British Post Office policy to provide all line transmission equipment and all microwave radio equipment carrying telephony or main television circuits with a power supply giving no break in transmission on mains failure. Where the equipment operates directly from a.c. this "no-break" supply is normally derived from a power plant incorporating a continuously running motor-alternator or continuity set. In addition, an automatically-started engine-driven generator is installed to power the continuity set during a long-duration mains failure and to supply the equipment in the event of a fault developing in the continuity set.

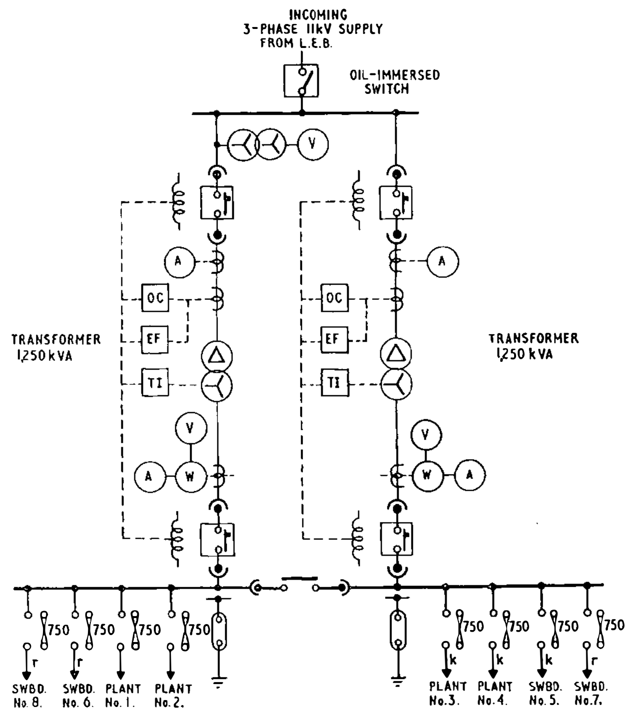
In certain very large stations, of which the combined Museum Telephone Exchange building and the Post Office Tower is an example, the transmission and radio loads amount to hundreds of kilowatts, and the capital and running costs of an arrangement such as that described above would be prohibitive. Furthermore, these stations are always situated in major cities where it is usually possible to obtain two high-voltage supplies from separate main networks. Interruptions to high-voltage supplies of this type are very rare, and the possibility of a simultaneous failure of two such supplies is likely to be even less frequent than a complete failure of a no-break power plant. It is, therefore, current Post Office practice at large stations similar to Museum to dispense with continuity sets and to provide automatic control gear to effect a rapid change-over between two alternative high-reliability mains supplies (short break) on the failure of the one in use and to start a stand-by engine-alternator set to restore supplies (long break) in the unlikely event of both mains supplies failing.

Exchange switching equipment and transmission and radio equipment designed for operation from batteries are covered against prolonged failure of the public electricity supply by automatically-started engine-alternator sets that provide an alternative source of power for the battery float-charging rectifiers as well as for essential accommodation services.

All essential power for the Museum Telephone Exchange and the Post Office Tower is supplied from five equally-rated power plants each equipped with a single running* stand-by diesel-alternator set and an automatic control and distribution cubicle; the less important loads not requiring a stand-by supply are supplied from separate distribution switchboards. When the building is fully operational almost 3½ MW of power will be required, and a total installed stand-by generating capacity of 2½ MW is provided.

HIGH-VOLTAGE AND MEDIUM-VOLTAGE SUPPLIES

The high-voltage and medium-voltage supplies are shown diagrammatically in Fig. 1. An identical arrangement is used for the alternative supplies.



OC—Overcurrent relay. EF—Earth-fault relay. TI—Winding temperature indicator. k—Key interlock between supplies No. 1 and 2. r—Remote interlock between supplies No. 1 and 2

FIG. 1—HIGH-VOLTAGE AND MEDIUM-VOLTAGE SUPPLY DIAGRAM (SUPPLIES NO. 1 OR 2)

High-Voltage Supplies

Two 11 kV 3-phase supplies are fed into the new telephone exchange building extension by underground feeders from different points of the London Electricity Board (L.E.B.) supply network, and terminate in a substation allocated to the L.E.B. switchgear and situated in the north-east corner of the sub-basement.

Each supply is cabled from the L.E.B. substation by two paper-insulated lead-sheathed steel-wire armoured (p.i.l.s.w.a.) cables into identical, 3-panel, free-standing, English Electric, air-insulated, single bus bar switchboards (Fig. 2) installed in separate high-voltage switchrooms next to the substation. The two switchboards have a

†Power Branch, E.-in-C.'s Office.

*Single running—i.e. not arranged for connexion in parallel.

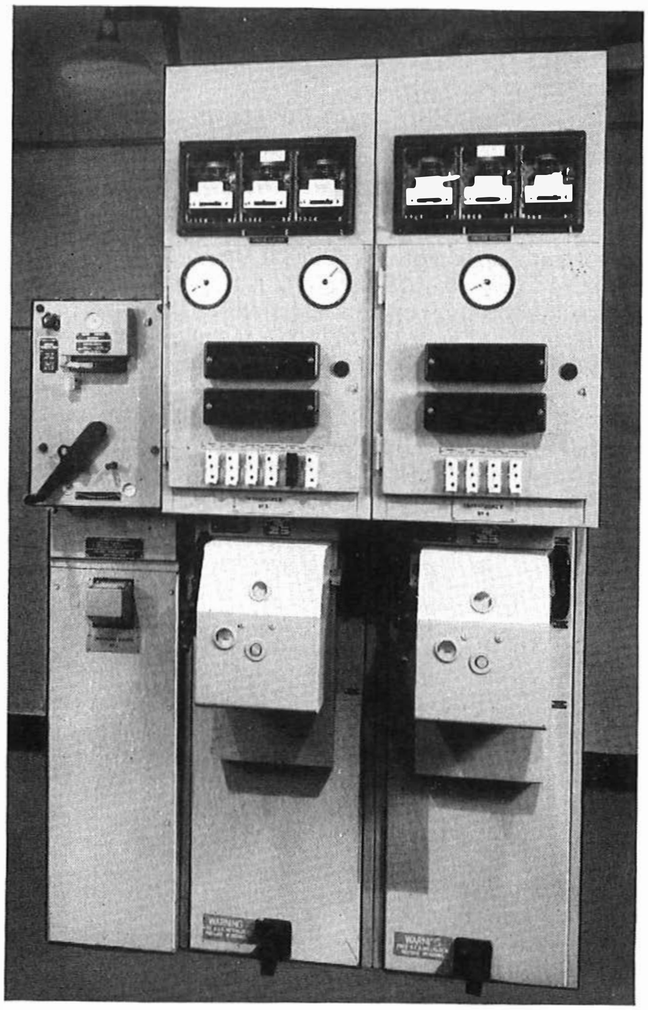


FIG. 2—INCOMING 11 KV SUPPLY SWITCHBOARD

short-circuit capacity of 150 MVA and are each equipped with an incoming oil-immersed switch and two vertical isolation, spring-closing, trip-free, oil circuit breakers each feeding one of four 1,250 kVA delta/star-connected transformers installed in the engine room with the remainder of the plant.

Inverse definite minimum-time (i.d.m.t.)* overcurrent and earth-leakage protection relays are fitted which are arranged to trip the high-voltage and medium-voltage circuit breakers on a fault. Tripping supplies are provided from two 30-volt alkaline batteries installed complete with charging rectifiers—one in each high-voltage switchroom.

Both high-voltage switchrooms are equipped with automatically-operated CO_2 fire-extinguishing apparatus. The two outgoing supplies from each switchboard are cabled to the transformers by two pairs of widely-spaced overhead p.i.l.s.w.a. cables which maintain segregation of supplies.

Transformers

Dry-type, naturally-air-cooled transformers were chosen; each pair is normally operated in parallel, and the star neutral point is brought out from the low-voltage winding to give a standard 4-wire 415-volt distribution system.

The four transformers, accommodated in ventilated cubicles at each end of medium-voltage switchboards No. 1 and 2, provide power supplies to the remainder of the plant (see Fig. 3). This arrangement enables direct connexions to be made from the transformer output terminals to the switchboard bus bars, thereby avoiding additional external cabling.

Each transformer weighs approximately 4 tons and is mounted on four rollers to allow it to be withdrawn through the front of the cubicle, the doors of which are fitted with key-operated interlocks to ensure that they cannot be opened before the transformer concerned is completely isolated from the 11 kV incoming supply.

Each transformer is protected against a rapid and dangerous rise of winding temperature, if overloaded, by a winding-temperature indicator specially developed for the Post Office. The apparatus consists of a heater coil, supplied from a current transformer, and a thermometer bulb placed together low down in the transformer cubicle and lagged to give an equivalent time-constant to the average winding-temperature rise as measured by the change in its resistance. The recording instrument is fitted with contacts which give a warning of high temperature at 170°C and trip the transformer from load when the temperature reaches 180°C. The indicator readings on test closely simulated the temperatures recorded by thermocouples embedded at selected points in the windings.

Medium-Voltage Switchboards No. 1 and 2

Medium-voltage switchboards No. 1 and 2 are identical English Electric switchboards which provide the alternative mains supplies to the five plant cubicles and to medium-voltage distribution switchboards No. 6, 7 and 8 serving the non-essential loads. Each switchboard is a free-standing, air-insulated, single bus bar switchboard made up of seven panels, and presents a flush frontal appearance; the short-circuit rated capacity is 31 MVA at 415 volts. As previously mentioned, the transformers are accommodated in the end cubicles; the next-to-end cubicles accommodate instrumentation and the 2,400 amp transformer air circuit breakers. The adjoining cubicles house eight 750 amp triple-pole and neutral fuse-switch units for outgoing circuits, and the centre cubicle accommodates another 2,400 amp air circuit-breaker forming a normally-closed bus-bar coupler.

Key-operated mechanical interlocks are fitted to the fuse-switch units, supplying plants No. 3, 4 and 5, to prevent supplies No. 1 and 2 being paralleled together. The outgoing feeders used are always chosen to allow spare capacity for the sudden transference of the load served by plants No. 1 and 2 to the alternative supply.

All the air circuit breakers have a trip-free operation and are arranged for horizontal isolation and withdrawal, live contacts being guarded by a shutter when the breaker is in the withdrawn position. The transformer air circuit breakers are equipped with 30-volt tripping coils operated with the tripping of the relative high-voltage breaker, or they can be tripped by local press-buttons.

*Inverse definite minimum time—having an operate time inversely proportional to the fault current but having a definite minimum time.

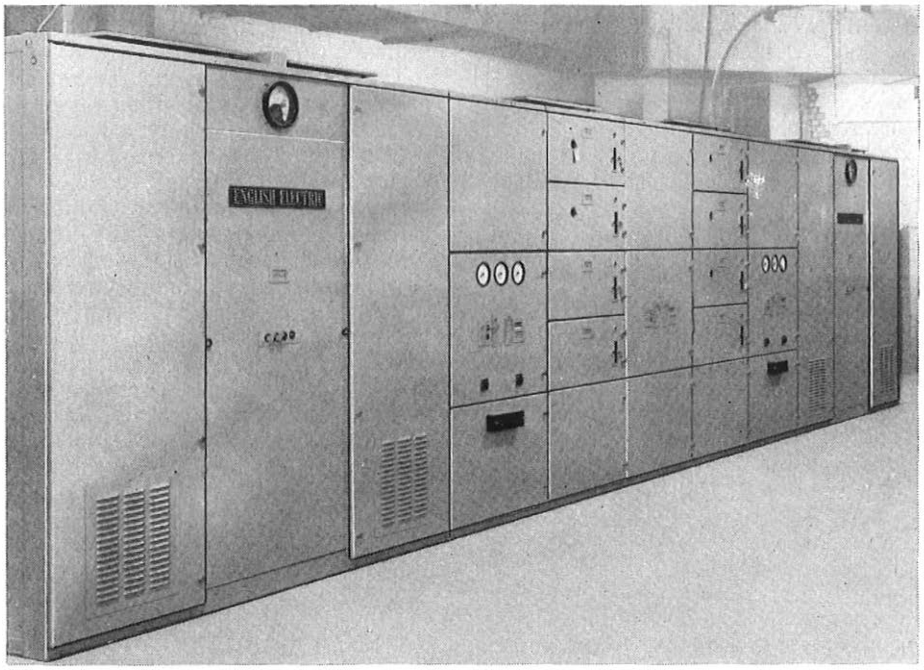


FIG. 3—COMBINED SUBSTATIONS AND MEDIUM-VOLTAGE SUPPLY SWITCHBOARDS

PLANT AUTOMATIC CONTROL AND DISTRIBUTION CUBICLES

Plants No. 1 and 2 provide the regulated supplies for the radio equipment in the Tower, the television and telephone repeater stations in the new extension building, and to transistor-supply power plants No. 1–4. Plants No. 1 and 2 are each equipped for short-break changeover of their connected loads, in the event of mains failure, to the alternative mains supply, or for long-break restoration of supplies from their engine-alternator sets if both incoming mains supplies should fail or if the output voltage departs from regulated limits for longer than 6 seconds.

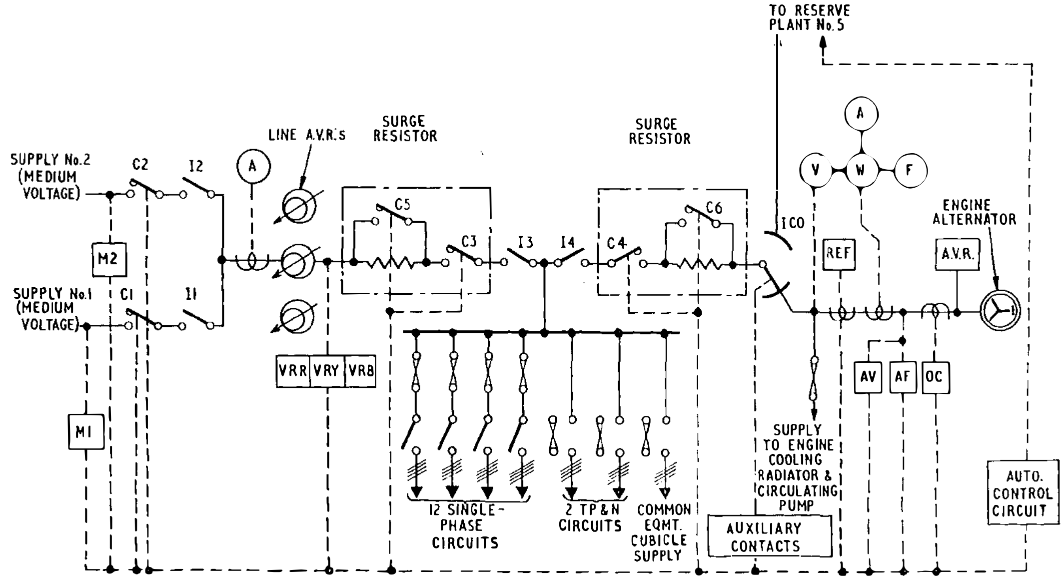
Plants No. 3, 4 and 5 provide unregulated 415-volt 3-phase 4-wire supplies from a selected incoming mains,

FIG. 4—PLANT NO. 1 AUTOMATIC CONTROL AND DISTRIBUTION CUBICLE

and, if this supply fails, long-break restoration of supplies from their engine-alternator sets only. In addition, a facility is provided to enable No. 5 engine-alternator set to be switched, together with its control system, to substitute any other engine-alternator set out of service; later, a mobile generating-set will be made available to serve the No. 5 engine-alternator set load in these circumstances. Each plant cubicle (see Fig. 4) accommodates supply-monitoring equipment, contactors, isolating switches, surge-limiting resistors, distribution section, engine-starting control gear, instrumentation and supervisory circuits, etc., and is of Electric Construction Co., Ltd., manufacture. All control switches, alarm-indicating lamps and instruments are situated at one end of the cubicle near to the alternator, and hinged doors or removable panels are provided for access to internal equipment.

Fig. 5 shows the general load-circuit schematic the supply is then returned to the cubicle for distribution to load.

The line voltage regulators are of the air-cooled, multiple-tapped transformer, motor-driven, electro-magnetically-controlled type manufactured by Messrs. Fosters, Ltd. Smooth control is achieved by a patented rotary switch comprising a fine-control switch that completes one revolution around the two equally-tapped halves of a fine winding to give intermediate adjustment before a coarse-control switch changes to the next coarse transformer tap. Over-travel warning-limit switches and terminal-limit switches are fitted to protect the driving mechanism, and, in the event of a fault, the driving motor can be declutched and the voltage re-adjusted by a hand control. The main-cable connexion boxes are arranged to allow a faulty regulator to be temporarily disconnected and the supplies through-connected.



AV—Voltage-monitoring relay. AF—Frequency monitoring relay. OC—Overcurrent relay. REF—Restricted earth-fault relay

FIG. 5—GENERAL LOAD-CIRCUIT SCHEMATIC DIAGRAM OF PLANTS NO. 1 AND 2

arrangement of plants No. 1 and 2. Plants No. 3, 4 and 5 are similar except that automatic voltage-regulators and automatic mains change-over facilities are omitted and supplies are distributed indirectly. Main-load contactors are latched-in, heavy-duty, triple-pole contactors housed in separate compartments key-interlocked with triple-pole isolators, provided to ensure that the contactor is fully isolated before the compartment door can be opened. All connexions between load contactors, surge resistors and isolators are made by copper bus bars, and the contactor-operating sequences are electrically interlocked.

Referring to Fig. 5, M1 and M2 are adjustable 3-phase transistor-type mains-failure monitoring relays which detect a mains failure at 93 per cent of the incoming-supply nominal voltage. The incoming supply is fed out from a common point by single-core cables to three single-phase line-voltage regulators, installed adjacent to the cubicle, which maintain the output voltage of each phase at 247 volts $\pm$ 1 per cent irrespective of variations in the input supply between 235 and 260 volts;

Assuming the load is served by mains supply No. 1 which then fails while mains supply No. 2 remains serviceable, the release coil of contactor C1 is energized to disconnect the load from mains supply No. 1 and the operate-to-close and release-to-open coils of contactors C1 and C2 are open-circuited, auxiliary contacts open-circuiting the contactor release circuit once contactor C1 has opened. Contactor C5 is next operated to the release position to insert a surge-limiting resistor in circuit; contactor C2 is then operated and latched in to supply the load at reduced voltage from mains supply No. 2 concurrent with the preparation of circuits for the release of contactor C2 and the re-closing of contactor C1. After approximately 200 ms, contactor C5 is operated to short-circuit the surge-limiting resistor and restore supplies at normal voltage, contactor C3 remaining closed throughout the operation. If mains supply No. 2 now fails supplies will be restored from the original mains by a reverse action, provided this supply has returned to a normal condition—failing this, series contacts M1X and M2X (not shown) will both be in the closed position to initiate engine starting. When the alternator voltage and frequency are both correct, contactors C3 and C5 are released and contactor C4 operated to connect the alternator to the load through its surge-limiting resistor, auxiliary contacts on contactor C4 preventing contactor C3 re-energizing before contactor C4 is released. After 200 ms, contactor C6 short-circuits the surge resistor, and a supply is restored to the load at correct voltage, contactor C5 remaining open with the mains surge-limiting resistor in circuit in preparation for a mains-supply restoration.

The output from each line-voltage regulator is monitored by single-phase transistor-type relays VRR, VRY or VRB. If the voltage varies sufficiently in either direction to operate the relay contacts, a regulator-failure warning is given and the plant engine-alternator set is started to restore supplies at correct voltage, but this action is deferred for 6 seconds to allow for recovery time from a temporary voltage excursion outside regulated limits. The monitoring-relay settings can be adjusted up to ± 10 per cent of nominal voltage, and are also provided with operate/release differential adjustment. Lamp indication is given of the mains supplies which are live and of which mains supply is serving the load, of individual line-voltage regulator failure, or of contactor C3 or C5 open-circuit conditions.

For security reasons the radio-equipment loads in the Tower are shared between two rising-mains systems, one of which is connected to plant No. 1 and the other to plant No. 2. The distribution sections of the two plants concerned are equipped for supplying these rising mains direct with two sets of three single-phase supplies; these distribution arrangements are described later. If the selected mains supply to plants No. 3, 4 or 5 fail, the appropriate plant engine-alternator set will be started to give long-break restoration of supplies from these plants.

Engine starting is controlled by a 50-volt d.c. Post Office designed circuit using standard Post Office relays and a uniselector for timing the various starting operations.

The engine lubricating-oil system is first primed by a large-capacity, positive-displacement, compressed-air operated pump, and, once sufficient oil pressure is detected at the engine by a pressure switch, the electro-magnetic air-starting admission valve is energized, lubricating-oil priming continuing for a predetermined time while the engine is turning over. As the engine fires and runs up to speed the increase in speed is monitored by a moving-coil relay supplied from a d.c. tacho-generator driven by gearing from the engine, and at a suitable stage the air-start valve is de-energized to cut off starting-air admission. Meanwhile, the alternator has commenced to generate and its voltage and frequency are monitored by relays AV and AF. Sufficient uniselector contact steps are allowed to give the voltage and frequency time to settle, and at the end of this period, assuming that the monitoring relays AV and AF have prepared the necessary circuits because the voltage and frequency are within the set limits, the load is transferred to the alternator supply. After the application of the load the uniselector continues to step on to insert the engine fault-protection circuits, and comes to rest on contact 36, the remaining steps being required when the engine is shut down and the load returned to a mains supply.

Restoration to the mains supply is effected by manual switching except in the event of an engine-alternator set fault shut-down; the load is then restored to a mains supply, assuming a supply is available. Monitoring relays AV and AF are single-phase transistor-type relays of similar pattern to the line-regulator voltage monitors and have their upper and lower contact settings adjustable between ± 10 per cent of nominal voltage and frequency. Starting and stopping equipment fitted to the engine is energized at the control-circuit voltage.

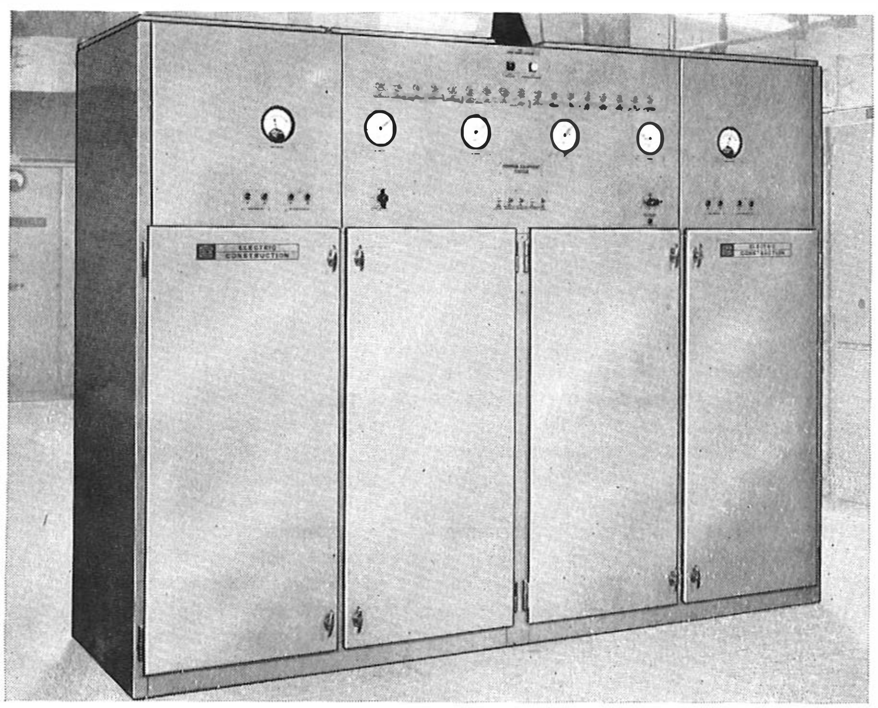


FIG. 6—COMMON EQUIPMENT CUBICLE

COMMON-EQUIPMENT CUBICLE

The common-equipment cubicle (Fig. 6) accommodates two batteries of Post Office Cells No. 22/100, which supply the power for operating the engine-starting and change-over circuits. A constant-potential battery-charging rectifier is provided for each battery within the cubicle, and a common low-battery-voltage warning circuit is fitted. Also accommodated within the cubicle are motor starters and other miscellaneous electrical apparatus connected with common engine auxiliaries, e.g. motor starters for the air-compressor driving motors and fuel-transfer pumps.

The battery for use is selected alternately, and a.c. supplies for the cubicle are obtained from the outputs of several plant cubicles to ensure that supplies are available under all operating conditions.

ENGINE-ALTERNATOR SETS AND AUXILIARIES

Each of the five engine-alternator

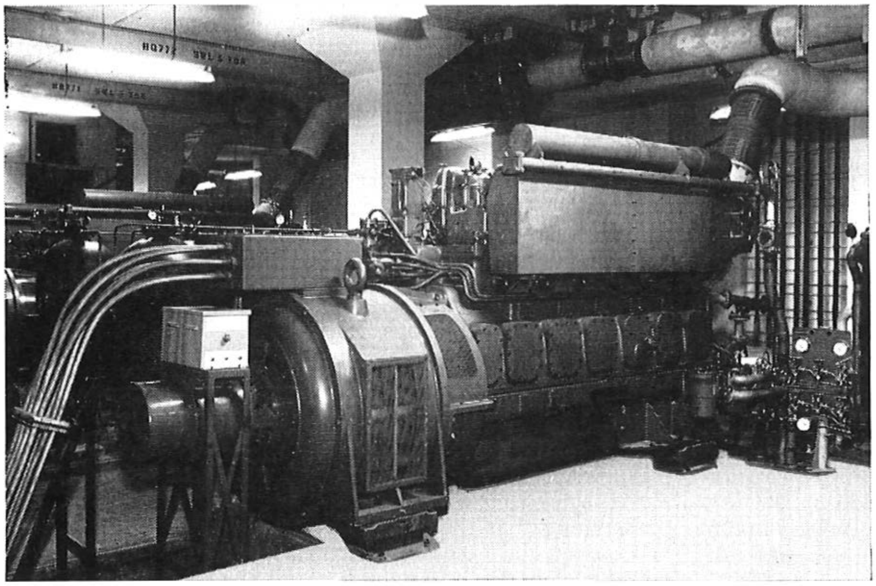


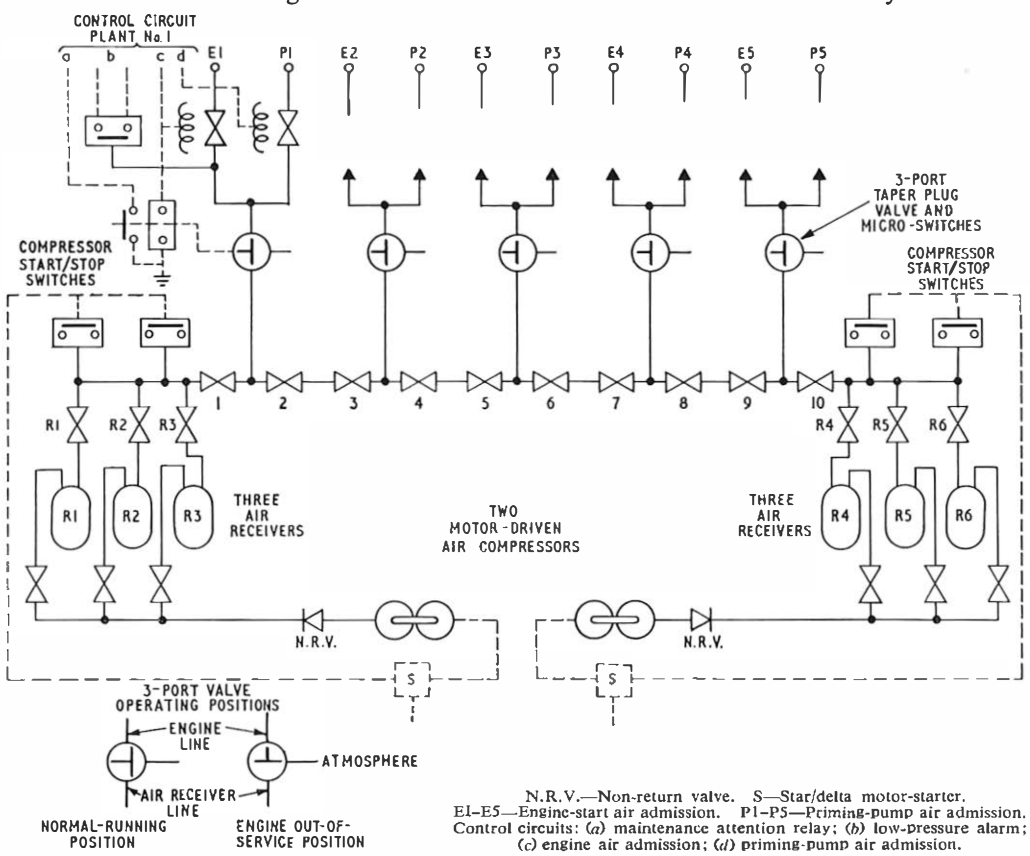
FIG. 7—ENGINE-ALTERNATOR SET

sets (Fig. 7) has a continuous rated output of 500 kW, and, in addition, each is capable of providing a 10-second intermittent overload rating of 600 kW to provide the additional power required from plants No. 3 and 4 for accelerating the two high-speed Tower lifts from rest.

The diesel engines are the English Electric, 6-cylinder in line, 4-stroke, water-cooled, 6 SRKA-type, with a bore of 10 in. and stroke of 12 in. Each engine is fitted with an exhaust-gas-driven Napier turbo-blower to give it a continuous output of 743 h.p. at 750 rev/min. Four-valve cylinder heads are fitted and a separate fuel-injection pump, operated from a common camshaft, is provided for each cylinder. Engine speed is maintained under all conditions of applied load to within ± 1 per cent of synchronous speed by an isochronously-set hydraulic governor that has a fast response to load changes.

Instead of the engine-alternator sets being mounted on deep-concrete foundation blocks weighing upwards of 70 tons each, the alternators are flange mounted on a bell housing bolted to the engine casing. This enables the combined engine-alternator unit to be supported directly from the floor on four Christie and Grey pedestal-type antivibrator mountings which provide a completely stable mounting while effectively preventing the transmission of engine vibration to the building structure.

Fig. 8 shows the compressed-air engine-starting-supply system which is normally operated with control valves No. 4 and 5 closed to provide security of supply. Starting air at 300 lb/in^2 is admitted directly to the engine cylinders in turn through an air distributor driven from the engine camshaft. Each group of three $23\frac{1}{4}$ft^3 capacity air receivers is automatically maintained above the



N.R.V.—Non-return valve. S—Star/delta motor-starter.
E1–E5—Engine-start air admission. P1–P5—Priming-pump air admission.
Control circuits: (a) maintenance attention relay; (b) low-pressure alarm; (c) engine air admission; (d) priming-pump air admission.

FIG. 8—COMPRESSED-AIR STARTING-SUPPLY SYSTEM

minimum air-starting pressure by a two-stage motor-driven air-compressor.

A special 3-port valve, the purpose of which is to provide a means of removing starting-air pressure from the engine while maintenance is carried out, is fitted in each engine supply line. Each valve is monitored in the engine out-of-service position by a switch which sets up a maintenance-attention alarm warning condition on the plant cubicle. The compressed-air control valves, electromagnetic priming-pump air-admission valves and compressor-motor control switches are all contained within a single free-standing enclosed sheet-metal cubicle.

The Electric Construction Co., Ltd., alternators driven by the engines are salient-pole, revolving-field, enclosed ventilated, brushless machines and are fitted with overhung directly-driven exciters; the exciter armature and rotating rectifier diodes are mounted on an extended rotor shaft. The star point of the alternator stator winding is brought out to give a standard 3-phase, 4-wire supply, and the machines are specially designed to give a waveform containing a low proportion of third harmonics.

The alternator output voltage is controlled by varying the exciter field from the rectified output of an automatic voltage regulator; this regulator is of the flux-resetting,

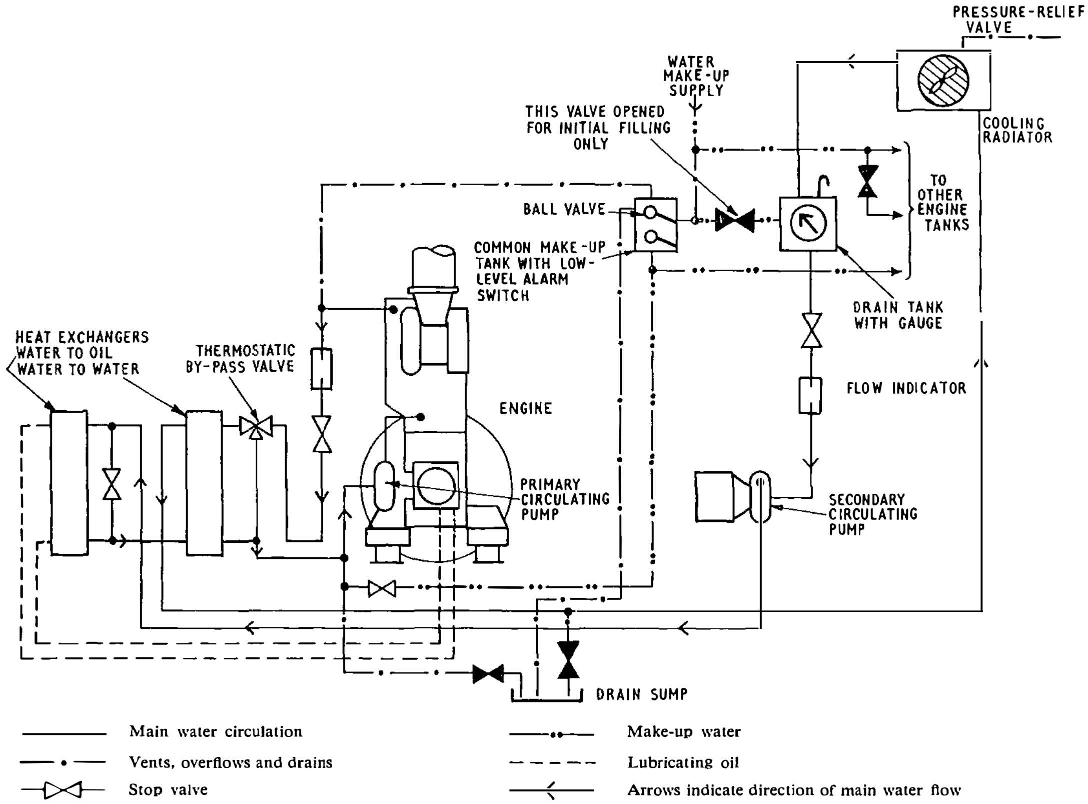


FIG. 9—ENGINE-COOLING SYSTEM

The engines are cooled by five large radiators installed in ground-floor accommodation. The radiator fans are driven by individual low-speed electric motors to ensure that fan noise is kept to a reasonably quiet level. An indirect engine-cooling system is used (see Fig. 9) in which a water-to-water heat exchanger is interposed between the primary (engine) and secondary (radiator) cooling circuits; secondary circulation is provided by a motor-driven pump and primary circulation by an engine-driven pump. A portion of the secondary water is passed through a second heat exchanger to cool the engine lubricating oil. When the engines are stopped the cooling water from each radiator drains down into separate 200-gallon reception tanks in the engine room, thereby giving protection against freezing in winter without the necessity of filling the system with an anti-freeze mixture. A thermostatically-controlled by-pass circuit is fitted to allow the engine to rapidly warm up from cold.

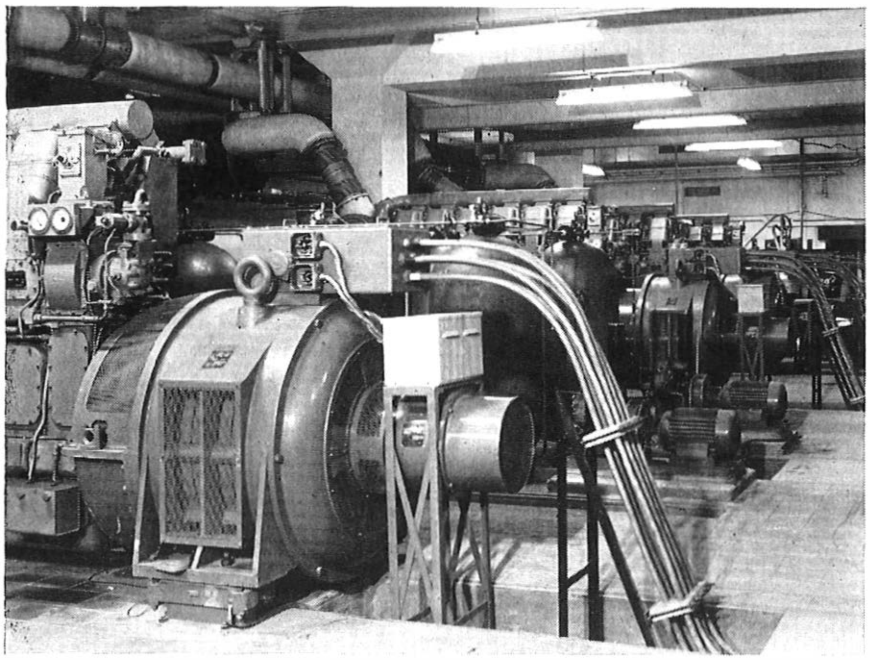
transistor, magnetic-amplifier type which operates on the principle of changing the flux in a high-quality magnetic core by a d.c. control voltage determined by the level of the alternator reference voltage. The alternator voltage is maintained to within $\pm 1\frac{1}{2}$ per cent of 247 volts phase-to-neutral under any unbalanced load conditions up to a 50 per cent proportion of load on any one phase or pair of phases. A small voltage-trimmer is provided for setting the output voltage level.

I.D.M.T. overcurrent and restricted earth-fault protection relays are fitted to trip the machine from load in the event of overcurrent or an earth fault. The maximum short-circuit current that can flow is also limited by the reactance of the machine and by a current-limiting circuit in the automatic voltage regulator. This circuit causes the exciter field to be quenched in the event of a fault.

The alternator terminal box is mounted on the top of the alternator frame to allow the main output cables to be taken in an easy sweep over the exciter and down into a floor trench leading to the appropriate plant cubicle.

Engine-protection circuits are provided to give an engine-cooling-water or lubricating-oil high-temperature warning alarm, and to shut the set down automatically and transfer the load to a mains supply irrespective of its condition in the event of overspeed, dangerously-low lubricating-oil pressure, or excessive cooling-water temperature.

Alarm warning conditions are also set up for uni-selector pulse-unit failure, low starting-air pressure, lubricating-oil priming failure (in which circumstance the engine will fail to start), alarm-type fuse rupture, excess engine-starting time, low engine-water make-up-tank water level, or if vital isolators or switches, e.g. switch ICO (Fig. 5), are left in an incorrect position for normal operation. Monitoring relay AV gives warning of low alternator volts or initiates the operation of the circuits to shut the engine down and return the load to the mains if the alternator voltage remains high for longer than 6 seconds; relay AF operates similarly to shut the set down on high or low frequency. When the engines are running, primary and secondary cooling-water flow may be observed through sight flow indicators, and adequate instrumentation is provided for determining engine speed, operating temperatures and pressures.



Note: The photograph shows the engine room prior to completion

FIG. 10—GENERAL VIEW OF ENGINE ROOM

In common with other Post Office prime-mover installations the engines are run on class-A fuel oil. They are supplied by gravity from two 300-gallon service tanks maintained to level by float-switch-controlled pumps from three 14,000-gallon, pressed-steel, rectangular storage tanks each divided into two compartments. The storage tanks are built up of 4 ft square plates bolted and welded together, and facilities are provided for transferring fuel from one compartment to another. Electrically-operated remote-reading service-tank contents gauges and high or low service-tank level alarms are provided; the gauge dials and warning lamps are located on the common equipment cubicle.

The storage and service tanks are installed in a fire-resisting brick chamber at one end of the engine room, and, in an emergency, fuel supplies to the engines may be cut off by a control outside the engine room.

Engine exhausts are carried in 14 in. diameter steel pipes to the building-extension roof in an internal duct where they discharge to atmosphere through terminal silencers; within the engine room the pipes and primary silencers are lagged with heat-insulating material to minimize heat dissipation.

The engine room is ventilated by an inlet-and-extract system controlled by switching-in pairs of fans to match requirements.

A general view of the engine room is shown in Fig. 10.

DISTRIBUTION AND CABLING

The two radio-equipment rising-mains systems provided to the level of apparatus-floor B 16* in the Tower each comprise four 0·2 in^2 mineral-insulated copper-sheathed (m.i.c.s.) cables. Plants No. 1 and 2 cubicle distribution sections are each equipped with 12 single-pole unlinked switches and independent 400 amp wedge-tightened fuse units, three of which from each cubicle are fused down to 200 amp and used for supplying the two radio-equipment rising mains. They form two separate sets of three single-phase circuits fused at origin, each with its own common neutral to which the connexion of 3-phase loads is prohibited. Single-phase connexion of radio equipment is made to the rising mains at the floor levels from distribution boards each equipped with sufficient 15 amp high-rupturing-capacity fuseways to provide flexibility for equalizing floor loads between the two systems. To maintain correct fuse discrimination the radio-equipment rack fuses are strictly limited to 2 amp maximum-rating surge-resistant fuses within a total limitation of all such fuses to 6 amp per rack.

The remaining single-pole unlinked switches and fuse units, suitably fused down, are used to supply the television repeater stations, television-control equipment and telephone-signalling equipment loads in the extension building. Plant cubicles No. 1 and 2 are also provided with a total of six 400 amp triple-pole and neutral fuse switches for distributing 3-phase supplies to Tower rising-main C, to the four transistor-supply power plants, to essential accommodation services and to the common-equipment cubicle.

Compensation for the average volt drop between the supply source and the load has been allowed for by the higher-than-normal plant output voltage of 247 volts phase-to-neutral.

*Jones, D. G., and Edwards, P. J. Post Office Tower, London, and the United Kingdom Network of Microwave Links. (In this issue of the *P.O.E.E.J.*)

Power supplies from Plants No. 3, 4 and 5 and also supplies not provided with engine stand-by are distributed from six distribution switchboards provided for the Post Office by Ottermill Switchgear, Ltd. These switchboards are air-insulated cubicle-type, fuseswitch-equipped switchboards installed together in the engine room. Distribution switchboards No. 3, 4 and 5 are supplied from the outputs of Plants No. 3, 4 and 5, respectively, and distribute supplies to lifts, telephone-exchange rectifiers and power plant, and to essential accommodation services; distribution switchboards No. 6, 7 and 8 serve less-essential services and derive their incoming supply from manually-selected alternative mains obtained from switchboards No. 1 and 2, the incoming alternative supply switches being fitted with mechanical interlocks.

Tower rising-main C, supplying essential 3-phase power, and Tower rising-main D, supplying non-essential power, are two 400 amp triple-pole and neutral copper bus-bar systems 372 ft long; the bars are enclosed in trunking and maintained in tension by a self-adjusting suspension unit. Three-phase supplies to each of the two high-speed Tower lifts are cabled separately from distribution switchboards No. 3 and 4 with sets of three 0·2 in^2 single-core m.i.c.s. p.v.c.-covered cables. M.I.C.S. cabling is also used extensively for cabling between the medium-voltage switchboards, plant cubicles, line-voltage regulators, for cabling engine auxiliaries and for main power distribution; exceptions are the alternator output cables to the plant cubicles, where seven single-core (two per phase and one neutral) varnished-cambric lead-covered cables are used per machine. Heavy-load-carrying m.i.c.s. cables are single-core cables, duplicated where necessary to obtain adequate current-carrying capacity, and where the phases are run together the cables are grouped in an equidistant formation to minimize inductive effects. There are also three triple-pole and neutral 400 amp copper bus-bar rising mains installed in ducts in the extension building to distribute lighting and small power supplies.

CONCLUSIONS

The plant described is the largest and most extensive automatic installation of its kind yet provided within a Post Office building. From the commencement of detailed planning it has taken over 3 years to design, manufacture, test and commission the plant, and as work has progressed several modifications have been made to improve its operation and cater for increases in load. The contract for the provision of the plant up to the plant cubicle output terminals was placed with the English Electric Co., Ltd., Rugby, and the Engineering Branch of the London Telecommunications Region were responsible for the distribution of supplies throughout the building and for ventilating the engine room.

Book Reviews

"Understanding Television." J. R. Davies. Data Publications. vii + 504 pp. 209 ill. 37s. 6d.

This volume is based on a series of articles appearing in the monthly journal *Radio Constructor* and consequently is notably free from errors.

In the preface, the author observes that although a television receiver appears to be complicated, it can be broken down into a number of individual circuit functions each of which is simple in operation and readily understood by anyone with a basic knowledge of radio principles. He then justifies this remark by describing in detail each of the sections, starting from very simple definitions of their purpose and leading to outline circuit details of various methods of achieving the required performance. The text is well illustrated, simply and clearly written, and uses a completely non-mathematical approach.

The book commences with an introductory chapter on the nature of television signals, including descriptions of the various systems in use in the world. In later chapters details of monochrome-receiver design are considered and pride of place is given to the 405-line standard, although any alternative arrangements required for 625-line working are adequately dealt with. A long chapter on colour television, again simply and clearly written, ends the volume. It is a little unfortunate perhaps that publication took place before u.h.f. television services were started in this country, since dual standard receivers are not mentioned and u.h.f. reception is dealt with only in a rather brief appendix.

The book can be confidently recommended to anyone who wishes to understand how the modern television receiver works.

R.A.D.

"Physics—Electronics Titles." Boston Technical Publishers, Inc. vii + 455 pp.

This book is a bibliography and key-words index of the titles of leading articles on physics and electronics published in about 200 journals during 1960. The book is arranged in four major sections: the Journal Index (pp. 1–11), the Key-Word-In-Context (KWIC) Index (pp. 13–234), the Bibliography (pp. 235–414), and the Author Index (pp. 415–452).

The Journal Index is simply a list in alphabetical order of the journals covered, showing in each case the publication address and the abbreviated form of the title of the journal used in the Bibliography. The KWIC Index is an alphabetical listing of key-words which appear in the titles of the articles; the key-words are arranged in line down the middle of each page, with the words which immediately precede and follow them in the title arranged on either side, so that when a given key-word is located a glance to the left or right of it will reveal its relationship to the title. A "wrap-round" technique is used so that the first words of a title follow key-words when these words occur as the last words in the title. Each indexed key-word has a reference code which ties the KWIC Index to the Bibliography. The Bibliography is arranged alphabetically by reference code and contains complete information on author, title, and source for each article indexed. Several key-words from one title will refer to the same uniquely coded article in the Bibliography. The Author Index is an alphabetical list of all the authors of the articles indexed, and alongside each entry is the reference code which refers the searcher to the Bibliography.

The publishers state that volumes for the years subsequent to 1960 are already in preparation. The series should prove extremely useful to anyone who has occasion to search the literature in the fields of physics and electronics.

D.C.G.

Reinforced-Concrete Radio Towers

J. B. MILLAR, B.Sc., A.M.I.E.E.†

U.D.C. 624.97.012.45:612.396.67

The radio-relay stations of the inland microwave-radio network are usually provided with steel-lattice towers to support the aerials. At certain stations a new standard type of reinforced-concrete tower is being used, and the main features of such towers are described.

INTRODUCTION

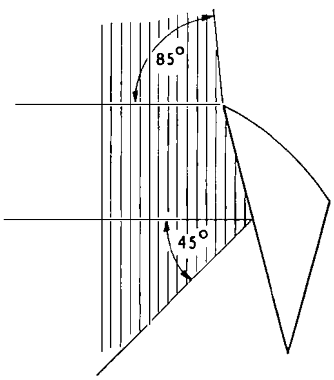
THERE are now over 100 radio stations existing, or in the course of construction, in the inland radio network. The most obvious features of such stations are the masts or towers that support the aerials. These are usually steel-lattice structures, but an interesting recent variant is a standard-type reinforced-concrete tower designed by the Ministry of Public Building and Works to meet British Post Office requirements. Six such towers are now being equipped, and one more is under construction. Their heights range from 160–380 ft. The associated radio equipment is housed in standard buildings adjacent to the towers.

DESIGN REQUIREMENTS

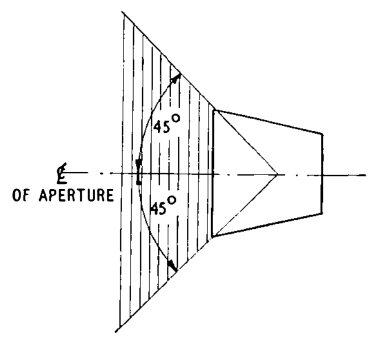
The shape and size of the tower are largely determined by the requirements of the aerials and feeders of the radio system used. The two main types of microwave aerial currently being used are parabolic dishes and horn paraboloids. Dishes up to 5 m in diameter have been used in this country, but a maximum diameter of 12 ft is more common. Such aerials impose dead loads of 1,500 lb and wind loads of over 5,000 lb on the supporting structures for a wind speed of 100 miles/h. The aerial feed is sometimes by coaxial cable, but more commonly by rectangular copper waveguide. The more recently adopted horn paraboloid is essentially a sheet-metal structure in the shape of an inverted right square pyramid, so sectioned by a paraboloid surface that a wave launched upwards from the apex is reflected along a horizontal path. The larger of the two sizes being used at present is about 28 ft high and 15 ft wide at the top. It weighs 15 cwt, and gives rise to a maximum design wind-loading of 7,000 lb.

A characteristic of horn aerials is their high capacity in terms of radio broadbands which results from the use of circular-waveguide feeders. However, this advantage can be realized only if the waveguide is kept straight within very fine limits. Maximum benefit is derived from the use of circular waveguide by employing it for the vertical portion of the system. At the lower end of each feed a band branching-unit allows the signals in each of the communication frequency-bands employed, and in both polarizations, to be fed into rectangular waveguides which can negotiate the bends necessary to reach the equipment in the adjacent building.

The minimum heights at which aerials may be mounted on the towers are determined from a study of the propagation paths to adjacent stations in the network.* The minimum allowable lateral spacing between adjacent horn aerials depends on the coupling loss required and on the r.f. band and channel arrangement in use. A standard aerial layout should provide for at least 70 db coupling loss between adjacent aerials, and this requires a minimum spacing of 17 ft 6 in. between the vertical axes of two large horns, and 12 ft for a large and a small horn, side by side with their bases at the same level. In addition, to avoid the effects of reflections from near obstacles, an area in front of each horn aerial must be kept clear, as shown in Fig. 1. A stiffness requirement



(a) Elevation



(b) Plan View

Sectors hatched must be kept free of obstructions

FIG. 1—DIAGRAM SHOWING CLEARANCE REQUIRED AT APERTURES OF HORN AERIAL

is also imposed by the high directivity of the microwave aerials. For example, the beam width between 3 db points of a large horn paraboloid aerial at 11,000 Mc/s is about 34 minutes of arc.

It was decided that where possible the waveguides should run inside the tower. In this way weather protection would be obtained and the waveguide fixings would not need to be designed to deal with wind loading. Since circular waveguides drop vertically from the horn aerials there was clearly a relationship between the

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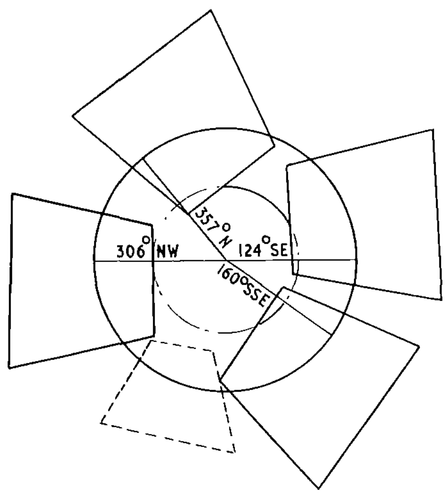
*LELLIOTT, S. R., and THURLOW, E. W. Path Testing for Microwave Radio-Relay Links. *P.O.E.E.J.*, Vol. 58, p. 26, Apr. 1965.

layout of horn aerials on the aerial galleries and the diameter of the tower. In fact, the aesthetic requirement of a slim core conflicted with the need for space on the aerial galleries to achieve the required physical spacing of adjacent horns to minimize crosstalk.

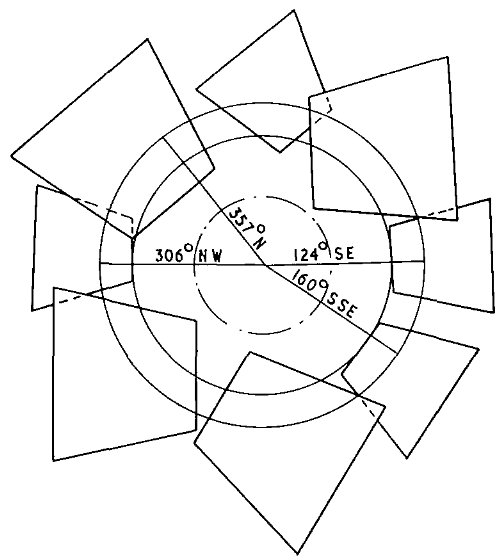
GENERAL DESIGN OF TOWER

The aerial layouts for the galleries were, therefore, designed jointly by the Ministry of Public Building and Works and the Post Office Engineering Department. The maximum aerial capacity of a concrete tower was based on the requirements for a tower at the crossing of two main routes, and, therefore, caters for a maximum of two large horn, two small horn and two parabolic aerials in each of the four directions, with about five additional parabolic aerials to meet contingencies. The tower was designed to carry the 16 horn aerials arranged on three galleries in such a way that straight vertical paths were kept clear for the circular waveguides. It is convenient to consider the design in relation to a practical case, and Fig. 2 gives the aerial layouts at Charwelton radio station.

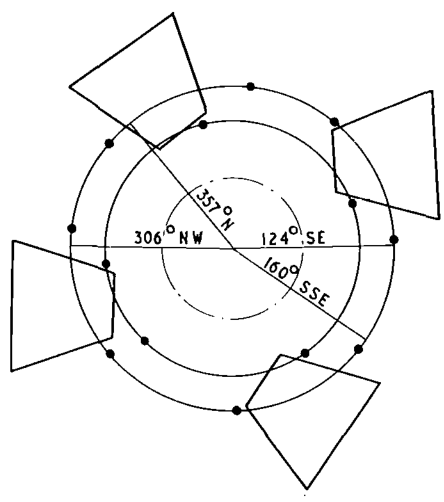
The waveguide runs are arranged on two pitch circles, and it will be noted that the large horn aerials on a route are arranged with one on gallery B4, the top gallery, and one on gallery B3, in order to obtain the necessary clearance within the restricted diameter. For the same reason, on gallery B3 it was necessary to raise the large horns relative to the small horns so that the centres of the apertures are spaced vertically by just over 16 ft in addition to a minimum horizontal spacing of 8 ft. It was thus possible to arrange the horn-aerial centres on pitch circles of maximum diameter 27 ft, and since the circular waveguides are suspended from these points, a diameter for the main body of the tower of just over 30 ft was possible. This diameter is greater than necessary from a structural-strength point of view, but readily permits the stiffness requirement imposed by the directional properties of the aerials. A separate gallery has been provided for parabolic aerials, though in certain cases these may be mounted on the horn-aerial galleries in front of the supporting columns of the large horns.



(a) Aerial Gallery B4



(b) Aerial Gallery B3



(c) Aerial Gallery B2

FIG. 2—HORN-AERIAL GALLERIES AT CHARWELTON RADIO STATION SHOWING FULL COMPLEMENT OF AERIALS

The main body of the tower, which is circular in section, tapers parabolically to a height of 60 ft, and thereafter has a straight taper of about 1 in. in 13 ft as far as the aerial galleries. The wall thickness varies from 2 ft at the base to 9 in. at the top. The aerial galleries are designed as cantilevers supported on a central core of 13 ft 6 in. outside diameter. The core is in turn fixed to the main body of the tower by six "diaphragm" walls arranged in a regular pattern. Fig. 3 shows the 380 ft

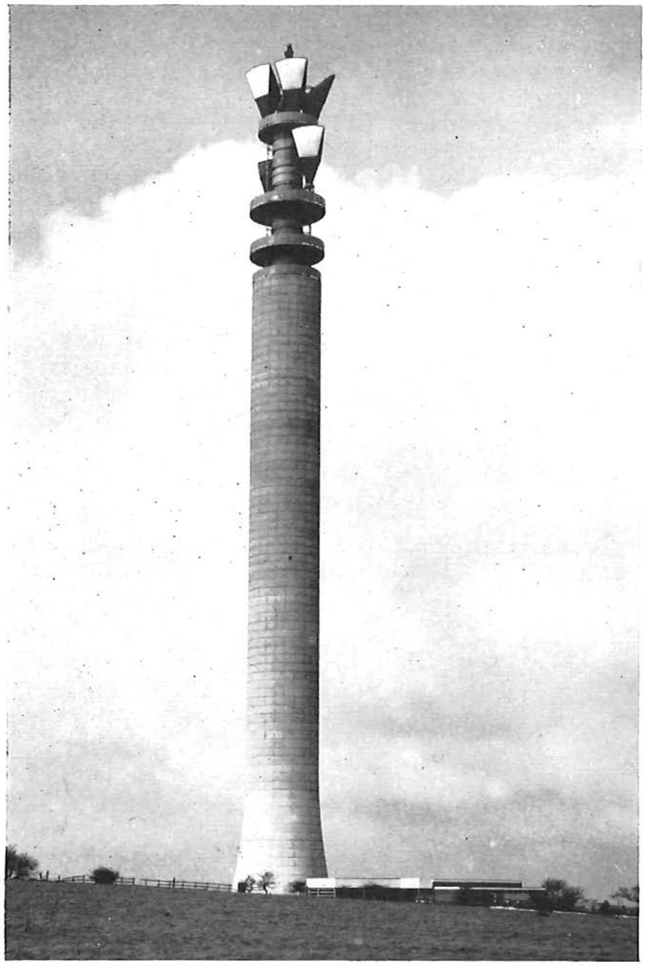


FIG. 3—CHARWELTON RADIO-STATION TOWER

tower at Charwelton, near Daventry, on the London–Birmingham radio-relay link.

Access to the top of the tower, to the point where the aerial-gallery core starts, is by steeply inclined steel stairways with rest platforms every 15 ft. Alternate rest platforms are extended to give access to all the waveguides passing down the tower, the platforms being made of open-grid galvanized-steel flooring with holes to clear the circular waveguides. Vertical steel ladders with frequent rest platforms are installed in the aerial-gallery core, giving easy access to the aerial galleries. A sectional view of the Stokenchurch tower is shown in Fig. 4.

CRANE

The crane shown in Fig. 5 is used for aerial installation and maintenance purposes, and has a safe working load of 30 cwt at a 30 ft radius. The lifting winch is electrically driven, but luffing and slewing are achieved manually. The control gear is situated on a platform inside the aerial-gallery core, and, during lifting operations, the winch operator is given instructions by telephone.

AIRCRAFT WARNING LIGHTS

Aircraft warning lights are fitted to structures only

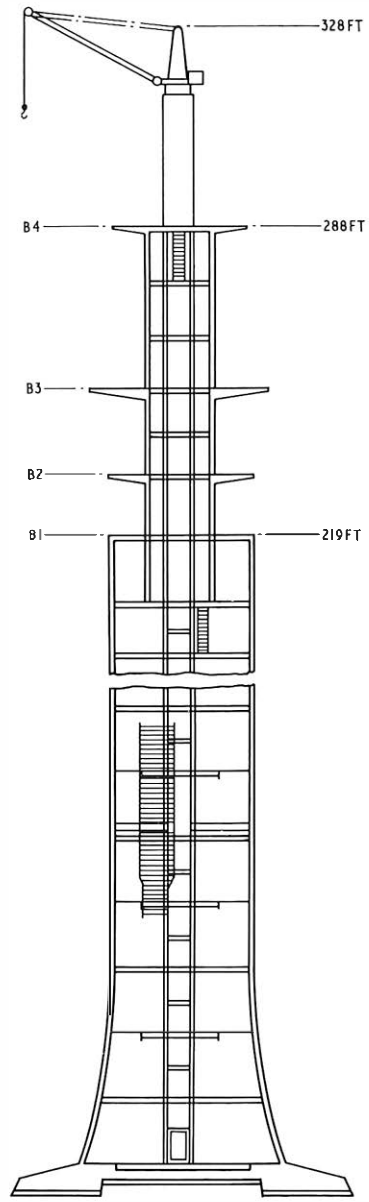


FIG. 4—SECTIONAL DIAGRAM OF STOKENCHURCH RADIO-STATION TOWER

where requested by the Ministry of Aviation, and on the standard concrete towers the Warning Light Specification has been met. For the Stokenchurch station, this entailed fitting one lamp at the top of the tower, three symmetrically arranged lamps on the top aerial gallery, and a further three lamps at 150 ft. The topmost lamp is fitted to a steel support which allows it to be lowered to about 4 ft above the top gallery for maintenance. All the other lamp fittings are also arranged so that they can be retracted to a safe working position for maintenance. Filament-type lamps of

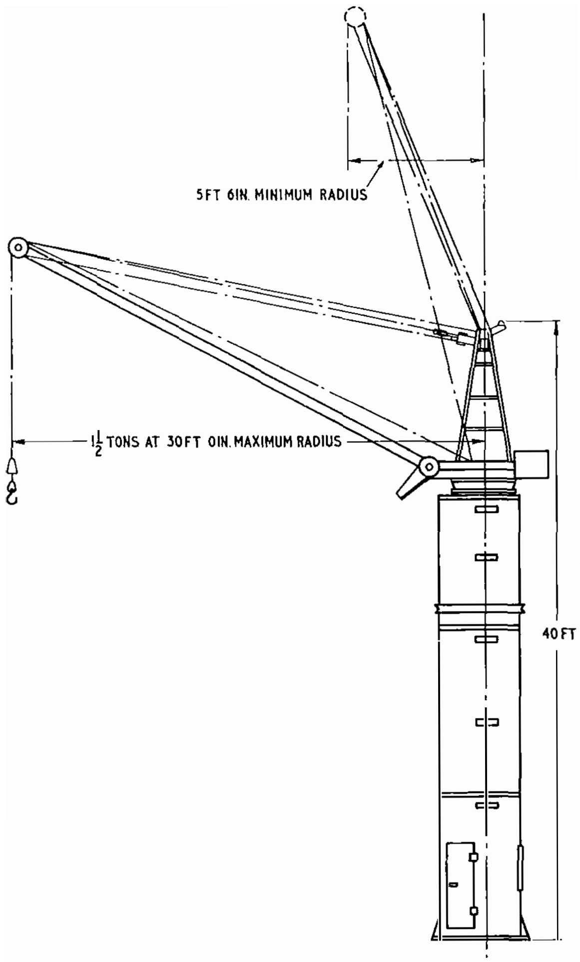


FIG. 5—CRANE USED FOR REINFORCED-CONCRETE TOWER

250-watt rating are used, but these are run at 215 volts instead of their rated voltage of 240 volts in order to extend their lives to 1,500 hours. Ministry of Aviation Regulations require the lamps to be changed regularly at intervals of 2 months unless a lamp-failure alarm is fitted. At Stokenchurch such an alarm has been fitted, and it is hoped to extend the routine lamp-changing interval to 3 months.

MAINTENANCE

One of the important advantages of concrete towers is the small amount of maintenance that the fabric of the structure requires. In addition, access to the waveguides and aerial-supporting steelwork for inspection purposes is made very easy by the access ladders and platforms within the tower. Special access gear is being developed to enable work to be performed on the front surfaces of horn and parabolic aerials *in situ*.

CONCLUSIONS

By careful design it has been possible to provide, within a tower diameter of 30 ft, waveguide runs and, aerial galleries sufficient for the most heavily loaded station yet envisaged for the radio-relay network. However, this type of concrete tower has proved to be considerably more expensive, to take longer to provide, and to require rather greater heights and longer waveguide runs than conventional steel-lattice towers.

Moreover, planning authorities, in general, have been no more willing to accept this type of tower than others, and it is, therefore, for all the foregoing reasons, unsuitable for general adoption. However, towers of this type should require little maintenance, provide ready access to aerials and equipment, and be particularly convenient for television outside-broadcast relays, and the permanent crane will ease aerial maintenance.

Book Received

"Introductory Circuit Analysis." S. Ivor Pearson and George J. Maler. John Wiley & Co., Ltd., London and New York. xv + 546 pp. 438 ill. 81s.

The two members of the Department of Electrical Engineering of the University of Colorado who wrote this book, a first course in electric-circuit analysis, describe its origins in their preface thus: "A new text in an established discipline usually comes into being because some teachers have felt strongly that a change in sequence or emphasis would improve the learning process. If such feelings lead to the creation of class notes and if such notes survive several years of class use with the resulting revisions, these notes may appear in book form. Such is the case for this text." Each chapter contains fully-worked examples to illustrate the principles discussed and ends with a large selection of problems, complete with numerical answers where required. A detailed list of symbols is given at the beginning of the book.

Chapter 1 is a short chapter whose purpose is to state rather concisely the important relationships in field theory on which circuit theory is based, while in Chapter 2 circuit elements are defined, and laws and conventions are stated. The dependence of these definitions and laws on electromagnetic field theory is shown whenever this is possible.

From a mathematical point of view, linear circuit theory requires the solution of linear differential equations with constant coefficients. There are two important methods of solution: the classical method and the Laplace transform method. Chapter 3 introduces the two methods and Chapter 4 presents general circuit reduction methods and theorems. Chapter 5 is concerned with the development of the phasor domain and some of its applications, Chapter 6 dealing with the loci of phasor network functions for a variable element and with the frequency characteristics of network functions.

Because of the large amount of nomenclature and techniques in circuit theory, the driving functions have been limited to sinusoids up to this point in the text: in Chapter 7 these are extended to general periodic functions by the use of Fourier series. Chapter 8 is devoted to 3-phase circuits under steady-state conditions, the previous introduction to Fourier series permitting the consideration of harmonic voltages and currents.

In Chapter 9 complete solutions are obtained for pulses of various types by both classical and transform methods, while Chapter 10 deals with problems of mutual inductance and with transformers. Finally, in Chapter 11 the ideas of analogues are introduced.

Birmingham Radio Tower

B. L. G. HANMAN, B.Sc.(Eng.), and N. D. SMITH†

U.D.C. 624.97:621.396.67

A new radio tower is being built in Birmingham to provide similar facilities for microwave transmission to those of the London Post Office Tower. The design of the Birmingham tower differs radically from that of its London counterpart; the planning and salient design features of the tower are briefly described.

INTRODUCTION

ECLIPSED somewhat by its more illustrious forerunner in London, a new radio tower commenced building in Birmingham at the beginning of 1964 to provide there basically the same facilities as those provided by the Post Office Tower.[1] As in London, the existing lattice-steel mast on the roof of Telephone House at Birmingham has insufficient aerial capacity to meet present-day needs of microwave radio transmission, and its usefulness is similarly threatened by the advent of tall buildings.

The new tower, which is being built through the normal agency of the Ministry of Public Building and Works (M.P.B.W.), will be approximately 500 ft high and should be ready for equipment about the end of 1965. A résumé of the planning stages and a description of the tower are given below.

Early History

In 1958 a new radio link from Birmingham to Norwich was authorized to be provided for the British Broadcasting Corporation (B.B.C.), and, in addition to the provision of some new intermediate radio stations, it became necessary to develop terminal facilities at Birmingham to cater for the new link and for future requirements. Study of the situation led to the conclusion that a new radio out-station should be acquired within a reasonable cabling distance of Telephone House, and search for a suitable site started about the middle of 1958. Possible sites at Bordesley Green, Fordrough Lane, Warley, Queslett and a few other places were all investigated but, by about the end of 1959, it became increasingly obvious that, for one reason or another, it was proving extremely difficult, if not well-nigh impossible, to acquire a suitable site to meet Post Office requirements.

Some preliminary thought and economic study had previously been given to the possibility of high radio towers both in Birmingham and Manchester. In view of the seeming impasse at Birmingham a new study was made of the position in the first half of 1960. This included the development of Turner's Hill, an existing radio station about 8 cable-miles distant from Telephone House, which was used as the final repeater station on the original London–Birmingham 900 Mc/s radio link. The practical alternatives at the time seemed to be the construction of a central high tower on a site close to Telephone House, or the use of the Turner's Hill station with cable extension of the radio circuits into Telephone House. Among various assumptions which, of necessity, had to be made was that accommodation for radio equipment would be found within the central high tower, although separate accommodation would have to be provided for stand-by engine-sets and associated power plant. The reason for housing radio equipment within the tower is that the length of the feeders between the aerials and radio equipment must be kept to a minimum in order that feeder losses shall not be excessive.

The cost comparison was based on one or two rather uncertain factors, one in particular being the actual capital cost of such a tower; the result was somewhat marginally in favour of the central tower. When costed over a longer term of years, however, the advantage of the central tower was more apparent. It was fortuitous that the site for the new Regional Director's office, on the opposite side of Newhall Street from Telephone House, included sufficient spare land for the project. This land had been held by the Post Office on lease from 1937 and had been purchased outright in 1957. A preliminary survey of the spare ground in the second half of 1960 indicated that, although the site sloped down towards Snow Hill railway station in one direction and was backed by a canal in another, it could nevertheless be used for the purpose intended. From the point of view of closeness to Telephone House the site could scarcely have been better located, except by interchanging it with the site of the Regional Director's office. This possibility was ruled out because the planning of the office building was well in hand at the time in question.

During the remainder of 1960 and the first half of 1961, preliminary planning took place. After some difficulty, technical clearance was obtained from the Ministry of Aviation, through the normal machinery of the Joint Civil and Services Telecommunications Committee, for a tower 500 ft high. At one stage the Post Office proposed an increase to 600 ft, but this was firmly resisted on the grounds that a tower of such a height would necessitate non-standard procedures for aircraft approaching Birmingham Airport from the north-west. Once this initial hurdle had been surmounted, considerable discussion ensued with M.P.B.W. regarding Post Office requirements in the tower and, most important from the architectural view point of the Ministry, concerning the precise shape and design of the tower. So far as Post Office requirements were concerned these were, broadly speaking, similar to those for the London tower both in respect of the number of aerials and amount of equipment.

PROPOSALS FOR TOWER DESIGN

The original intention regarding the actual shape of the tower had been to use a London-type structure restricted in height to 500 ft and having no public floors above the aerial galleries. At the beginning of 1962, when it became necessary to start planning in earnest, the London tower-foundation contract had been running for some 6 months and it was already evident that the cost of this tower was going to exceed the first estimates, probably by a substantial amount. It therefore seemed probable that the original cost figure assumed for the Birmingham tower would be too low also. In view of this, and the marginal cost advantage of the Birmingham tower, thought was now directed towards a cheaper structure for Birmingham.

†Exchange Equipment and Accommodation Branch, E.-in-C.'s Office.

[1]JONES, D. G., and EDWARDS, P. J. Post Office Tower, London, and the United Kingdom Network of Microwave Links. (In this issue of the *P.O.E.E.J.*)

By this time there was an agreed design of circular reinforced-concrete tower for Stokenchurch Radio Station and elsewhere,[2] a design which, moreover, had been approved by the Royal Fine Art Commission, the appropriate Government advisory body dealing with questions of public amenity. This design, usually referred to as the "Chilterns" type of tower, basically comprises a reinforced-concrete hollow cylinder, approximately 32 ft in diameter, surmounted at the top by a second reinforced-concrete hollow cylinder $13\frac{1}{2}$ ft in diameter, which carries three cantilevered aerial galleries and extends over a height of about 70 ft. By increasing the diameter a few feet, putting floors at regular intervals in the main body of the tower and by various other modifications, e.g. the introduction of lifts, the M.P.B.W. considered that a suitable tower could be designed for Birmingham at a cost of less than half that of the London tower. Such a cost, actually less than £300,000, was well below the figure which had been assumed for the latest cost studies and, hence, was economically quite favourable.

[2]MILLAR, J. B. Reinforced-Concrete Radio Towers. (In this issue of the *P.O.E.E.J.*)

To meet the requirements of the Post Office Engineering Department, the internal diameter of the tower was increased to 37 ft in order to ensure adequate space for equipment on the various floors; the design of the tower then began to take a definite form. In June 1962 the Postmaster-General approved the proposal to plan for a Chilterns-type tower which would incorporate no facilities for public admission. Later in the same year, outline plans were submitted to Birmingham Corporation and duly accepted, with no complications regarding public admission—it had always been feared that the City Authorities, with the fore-knowledge of the London example, might press hard for the inclusion of a viewing gallery for the public and perhaps other public facilities. This hurdle safely passed, the next notable step, which occurred in October, was a totally unexpected change in design of the tower proposed for aesthetic reasons by the Chief Architect of the M.P.B.W. This change was from the basic circular cross-section of the main part of the Chilterns tower, which incorporated all the apparatus floors, to a basic square section. The actual section, which is almost square with rectangular "cut-outs" in each corner, will be apparent from Fig. 1.

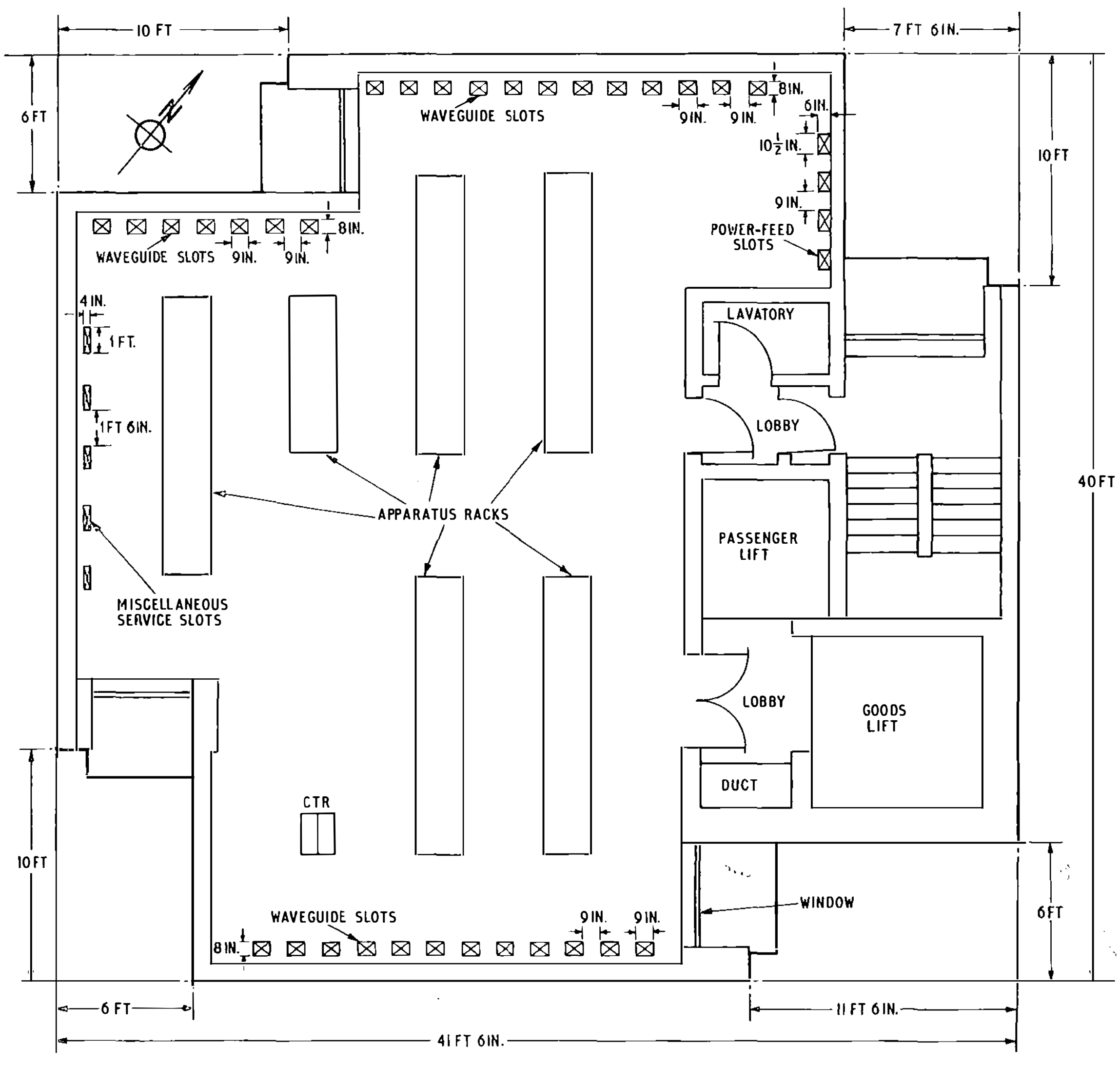


FIG. 1—TYPICAL APPARATUS-ROOM FLOOR PLAN

Above the trunk of the tower, the design remained as previously, i.e. the section carrying the aerial galleries was to be circular in form and of the same diameter as before. There were, of course, changes in structural design resulting from the change-over from square to circular cross-sections, instead of from circular to circular.

Although this alteration in design was viewed with some alarm by the Post Office, appearing as it did when planning was well under way, the new design was agreed quickly both by Birmingham Corporation and the Royal Fine Art Commission. Moreover, from the point of view of apparatus layout, the advantage lay with the new design rather than with the old. Although, inevitably, there was some delay due to the change, this was minimized by the prompt attention given to the new plans both by the M.P.B.W.'s architects and engineers and by the Post Office staff concerned.

The design, based on this new cross-section, was finally completed in time to achieve a contract start date of July 1963.

TOWER DESIGN DETAILS

Basic Features

The tower structure is built entirely of reinforced concrete, the reinforcement being particularly heavy at the corners to give the necessary strength to the rather unusual shape.

The wall thickness of the main section varies from 1 ft 6 in. at the bottom to 9 in. at the point immediately under the band-branching room (see Fig. 2). The reduction in thickness is achieved in three steps. The walls of the band-branching room are thickened up to 12 in. to give extra strength to take the stress imposed by the aerial galleries. Floors are of reinforced concrete, each being supported on two main beams, also of reinforced concrete.

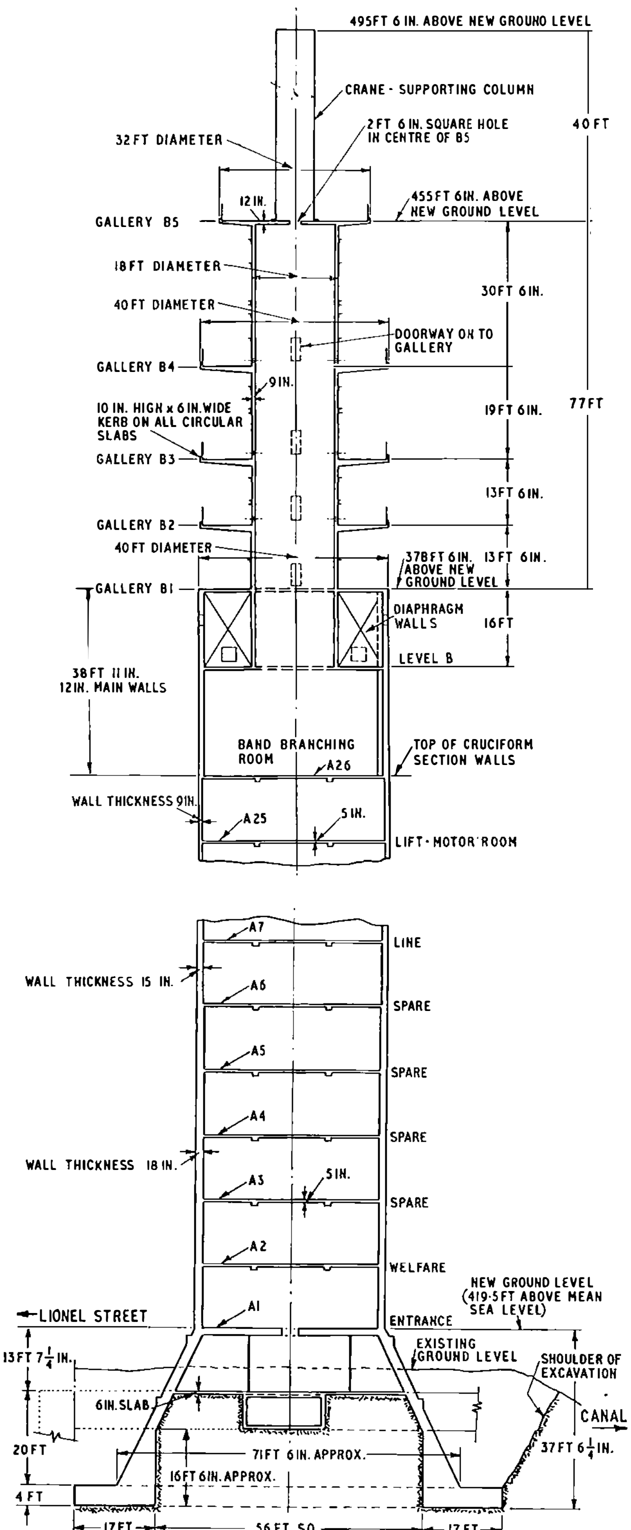
As the reinforcement is being used for the lightning-protection path, the vertical bars are welded together and, at each floor, the horizontal bars are welded to all the main vertical bars. At each floor, three connexions to the reinforcement are provided for earth connexions to equipment within the room. The reinforcement is connected to earth by means of earth spikes driven into the subsoil immediately underneath the tower.

As the subsoil at the tower location is sandstone the foundations did not need to be as complex as those for the London tower, which stands on clay. The foundations consist of a reinforced-concrete structure in the form of a truncated square pyramid with the base extended horizontally. The area within the base was not excavated, so that the floor of the basement rests on solid ground. The overall dimensions of the foundations and the levels related to Lionel Street are apparent from Fig. 2.

Aerial Galleries and Lifting Crane

As the primary purpose of the tower is to support aerials at a height which should allow the radiation paths to clear all buildings in Birmingham, it is, perhaps, appropriate to describe the tower from the top downwards.

The highest point of the tower is set by the aerial-lifting crane. This crane stands on the top aerial gallery, and its body, which is cylindrical in shape and made of steel, provides lateral support for aerials mounted on this gallery. The crane jib is normally folded against the vertical column, but, when in use, it is raised to a position where it can rotate through 360°, and it is thus



Floors A8 to A24 are spaced at 13 ft 7 in. intervals and are utilized as follows: A8—Line equipment. A9—Spare. A10—Control equipment. A11—2,000 Mc/s baseband equipment. A12—4,000 Mc/s and 6,000 Mc/s baseband equipment. A13—6,000 Mc/s baseband equipment. A14—11,000 Mc/s baseband equipment. A15—Stores. A16—Reserved for future batteries. A17—Batteries. A18—Outside-broadcast equipment. A19—2,000 Mc/s r.f. equipment. A20—2,000 Mc/s and 4,000 Mc/s r.f. equipment. A21—4,000 Mc/s and 6,000 Mc/s r.f. equipment. A22—6,000 Mc/s r.f. equipment. A23—11,000 Mc/s r.f. equipment. A24—Wave-guide-pressurizing equipment.

FIG. 2—VERTICAL CROSS-SECTION OF TOWER

capable of placing aerials on any gallery in any position. The crane is electrically operated for hoisting purposes only, the winch being placed within the concrete column towards the top of the tower; the jib is raised, lowered or slewed manually.

In order to prevent possible damage to aerials, due to swinging against the side of the tower whilst being hoisted, guide rails have been provided running up one side of the tower from ground level to the top level of the main, square, section of the tower. The load, which will normally be a horn-type or a parabolic aerial, will be attached to a cradle running in guides up the vertical rails.

The top 77 ft of the tower, excluding the crane, is made up of circular aerial-supporting galleries. There are four of these spaced as shown in Fig. 2. Whilst parabolic aerials may be located on any gallery, the larger type of horn aerial can be located only on the top two, B4 and B5, where there is sufficient spacing. The lower three galleries are 40 ft in diameter, which is the same dimension as that between two parallel sides of the main body of the tower; the top-most gallery, however, is only 32 ft in diameter.

The galleries are cantilevered from a circular concrete column, of 18 ft diameter, which provides lateral support for the aerials and which contains access ladders and facilities for supporting rectangular waveguides entering this column through apertures at each gallery level.

As the circular waveguides used with horn aerials must drop vertically from the bottom of the horn, suitable holes are provided in the aerial-supporting galleries so that these waveguides can pass without interruption into the band-branching room, which is situated under the aerial galleries.

Square Section of Tower

The square section of the tower mainly houses apparatus rooms, although at the top there are a few special-purpose rooms, e.g. the lift-motor room. The first 16 ft of the section is used to make a rigid structural connexion between the cylindrical aerial-gallery part of the tower and the main part below. The connexion is made by eight diaphragm walls or ribs of reinforced concrete, and these are placed radially with respect to the cylindrical section and are spaced in an approximately equiangular manner. Small departures from a truly symmetrical arrangement of the ribs were necessary in order to avoid some of the vertical runs of circular waveguide, which must, as stated before, pass uninterruptedly into the room below. The diaphragm walls, which are 1 ft thick, extend over the full height of 16 ft of this floor (level B of Fig. 2). They divide the space into eight small and awkwardly-shaped "cells;" personnel access to these is necessary for waveguide installation and maintenance, the access being provided through $2\frac{1}{2}$ ft square holes, some of which are located in the cylindrical wall and some in the ribs themselves.

Immediately beneath the structural space is the band-branching room, designated A26. This room is square in plan and is used to house the band-branching units where the rectangular waveguides are connected to the circular waveguides. These rectangular waveguides then connect to the equipment racks, situated on the floors below. The dimensions of this room are dictated by the need to provide adequate circulation space for waveguides to pass from the band-branching units to their appropriate waveguide slots in the floor.

In order to allow the rectangular waveguides to be run easily from floor to floor, a series of waveguide slots has been provided in the floor of the band-branching room, and these waveguide slots are repeated on every floor of the tower, so that vertical runs exist from top to bottom of the tower. From the ceiling of A18 upwards the slots may be regarded primarily as waveguide slots although they will be used also for inter-floor internal cabling. From the floor of A18 downwards the slots will be used for the external cables entering the tower, to bring them up to the floors housing transmission equipment, and also for further inter-floor cabling. The slots could not be made any larger because of the heavy reinforcement necessary in the floors. Similar slots are provided for power and miscellaneous services.

Under the band-branching room the tower plan changes again, in as much as the rectangular recesses mentioned previously appear at each corner, giving rise to the shape shown in the plan of Fig. 1. All rooms in the tower beneath the band-branching room are basically of this same shape, which is determined not only by the outside walls but also by the lift wells and staircase. This shape is, of course, not an ideal one for laying out equipment but is one which arises jointly from the architectural design of the tower and the necessity to provide access to each floor.

The room immediately under the band-branching room is used as the lift-motor room (A25) and contains the equipment for one passenger lift and one goods lift. The water-storage tanks are also situated on this floor.

Under the lift-motor room is a room (A24) which is used for miscellaneous equipment such as that for aerial pressurization. This floor will not be used for equipment racks as it is not served by the lifts, the highest floor at which these will stop being A23, the next one beneath; in effect, A24 provides over-run space for the lifts. Basically, the radio equipment occupies the top floors in order to keep the waveguides as short as possible, for the reason mentioned earlier. The first apparatus room proper appears as A23, and this room will be used for the higher-frequency equipment to take advantage of the shortest waveguide runs available. Below this all rooms are actual or potential apparatus rooms. A typical equipment layout for the apparatus floors is shown in Fig. 1, and their particular usage is shown in Fig. 2. The battery rooms shown at levels A16 and A17 have been so placed to allow the shortest possible bus-bar runs, as large cross-sections of bus bar are necessary to allow for the heavy currents to be carried.

In the lower half of the tower, one floor (A2) has been allocated to welfare purposes, and an office for an Assistant Executive Engineer is provided on floor A9.

At the foot of the tower there are two large concrete areas, one above the other and each approximately 130 ft square, inclusive of the 40 ft square of the tower itself. The upper of these levels, which corresponds to level A1 of the tower, is called the podium and will provide space for parking cars. The entrance to the tower is at this level. Below this is the basement level, and the power and engine rooms are located here close to the canal. There is access for vehicles to the basement area, for delivery of plant, by means of a ramp down from Lionel Street, but parking of vehicles will be prohibited in this area. Below the basement again there is a sub-basement, which is restricted largely to the space immediately under the power and engine rooms. The cable tunnel mentioned in the next section is at this level.

DISTRIBUTION OF POWER AND COMMUNICATION CABLES

All power distribution is effected through slots in the floor similar to the waveguide slots; these slots are situated in the north corner of the building and are provided on all floors. The only exception to this distribution is that of the low-voltage bus bars from the battery room which, because of their large size, occupy a vertical duct situated in the lift lobby.

Communication cables enter the tower through a 6 ft × 6 ft tunnel, which is connected to the street tunnel in Lionel Street and which will also eventually be extended to Telephone House via the canal side of the new Regional Director's Office. This tunnel is situated under the base of the tower, and the cables are fed through holes into the tower basement, which is used as a cable chamber. In the ceiling of this chamber, holes are provided against the walls to which the cables are led. Slots were not allowed in this ceiling because of the high stressing at this point. The cables reach the apparatus rooms by means of the floor slots already mentioned.

LIFTS AND STAIRWAY

The goods lift is designed to take apparatus racks, and the cage has a clear height of 10 ft. The passenger lift, which takes four people and is of smaller dimensions, runs at a higher speed. Lobbies are provided at each landing primarily to act as smoke traps in the event of fire.

A staircase is provided mainly for emergency use, and a smoke-trap lobby is provided at all staircase landings. Lavatories are provided on every third floor and are accessible from the staircase landing.

VENTILATION

Normal window ventilation is used throughout the tower. It is not expected that the heat dissipation from equipment will be greater than can be dealt with by this ventilation in the early stages of the equipment provision. However, to safeguard the future when the tower becomes more fully equipped, provision has been made to fit two air-conditioning units on each floor. These units consist of two parts: one fitted in a window space and the other a free-standing cabinet in the apparatus room itself. Each unit will deal with the thermal equivalent of about 15 kW.

POWER PLANT

Duplicate mains supplies are provided for the tower installation, and the power room therefore contains transformers and switch gear for the supplies. The supply for the adjacent Regional Director's Office is taken from the same sub-station.

Two engine-driven stand-by sets are also provided to guard against a total power failure. The engine exhaust and air outlets are taken through the wall of the power room over the canal, which runs alongside the building, whilst fresh air for the engines is drawn through louvres from the space under the podium slab.

AIRCRAFT-WARNING LIGHTS

In order to satisfy requirements laid down by the Ministry of Aviation, warning lights are being provided for the benefit of aircraft. The lights are required to be placed approximately every 150 ft up the tower and are consequently located at levels A12, A23 and B5. There will be four lights at each level, one at each corner of the square in the case of levels A12 and A23; for the B5 level, which is on the circular top aerial gallery, the lights will lie in the same vertical planes as opposite pairs of the lower lights. In addition, a single light will be placed on top of the crane; this will be replaced later by an occulting beacon when a suitable design has been approved by the Ministry of Aviation.

CONCLUSIONS

The building of the Birmingham tower has presented some special problems. Because of the peculiar shape and of the change of shape at the top of the tower, there have been some serious problems with the shuttering required for the concrete work. Partly because of these difficulties and partly also for other reasons, the erection of the tower has fallen somewhat behind schedule, but it is hoped that construction will be sufficiently far advanced for some equipping of apparatus floors to commence in 1965. Fig. 3 shows the stage of construction reached at the end of May 1965.

The completion of the structure will give rise to a new and striking feature of the Birmingham sky-line and at the same time will make available to the Post Office what should prove to be an extremely useful addition to the microwave radio network.

FIG. 3—TOWER UNDER CONSTRUCTION

A New Instrument for the Precise Measurement of Dielectric Loss

F. JONES, B.Sc.(Eng.), A.M.I.E.E., and G. E. MORSE†

U.D.C. 621.317.79:621.315.28:537.226.31

The precise measurement of dielectric loss is of particular importance in estimating the transmission loss of submarine telephone cables. A new resonant-circuit technique is described that permits the direct measurement of the loss angle of low-loss dielectrics with greater precision than hitherto.

INTRODUCTION

IT is well known that the dielectric loss of a cable contributes an increasing proportion of the cable transmission loss as the frequency of transmission is increased. For a dielectric in which the loss angle does not vary with frequency the contribution to the transmission loss increases linearly with frequency, whereas the remainder of the transmission loss, contributed by the conductor resistances, increases substantially in accordance with a square-root-of-frequency law.

When transmitting over long distances, notably in submerged-repeater systems, the repeater-gain characteristic must closely equalize the transmission loss of the cable. The cable loss must, therefore, be predicted as precisely as possible, and accurate measurements of the loss angle of the dielectric are very desirable. It is interesting to note that a variation in loss angle of 1×10^{-5} radians produces a variation of more than 50 db over 2,000 nautical miles of cable at 10 Mc/s.

A number of techniques[1] are already available for measuring dielectric loss: low-frequency measurements can be made with a variety of bridges; at high frequencies, i.e. exceeding 1 Mc/s, most precision is obtained by using resonant-circuit techniques, such as the Hartshorn-Ward equipment,[2] and "Q" meters. For cables the dielectric loss is more significant at the higher frequencies, and resonant-circuit techniques are of most interest. Existing resonant-circuit techniques are, however, restricted in accuracy. One factor is the inherent loss of the measuring circuit itself. With low-loss dielectrics the increase in loss obtained by adding the dielectric under test is, in many instances, less than that of the measuring circuit, with a consequent decrease of accuracy.

A new technique[3,4] has, therefore, been devised in which the inherent loss of the measuring circuit is neutralized. This technique permits the loss of the dielectric to be directly measured, with consequent improvement in the accuracy of the measurement.

PRINCIPLE OF MEASUREMENT

The new technique for measuring dielectric loss uses the well-known principle that the decay of a transient oscillation in a resonator circuit is determined by the losses in the circuit. The decay of an induced transient oscillation in a resonator, formed by the parallel combination of an inductor and a capacitor, is modified by amplifying a signal from the resonator and re-injecting it into the resonator; a loss-free condition, indicated by zero decay of the transient oscillation, can be obtained by varying the amplifier gain. When a capacitor containing the dielectric under test is replaced by a loss-free capacitor of the same value, the change in the gain of the amplifier is a direct measure of the dielectric loss in the test capacitor.

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THEORY OF MEASUREMENT

In the circuit of Fig. 1 assume that the inductance L has an associated resistance r, and that the capacitance

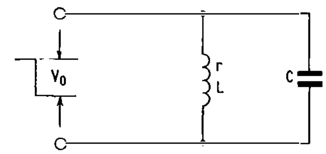


FIG. 1—ELEMENTARY RESONATOR

C is loss-free. The oscillatory function, obtained by the removal of a d.c. voltage, decays in accordance with the exponential

$$V = V_0 e^{-(r/2L)t}, \quad \ldots\ldots\ldots\ldots\ldots (1)$$

where V is the voltage across the capacitor after time t.

However, if the circuit loss is allocated to the capacitance, and results in a loss angle given by $\tan \Delta$, then the decay of amplitude may be expressed as

$$V = V_0 e^{-(\omega \tan \Delta/2)t} \ldots\ldots\ldots\ldots\ldots (2)$$

The substitution of the loss-free capacitor by one containing a lossy dielectric results in an increase of the $\tan \Delta$ term. The loss of the dielectric can thus be determined from measurements of the change of the decay.

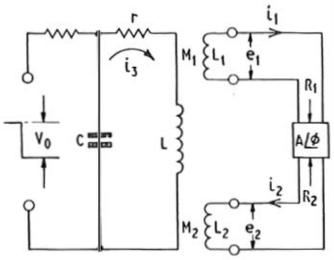
Measurement of the change of decay is considerably improved if the effect of the loss due to the coil and other sources is neutralized. The amplitude of the oscillation with a loss-free capacitor in circuit is then maintained at its initial value and forms a convenient reference condition. The decay obtained in the oscillation, when the loss-free capacitor is changed for one containing the dielectric under test, is then a direct measure of its loss. In the present equipment the losses in the resonator are again neutralized, the dielectric loss being measured by the changes required to restore neutralization of the resonator losses.

A convenient way of neutralizing resonator losses is to pick up a signal by a loosely-coupled coil, to amplify it, and to re-inject it into the resonator by means of a second loosely-coupled coil. Neutralization is obtained by adjusting the amplifier gain. A schematic diagram of the circuit used is shown in Fig. 2, and its theory of operation is given in the Appendix, where it is shown that the relationship between the loss angle of the dielectric under test and the change of amplifier gain can be expressed as

$$\tan \delta = \frac{M_1 M_2 \sin\phi}{LL_2} (A_2 - A_1) \ldots\ldots\ldots (3)$$

in the terminology shown in Fig. 2.

In this expression it is seen that the phase change through the amplifier is significant in a measurement, and that attention should be given to the phase change during a measurement. Equation A11 of the Appendix



M_1, M_2—Mutual inductances
L, L_1, L_2—Self inductances
A—Amplifier gain (voltage)
ϕ—Phase shift in amplifier
R_1—Amplifier input resistance
R_2—Amplifier output resistance

FIG. 2—OSCILLATORY CIRCUIT

gives sin ϕ as a function of (A, ω) and it can be expressed graphically, as shown in Fig. 3. In this diagram, the full line is a sine curve. Considering ordinate values given by $f(A, \omega)$, then, when the value of the function coincides with the curve for an arbitrary phase change, the transient oscillation maintains its initial amplitude. If the function exceeds this value the oscillation amplitude increases with time, and, conversely, when the function is less than this value, the oscillation amplitude decreases with time. The correct condition for measurements is therefore indicated by the curve. It is seen that values of ϕ which deviate from 90° provide increased sensitivity of measurement, but stability of the phase shift becomes more critical as sensitivity is improved by this means. If an operating phase change of 90° is used, it becomes possible to check the correct phase change by adjusting it to give maximum amplitude of oscillation at the end of the transient oscillation. Stability of the phase change is also least critical for a value of 90°, and it has, therefore, been adopted in spite of the loss in sensitivity.

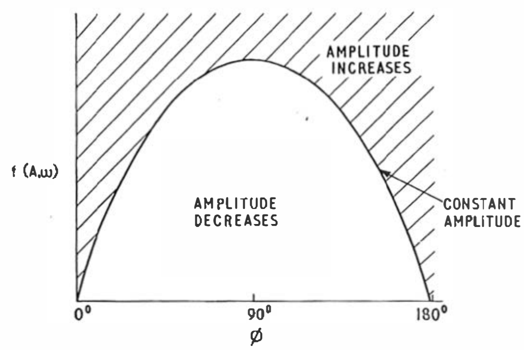


FIG. 3—OSCILLATION DIAGRAM

Examination of equation 3 also shows that optimum sensitivity of measurement is obtained when the coefficients of mutual inductance are small, and the values of the resonator inductance and the second coupling inductance are high. The sensitivity of measurement is also influenced by the duration of the transient oscillation and improves with longer duration times.

CONSTRUCTION OF THE EQUIPMENT

A block schematic diagram of the equipment is shown in Fig. 4. The basic resonator circuit is constructed in a form which permits the coil to be switched between a standard air capacitor and the test capacitor by means of a reed relay. When one capacitor is switched to the coil a transient oscillation is induced by the signals from a pulse generator. Successive pulses produce transient oscillations in the air capacitor and test capacitor, respectively. The decays of these transient oscillations are controlled by the loop formed by the phase-shift network, amplifier 1, and the attenuator. The switching pulse of the resonator-circuit relay A is derived from the pulse generator via a time-delay network and a stage which halves the repetition rate. The time-delay network ensures that the relay contacts operate between the pulses of oscillation. To display the transient oscillations, a signal is tapped off at the output of amplifier 1 and fed to the Y-plates of an oscilloscope via amplifier 2. The time-base of the oscilloscope is triggered by a pulse derived from the pulse generator via another time-delay network, a stage which halves the repetition rate, and a differentiating circuit. The display presented on the oscilloscope is thus two trains of oscillations, one associated with the standard air-capacitor and the other associated with the test capacitor. The decays of the oscillation trains are controlled by the attenuator in the feedback loop. A representative trace obtained with the equipment is shown in Fig. 5.

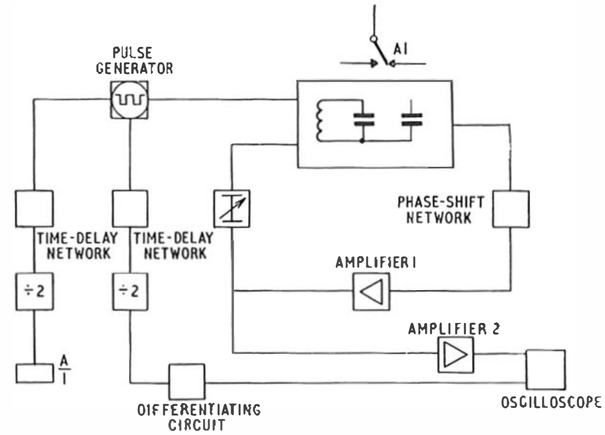
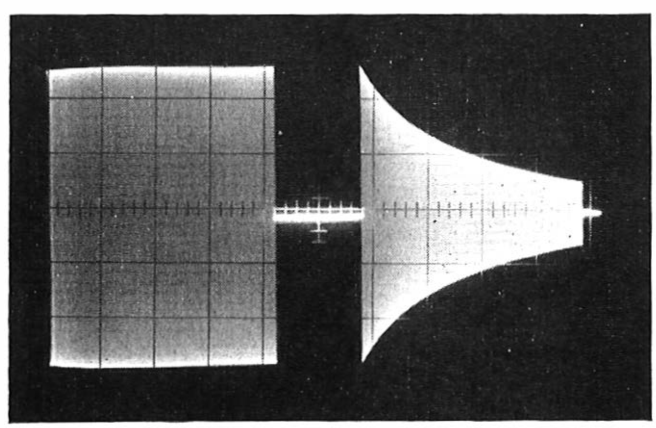


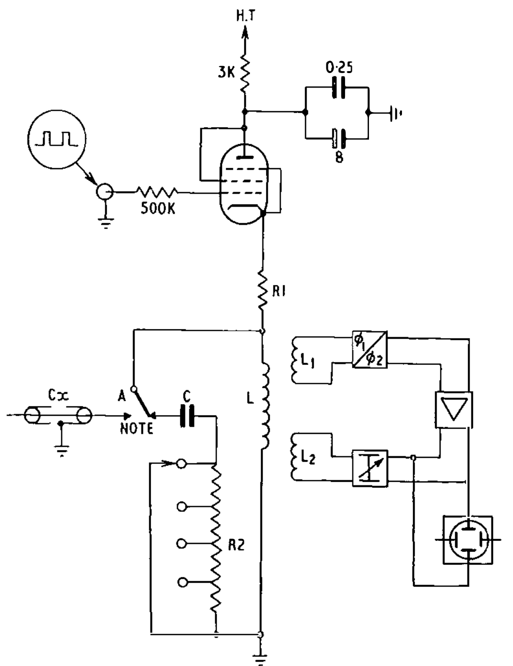
FIG. 4—BLOCK SCHEMATIC DIAGRAM OF TEST EQUIPMENT

The basic transient-generator circuit is shown in Fig. 6. The resonator is composed of inductor L, and its



Tan $\delta \simeq 10^{-4}$ radians

FIG. 5—TYPICAL TRANSIENT DISPLAY



Note: Relay A is a mercury-wetted-contact reed relay
FIG. 6—BASIC CIRCUIT OF TRANSIENT GENERATOR

associated internal resistance, which is connected to either a standard air capacitor, C, or to a test capacitor, C_x, via relay contacts A. Incorporated in the circuit is a series resistor, R2, which can be switched in for the purposes of calibration.

The resonator forms the cathode circuit of a switching valve. When a suitable train of pulses is fed to the grid of the switching valve from the pulse generator, the valve becomes alternately conducting and non-conducting. During the conducting phase, a d.c. voltage is present across the resonator, but oscillations are suppressed by the low shunt impedance of the valve. During the non-conducting phase, the d.c. voltage across the resonator disappears and a high shunt impedance is simultaneously presented by the valve. A transient oscillation results during the non-conducting phase of the valve. A signal induced in the loosely-coupled coil L is amplified in the loop circuit, and is re-injected into the resonator from the second loosely-coupled coil L2.

The coil combinations L, L1 and L2 are plugged in position. For operation at any particular frequency, a coil combination is constructed for the frequency. The capacitor C has been selected to be 50 to 55 pF in this equipment, the small variation being obtained by means of a trimmer capacitor.

When the frequency is changed, the amplitude of oscillation is influenced due to the change of coil. The resistor R1 has, therefore, been inserted between the coil and the switching valve to control the amplitude. This resistor is associated with the coil and is changed with a coil change.

The construction of the capacitors associated with the resonator is shown in Fig. 7. The form shown was adopted to permit measurements on samples of coaxial submarine cable. Other forms of capacitor, e.g. for measurements of liquid dielectrics or thin sheets of insulation, can be devised. A cylindrical block of polystyrene supports the centre conductor of the standard air capacitor and also the connexion to the cable centre-conductor. The block of polystyrene is clamped between two brass end-plates. One of the end-plates is joined to the outer, coaxial, conductor of the standard air capacitor. The outer conductor of the cable is connected to a brass terminal-plate, which is in turn bolted to the second end-plate. By arranging that the connexions to the cable are symmetrical about the centre line with the supports of the air capacitor, then, on switching from one capacitor to the other, the cable sample is effectively being compared with a length of coaxial air-capacitor. Switching of either capacitor to the coil is accomplished by a small reed relay with mercury-wetted contacts. To ensure equality of the losses of the capacitor supports and connexions, the brass end-plates are recessed to provide minimum surface leakage, and care is taken to ensure substantially equal resistances from the resonator coil to the capacitors. As a further precaution, the electrodes and the trimmer capacitor of the standard are finished by a gold flash. The capacitor head and the associated coil are seen mounted on the complete equipment in Fig. 8.

The output coupling coil from the resonator feeds directly into the phase-shift network shown in Fig. 9. A phase-splitting valve, V1, feeds into two cathode followers, V2, to provide a balanced voltage from a low-impedance source. The input valve V1 provides a high-impedance input and minimizes the load reflected into the resonator circuit. A variable resistor-capacitor combination provides the required phase shift; coarse variation is obtained by adjustment of the resistor, final adjustment being made on the capacitor. The signal is

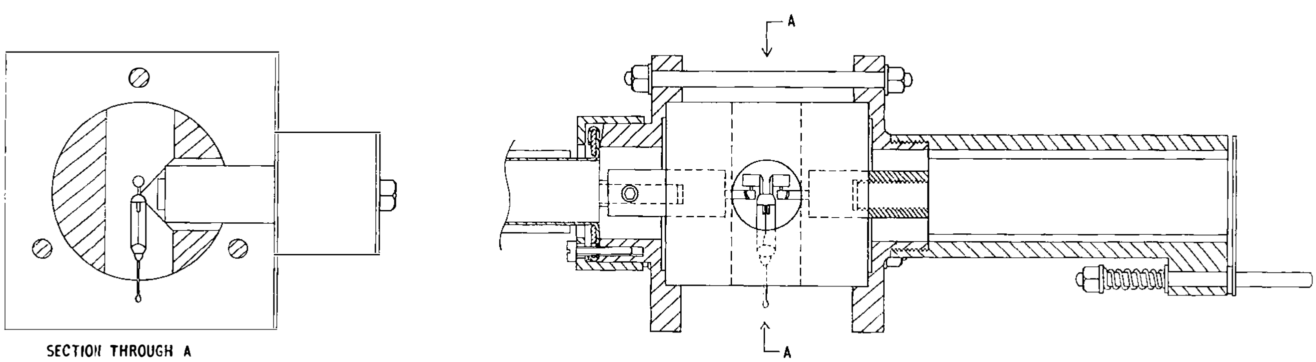


FIG. 7—CONSTRUCTION OF CAPACITOR HEAD

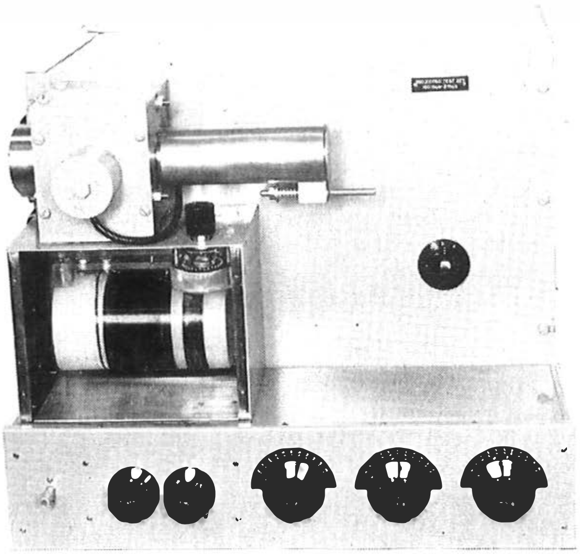


FIG. 8—COMPLETE TEST SET

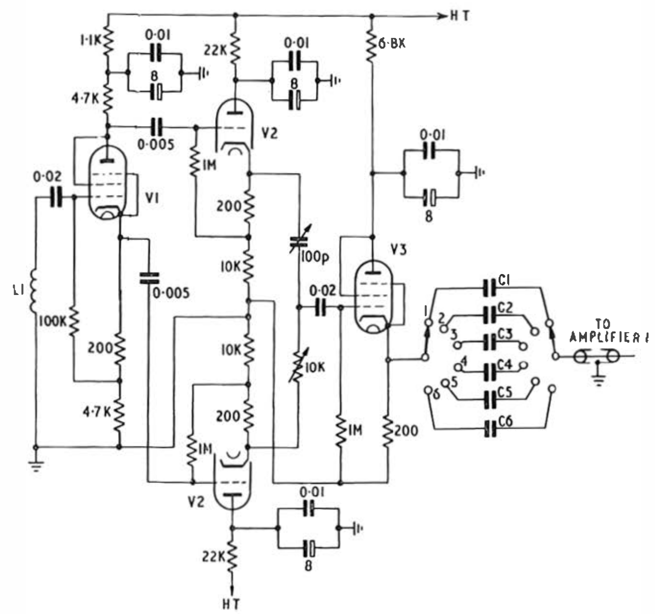


FIG. 9—PHASE-SHIFT NETWORK

fed into the amplifier via the cathode-follower valve V3. Switchable capacitors on the output of this stage enables the phase-shift capacitor to be adjusted to a convenient portion of its travel.

The amplifier in the feedback loop needs to be highly stable, and an existing amplifier, the Amplifier No. 95A, was found to be suitable as regards stability and bandwidth.

The amplifier feeds into the attenuator network shown in Fig. 10. Two stages of attentuation are provided. The potential divider before the input valve V1 gives coarse and fine gain control for a preliminary setting of the loop gain, and is normally used to neutralize the losses with the air capacitor in circuit. The output from valve V1 is connected to a 6 db 100-ohm pad, and variations in steps of 10^{-2}, 10^{-3} and 10^{-4} db are provided

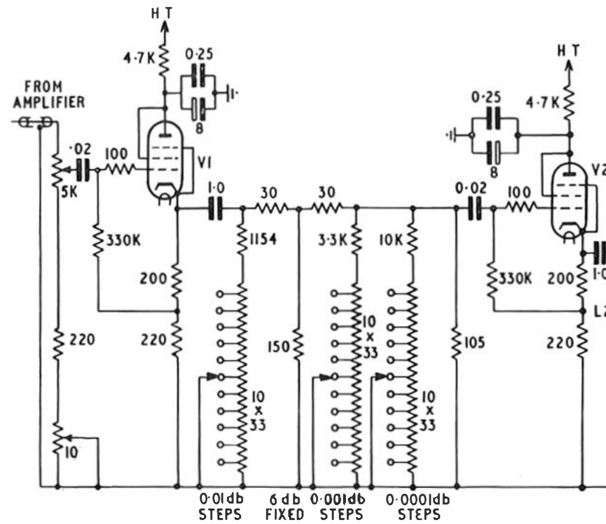


FIG. 10—ATTENUATOR NETWORK

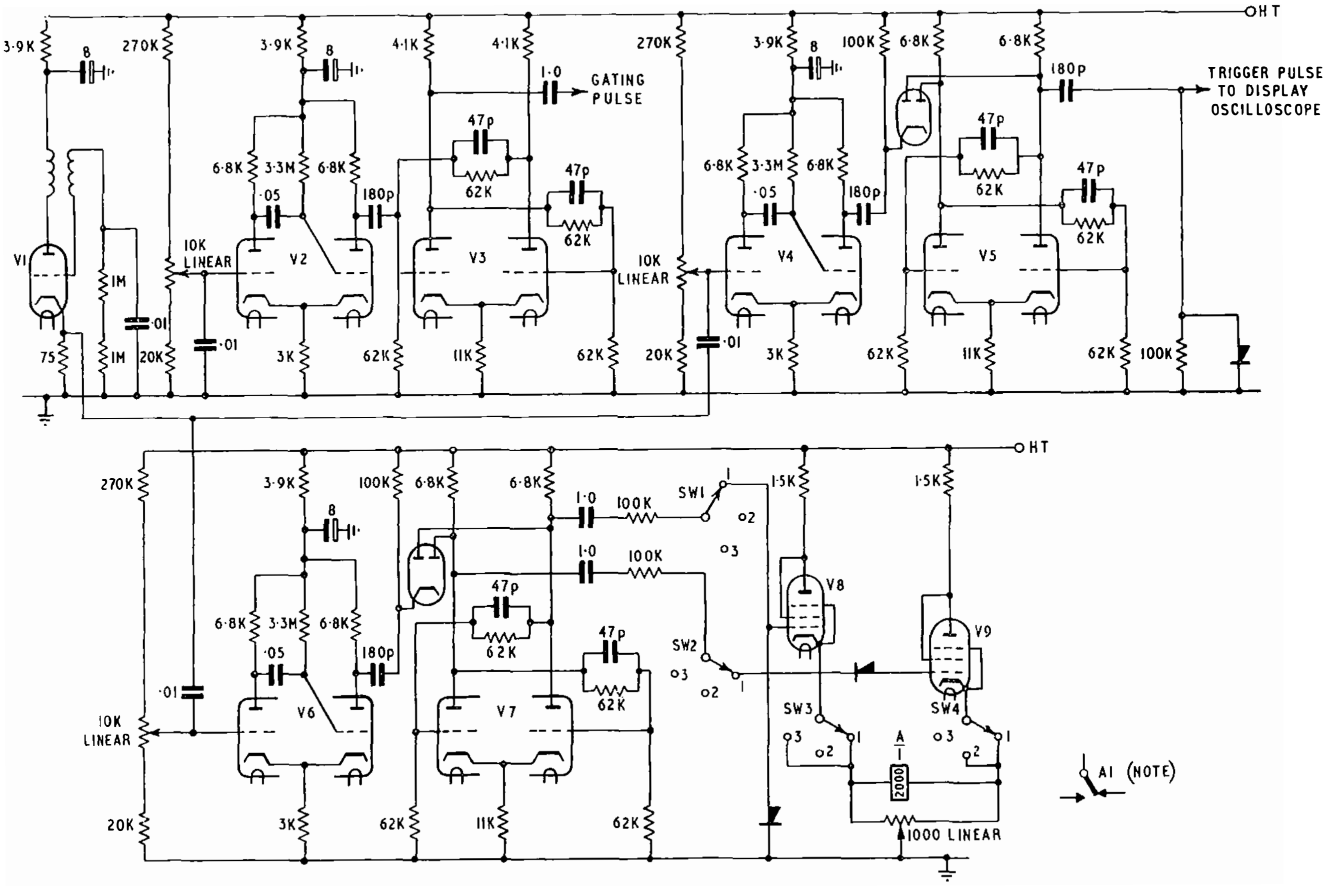
by resistor networks shunting the input and output impedances. It is readily demonstrated that the provision of parallel networks of resistors is permissible provided that the changes are small enough to give substantially linear relationship between the db change and the change in voltage ratio. This attenuator is normally used to measure the difference in loop gain required to neutralize the amplitude decay with the standard air capacitor and the capacitor to be tested in circuit, respectively. The output signal from the attenuator is fed into the second coil coupled to the resonator, via a cathode-follower valve, V2, to complete the loop.

The switching circuits are shown in Fig. 11. Three sets of switching circuits are fed in parallel from the blocking-oscillator valve V1, which generates pulses at a rate of 50 pulses/second. The valves V2 and V3 generate the switching pulses to the transient generator. Valve V2 is preset to give a mark-to-space ratio of 3 : 1 so that the duration of the transient oscillations is 15 ms, and an interval of 5 ms is available for relay operation. The valves V6 and V7 drive the relay. The stage V6 provides delay in the trigger pulses applied to the multivibrator V7. The latter is adjusted to run at 25 pulses/second and feeds the relay winding via the output stages V8 and V9. The relay contacts are made to operate in the space period of the transient pulses by adjusting the amount of delay provided by stage V6. Stages V4 and V5 are similar in operation to stages V6 and V7 but, after differentiation of the output pulse, they generate the trigger pulse for the oscilloscope display.

In addition to automatic switching of the transient display, the relay winding may be switched by means of switches SW1–4 (Fig. 11) to manual operation of the switching sequence. Both the transient oscillations displayed then relate to the capacitor to which the relay is switched.

OPERATION OF THE EQUIPMENT

Measurement on a cable sample is readily made. The sample of cable is prepared so that, when connected to the equipment, it has a capacitance of about 40 pF. The frequency of oscillation with the standard air



Note: Contact A1 connects the resonator circuit of the transient generator either to the standard capacitor or to the test capacitor, as shown in Fig. 6

FIG. 11—SWITCHING CIRCUITS

capacitor in circuit is adjusted to equal that with the test sample in circuit by variation of the trimmer on the standard air capacitor. This operation is accomplished by comparing the transient oscillations with a separately-generated continuous oscillation in a Lissajous figure on an oscilloscope, the equipment being switched to manual operation.

With automatic switching, the sections of loop attenuator are adjusted, in turn, to produce zero decay of both transient oscillations displayed. The difference between the attenuator settings required is a measure of the dielectric loss of the cable sample. During this operation, a check is made that the phase shift, through the amplifier and phase-shift network, is 90° by slight variation of the phase controls to ensure that the amplitude of oscillation at the end of the transient is a maximum.

To convert changes of loop gain to loss angle, a calibration is performed using the series resistors shown in Fig. 6. Known values of resistance are inserted in steps, each step having a value of 0·1 ohm, and the changes in loop gain to restore zero decrement are noted. From these observations a curve of loss angle ($\omega R_2 C$) is plotted against change of loop gain. A calibration curve taken on the present equipment is shown in Fig. 12. It is to be noted that the loss angle read from the calibration curve relates to a combination of the test sample and the capacitance of its connexions to the relay contact.

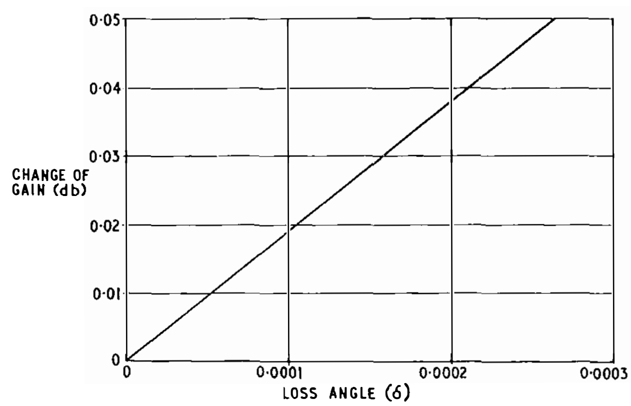


FIG. 12—CALIBRATION CURVE

A correction is necessary to arrive at the loss angle of the test sample, as shown in equation A18 of the Appendix.

To change the frequency of a measurement, the coil and its coupled windings is unplugged and a set of coils for the frequency required is plugged into circuit. The present equipment is designed to test at frequencies up to 3 Mc/s.

ACCURACY OF MEASUREMENT

A number of factors which influence the accuracy of a measurement have been mentioned. Attention has been given to these and several other points to ensure the maximum degree of accuracy.

In the capacitor head of the equipment, in addition to providing symmetry to the supports of the air-capacitor conductor and leads to the test sample, so that losses due to the supports cancel, attention has been given to minimizing the unavoidable leakage across the ends of the test sample. The connexion to the cable centre-conductor is allowed to project slightly from the large-diameter connector, and it thus provides the maximum leakage path in the sample dielectric. Check measurements have been made in relative humidities of up to 80 per cent. A measurement is not affected by relative humidities of up to 60 per cent, but drying of a sample is necessary for higher humidities. The unbalance of series resistances in the connexions to the capacitors has also been investigated. An unbalance of the order of one milliohm in the series resistances will produce an error of 10^{-6} radians at 3 Mc/s or about 1 per cent with recent polymers of polythene. The contact resistances of the mercuty-wetted reed relay are about 10 milliohms, and differences are of the order of one milliohm; these values are tolerable. The conductor resistance of a submarine-cable sample, e.g. of Lightweight cable, can assume values which are not tolerable, and correction is normally made for this contribution to the dielectric loss angle of a sample.

The gain stability in the amplifier loop is another source of inaccuracy in a measurement. The Amplifier 95A is highly stable for normal requirements, but its long-term gain stability is only of the order of 0·01 db. Its short-term gain stability is much improved, and periods of minutes are obtained when the stability is better than 0·0001 db. The stability requirements are catered for by stabilized power supplies and by the use of automatic switching to reduce the period of a measurement to a minimum.

During a measurement the phase-shift network control is adjusted, and care has been taken to ensure that the attenuation characteristic of this control does not vary unduly over the normal range of adjustment required for a measurement.

A further potential source of error is in the process of calibration, owing to the variation with frequency of the series resistors used. Copper-wire resistors are used for this operation, and, to ensure minimum increase from skin effect, the wire size selected is 52 s.w.g. Only low values of resistance are required, making the resistors physically small, so that shunt-capacitance effects are negligible. The stray inductance of the resistors operates to change the frequency of the transient, but a check measurement has shown that this effect is also negligible.

The equipment in its present form has a reading accuracy of about 2 per cent when measuring loss angles of 10^{-4} radians, but the absolute accuracy is probably not better than 5 per cent, although the latter requires further investigation.

OTHER APPLICATIONS

The sensitivity of the equipment described shows a marked improvement over other methods of dielectric-loss measurements, and it is thought probable that similar improvement in sensitivity would be obtained with other aspects of measurements employing tuned circuits or resonators. Measurements involving losses in resonant coaxial lines would show improved sensitivity, as would those in resonant cavities at still higher frequencies.

CONCLUSIONS

An equipment has been developed which provides an improved sensitivity of measurement over existing resonant-circuit techniques. The principle used is that the losses in a resonator are neutralized by a feedback-loop circuit. A transient oscillation is used as a convenient method of indicating exact neutralization.

References

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[2]HARTSHORN, L. Radio Frequency Measurements (*Chapman and Hall*), p. 196.

[3]JONES, F. Provisional Patent Specification No. 19336, 1962.

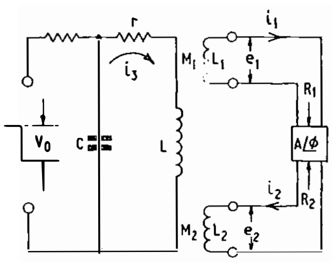
[4]JONES, F. A New and Precise Method of Measuring Dielectric Loss. *Electronic Engineering*, Vol. 35, p. 733, Nov. 1963.

APPENDIX

MEASUREMENT OF DIELECTRIC LOSS BY DECAY OF TRANSIENT OSCILLATION

The Conditions in the Feedback Loop for Sustained Oscillations in a Resonator

Referring to the circuit outlined in Fig. 13, the oscillations in the resonator formed by inductor L and capacitor C can be sustained when the power contribution to the circuit equals or is greater than the losses in the circuit, after the voltage V_0 has been removed.



M_1, M_2—Mutual inductances
L, L_1, L_2—Self inductances
A—Amplifier gain (voltage)
ϕ—Phase shift in amplifier
R_1—Aplifier input resistance
R_2—Amplifier output resistance

FIG. 13—OSCILLATORY CIRCUIT

The power losses in the circuit are: $|i_3|^2 r$, $|i_1|^2 R_1$ and $|i_2|^2 R_2$. The power contributions to the circuit are given by $|e_2| . |i_2| \cos\theta$ and $|i_2|^2 R_2$, where θ is the phase angle between e_2 and i_2.

The condition for sustained oscillations is, therefore:

$$|e_2| . |i_2| . \cos\theta \geqslant |i_3|^2 r + |i_1|^2 R_1 \quad \text{A1}$$

To assist in evaluating equation A1 the relationships between currents and voltages can be written down by inspection of Fig. 13:

$$e_2 = AR_1 i_1 e^{j\phi} - R_2 i_2 \quad \text{A2}$$

$$(R_1 + j\omega L_1) = -j\omega M_1 i_3 \quad \text{A3}$$

$$\text{and } e_2 = j\omega L_2 i_2 + j\omega M_2 i_3 \quad \text{A4}$$

From equations A2–A4,

$$i_1 = \frac{M_1(R_2 + j\omega L_2)}{M_1 A R_1 e^{j\phi} + M_2(R_1 + j\omega L_1)} . i_2 \quad \text{A5}$$

$$\text{and } i_3 = \frac{-(R_2 + j\omega L_2)}{AR_1\left(\frac{j\omega M_1}{R_1 + j\omega L_1}\right)e^{j\phi} + j\omega M_2} . i_2 \quad \text{A6}$$

If it is assumed that $R_1 \gg \omega L_1$ and $R_2 \ll L_2$ then equations A5 and A6 become:

$$i_1 = \frac{j\omega M_1 L_2}{R_1[AM_1 e^{j\phi} + M_2]} . i_2 \quad \text{A7}$$

$$i_3 = \frac{-L_2}{AM_1 e^{j\phi} + M_2} . i_2 \quad \text{A8}$$

From A4 and A8

$$e_2 = \frac{\omega L_2}{P} \cdot e^{j(\psi + \pi/2)} \cdot i_2 \ldots\ldots\ldots\ldots \text{A9}$$

$$\text{where } P = \sqrt{\left(1 + \frac{M_2 \cos\phi}{AM_1}\right)^2 + \left(\frac{M_2 \sin\phi}{AM_1}\right)^2}$$

$$\text{and } \psi = tan^{-1}\left[\frac{M_2 \sin\phi}{AM_1} \Big/ \left(\frac{1 + M_2 \cos\phi}{AM_2}\right)\right].$$

The conditions for sustained oscillation can now be written as:

$$\frac{\omega L_2}{P} \cdot \sin\psi \geqslant \left(\frac{L_2}{M_2 Q}\right)^2 r + \left(\frac{\omega M_1 L_2}{R_1 M_2 Q}\right)^2 \cdot R_1, \ldots\ldots \text{A10}$$

$$\text{where } Q = \sqrt{\left(1 + \frac{AM_1 \cos\phi}{M_2}\right)^2 + \left(\frac{AM_1\, sin\,\phi}{M_2}\right)^2}.$$

Substituting for $\sin\theta$ in A10 and rearranging,

$$\sin\phi \geqslant \frac{L_2}{\omega AM_1 M_2}\left[r + \frac{\omega^2 M_1^2}{R_1}\right] \ldots\ldots \text{A11}$$

The equation A11 gives the conditions to be satisfied if the oscillation in the resonator is to be sustained, when the voltage V_0 is removed.

The Relationship between Dielectric Loss and Amplifier Gain

To perform a measurement, the resonator is first adjusted to oscillation with a substantially loss-free capacitor. At a given phase shift ϕ_1 assume the amplifier gain is A_1 for equality of equation A11, with a coil resistance of r_1. After substituting the capacitor for one of equal value, but containing a dielectric of loss angle expressed by $\tan\delta$, assume the amplifier gain is A_2 and that the equivalent series resistance in the resonator circuit is r_2. Further, assume that $\omega^2 M_1^2/R_1 \ll r$.

$$\text{Then } r_1 L_2 = \omega M_1 M_2 A_1 \sin\phi_1 \ldots\ldots \text{A12}$$

$$\text{and } r_2 L_2 = \omega M_1 M_2 A_2 \sin\phi_1 \ldots\ldots \text{A13}$$

$$\text{or } (r_2 - r_1) = \frac{\omega M_1 M_2 \sin\phi_1}{L_2}[A_2 - A_1] \ldots\ldots \text{A14}$$

$$\text{But } \tan\delta = (r_2 - r_1)/\omega L$$

$$\text{or } \tan\delta = \frac{M_1 M_2 \sin\phi_1}{LL_2}[A_2 - A_1] \ldots\ldots \text{A15}$$

Correction for Residual Capacitance in Circuit

In a practical measurement, the capacitance C across the inductance L in Fig. 1 is not completely replaced by one containing a test dielectric. Let the residual capacitance be C_0 and the value of the test capacitor be C_x with a loss angle of $\tan\delta$. Let the measured loss angle of the composite capacitor be $\tan\Delta$. If the conductance of the test capacitor is G_x then:

$$\tan\delta = G_x/\omega C_x \ldots\ldots \text{A16}$$

$$\text{and } \tan\Delta = G_x/\omega(C_o + C_x) \ldots\ldots \text{A17}$$

$$\text{or } \tan\delta = \tan\Delta \cdot \left(\frac{C_o + C_x}{C_x}\right) \ldots\ldots \text{A18}$$

Using the technique of a known series resistor for calibrating the equipment, the series resistor should be assumed to be associated with the total capacitance $(C_o + C_x)$. If the resistor is assumed to be associated with the sample capacitance C_x only, then the correction term in equation A18 is squared.

Book Reviews

"Cours de Téléphonie Automatique. Système R6, Tome 2." (Automatic Telephony Course. Volume II. R6 System). M. Lacout and M. Jarcquet. Eyrolles. 265 pp. 98 ill. 48F.

The R6 system was introduced into France in 1928 and consisted originally of 11-outlet preselectors and three stages of decimal selection performed by uniselectors positioned in accordance with the outlets marked by digit-receiving uniselectors. Within five years, larger uniselectors (50/100 outlet and 25 outlet) were introduced and the direct control of the selection stages was replaced by a register system. Numerous other modifications culminated in the standard No. 1 system being brought into service in 1949 and containing, eventually, local, S.T.D. and incoming register-translators. Further simplification produced the standard No. 2 system which has registers suitable for both local and S.T.D. calls and uses all-relay common translators.

A textbook was originally issued for the French Post Office, and described the principles of the initial exchanges. This was subjected to many re-editions as the development proceeded. Eventually it was decided that further modification was inadvisable and the present authors were commissoned to write a completely new book, as part of an automatic telephony course. The resultant work is in two sections—one containing the text and simple explanatory diagrams, the other containing circuit-element diagrams together with copies of the official circuit diagrams of the various units of the R6 system. The text gives outlines of the apparatus used in the standard systems, the build-up of the various types of exchanges, inter-exchange signalling and details of the major circuit operations. There is almost no practical information such as descriptions of mechanisms, exchange layouts, or trunking and grading schemes, so presumably these will be covered in another volume of the series.

The presentation throughout is extremely clear and well-arranged so that the reader is not repelled by solid masses of circuit description, but is led stage by stage to a firm understanding. These volumes are confidently recommended to anyone who wishes to know the principles of the R6 system or merely desires to see how some of the basic problems of telephone switching can be solved.

H.B.

"High-Intensity Ultrasonics—Industrial Applications." Basil Brown, B.Sc., Ph.D., A.Inst.P., and John E. Goodman. Iliffe Books, Ltd. 235 pp. 108 ill. 55s.

This book is a comprehensive survey of the applications of high-intensity ultrasonics to industrial processes. The earlier part of the book deals with the theory and properties of ultrasonic waves and the latter part with the various uses to which they have been put. The graduate reader will find the book clear and concise, well indexed and with plenty of references so that any particular field of interest can be read up.

The first chapter deals with the propagation and absorption of ultrasonic waves in liquids, solids and gases. Then there is a chapter on cavitation, the phenomena of the formation of bubbles or cavities in liquids. These bubbles collapse to produce the intense shock waves which account for many of the useful properties of ultrasonics. Following chapters deal with the production of ultrasonics by mechanical devices (whistles and sirens) and electrical means (magnetostrictive and piezoelectric transducers).

Ultrasonic cleaning is the first process described. Much useful information is given and many examples are quoted. However, as the book says, cleaning efficiency is much influenced by the solvent used and its method of application. This opens up a much wider field not dealt with.

The use of ultrasonic homogenization to form emulsions for processes in the food, cosmetics and chemical industries makes fascinating reading.

Metallurgical effects described include ultrasonic soldering and machining; also ultrasonic welding, fatigue testing and metal refining.

The final chapter deals with the chemical and biological effects of ultrasonics in influencing chemical and biological processes.

If one may criticize an otherwise excellent book, it seems a pity that the automatic ultrasonic cleaning plant illustrated in Plate 5.1 is described on page 119 as not successful.

D.C.S.

Detection of Errors in Data Transmission on 50-Baud Telegraph Circuits

D. W. E. WHEELE, A.M.I.E.E., and R. T. G. SALLIS†

U.D.C. 621.394.69:621.394.18

Investigations have been made into the effectiveness of various simple methods of error control on standard telegraph connexions. The investigations culminated in the development of a fully-electronic device, which can be used with standard telegraph equipment and be rented by customers who wish to use normal telegraph installations for transmitting low-speed data. Tests have shown that if a regenerative repeater is used in association with the preferred arrangement the detection of errors will be extremely high.

INTRODUCTION

STANDARD telegraph circuits and station equipment offer a ready means of transmitting data at 50 bits/second. Data information is often stored in the form of punched tape, and, if this is of the 5-track type, it can be transmitted directly by existing Post Office automatic transmitters, an equivalent punched tape being produced at the receiver. There is, therefore, very little difficulty in using existing terminal equipment for slow-speed transmission of data. It may be necessary to modify the standard equipment so that the characters equivalent to BELL and WHO ARE YOU, which are normally not printed or punched, are punched into the received tape.

Point-to-point telegraph circuits and switched networks are based on a transmission plan the objective of which is to ensure that a start-stop distortion of 30 per cent is not exceeded by more than one transition in 10,000 under the most onerous routing conditions.[1] This value of distortion is such that a very low character error-rate, of the order of 1 in 10^6, would be achieved if distortion were the only adverse factor involved. Since just less than 7 characters/second are transmitted, this is equivalent to one error in approximately 1·7 days of continuous transmission. In practice, however, line interruptions produce an error-rate which has been shown, by testing over a number of years on various circuit configurations, to have an average value of 1 in 40,000 characters, or one error in about 100 minutes of continuous transmission. However, a greater accuracy than this is generally demanded for the transmission of data. If errors cannot be avoided in the complete transmitting system it is important to ensure that each error is detected so that the appropriate action to eliminate it can be performed.

The inherent error-rate referred to does not embarrass the majority of telegraph users because the error can generally be detected when reading the printed copy, but practically all low-speed data signals are transmitted and received in the form of perforated tape, often using an alphabet different from the International Alphabet No. 2 normally used for telegraphs; even if a printed copy were also received on a standard teleprinter, visual detection of an error would in most cases be impossible as reference to this printed text is generally not of much use.

†Mr. R. T. G. Sallis is in the Telegraph Branch, E.-in-C.'s Office, and Mr. D. W. E. Wheele, who was also in that Branch, is now with the Ministry of Transport.

Interruptions and Errors

It must be noted that with the average error-rate of 1 in 40,000 characters on inland telegraph circuits the errors occur irregularly—typically, a group of a dozen or more separate character errors, with less than 1-minute intervals between errors in the group, will be followed by several hours of error-free transmission. The errors are produced by line interruptions either in the d.c. section of the circuit or, more usually, in the audio, carrier or coaxial sections of the bearer circuit of a voice-frequency (v.f.) telegraph system. These interruptions, which can cause distortion to, or complete loss of, the signal, are usually caused by intermittent faults and other factors which are very difficult, and consequently very expensive, to eliminate entirely. It is not economic to attempt any improvement beyond a certain standard and, therefore, this residual interruption rate is not unexpected.

ERROR CONTROL

When the application of some form of error control is being considered the cost of the control arrangements has to be balanced against the operational facility required. It is possible to use full error-correction apparatus with which errors are first detected and then automatically corrected so that a "clean" copy is presented at the receiving end. This is an expensive arrangement and is justified, for example, where the volume of data is great and the signalling rate and error expectancy are high, or in circumstances where human intervention to correct the error is prohibited. For data transmission over 50-baud telegraph circuits automatic error-correction may not normally be justified on economic grounds, and a simpler system of error detection without automatic correction is usually adequate. With such a system, when an error has been detected an alarm is given at the sending end and transmission is stopped; the operator at the sending end then retransmits that part of the message which contained the error. The message at the receiving end thus contains error copy as well as good copy.

Undetected Errors

No matter how powerful the adopted error-control methods may be, there will always be a residuum of errors which, for one reason or another, is not detected. These are known as undetected errors and it is the tolerable extent of these which will decide the complexity of the method used in any application. An undetected error-rate of 1 in 10^6 is generally tolerable for low rates of modulation. An error-detection system does not absorb the errors as does a correction system: it merely indicates their presence, and special separate steps have to be taken to remove them from received information.

Requirements for an Error-Detection System

Because the error-rate on telegraph circuits is low, and on average would require a retransmission about once in 2 hours, the first method to be developed was centred on error-detection systems without automatic correction; the following facilities were to be provided.

(*a*) It should be suitable for use over switched telegraph networks.

(*b*) Existing terminal equipments, such as the automatic tape-transmitter and the reperforating teleprinter would be used.

(*c*) The system should provide an undetected character error-rate of not worse than 1 in 10^6.

(*d*) The additional equipment would be associated with the terminal-station apparatus and, if possible, mounted on the same table.

METHODS OF ERROR CONTROL

Error detection and correction systems have already been developed for use on long-distance radio links.[2] These systems are capable of dealing with a very high basic error-rate and provide an output signal in which all detected errors have been corrected. The cost and complexity of this equipment is such that, although economic in its present application, it could not be considered suitable for use on individual customer's circuits on an inland telegraph network. Simpler solutions have therefore been investigated.

The methods of error detection can be broadly divided into two groups:

(*i*) simplex or single-path methods whereby it is necessary to add parity or checking elements to the code, and

(*ii*) duplex, loop or return-path methods (frequently referred to as information-feedback methods) in which the signal is returned from the receiving-end back to the sending-end where it is compared with the signal originally transmitted.

PARITY METHODS

There is no redundancy in the standard 5-unit telegraph code: thus, each of the 32 possible combinations has a characteristic significance, and any corruption of one combination turns it into another acceptable combination. It is possible to devise a limited form of error detection using a 5-unit code for application to the 10 numeric characters of an alphabet, by arranging that corruptions in the element combination used for one numeral are extremely unlikely to produce the combination for another numeral. This method can be adopted whenever it is important to indicate that an incorrect numeral has been received.

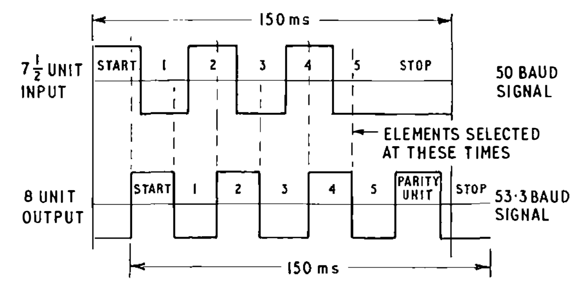
For more general purposes it is necessary to introduce some redundancy into the code and this is done by adding parity or checking elements to each character combination. The polarity of these additional elements is arranged to give each combination some common characteristic. For example, the sum of the positive or negative elements of a combination can be made an even or odd number, and at the receiving end the existence of the chosen characteristic can be checked and suitable decisions taken. The introduction of these parity elements therefore allows the detection of errors caused by any element inversions which destroy the chosen characteristic.

One disadvantage of any scheme which adds parity elements to an existing code is that the information rate is reduced by the same proportion as that of the added elements to the original-code elements; to off-set this it is usual to increase the modulation rate. This can be inappropriate if the telegraph circuit comprises standard v.f. telegraph channels which are designed for optimum operation at 50 bauds. However, their performance is not materially adversely affected at modulation rates of up to 60 bauds.

Single Parity Check

A simple method of providing redundancy in a 7½-unit telegraph character is to convert it to an 8-unit character.[3] In order to maintain the normal working speed of 400 operations/minute it is necessary to increase the modulation rate slightly.

Such a method was achieved by the addition of a simple binary circuit to a start-stop regenerative repeater,[4] adjusted so that, although the incoming signal is still at 50 bauds, the elements are examined at the higher speed of 53·3 bauds. This provides an 8-unit output in the same character period as that of the applied 50-baud input, i.e. 150 ms; the first six elements of the 8-unit output have the same code formation as the applied signal and the eighth element is used as a stop signal. The seventh element is used for the parity unit, its polarity being such as to maintain an overall odd or even characteristic for either the start or stop polarity, when assessed over all the character elements except the final stop element (see Fig. 1). At the receiving



In this example the parity unit has been chosen to ensure an even start-to-stop ratio, i.e. 4:4

FIG. 1—SIGNAL CONVERSION FROM 7½ TO 8 UNITS

end the inverse action takes place, the 8-unit 53·3-baud signals being retimed and converted to 7½-unit 50-baud signals. The redundant element is extracted, and if the appropriate odd or even characteristic is not maintained an alarm is operated to indicate an error.

The performance of this system has been investigated and the results show that about 1 error in 10 remains undetected. This would provide an undetected character error-rate of about 2 in 10^6 with the average basic error-expectancy of 1 in 40,000. If an additional circuit which will reject, as an error, any element shorter than 10 ms or longer than 130 ms is added to the device, a final undetected character error-rate of 1 in 10^6 can be achieved. Under unlikely extreme conditions, however, when late distortion of 25 per cent is immediately followed by an early distortion of 25 per cent this additional circuit will introduce a false error indication.

The system has several other disadvantages. The 8-unit 53·3-baud signal transmitted to line is non-standard and cannot be monitored by either a normal teleprinter or telegraph-distortion measuring set. Also, the input margin of the transmit and receive units are, respectively, 37½ and 33⅓ per cent because the signal is retimed at a speed differing from that of the incoming signal, and there is no storage device which would offset this disadvantage. This is not significant at the transmit terminal because the input will be fed direct from a transmitting machine with comparatively low output distortion (less than 10 per cent). The restriction at the receiver is more important, although the value of 33⅓ per cent is very little worse than the minimum receiver 35 per cent margin which the telex network has been designed to tolerate. Some improvement could be obtained if the converted output were made 7½ units at 52 bauds instead of 50 bauds; such an output can be regarded as a distorted 50-baud signal and should present no disadvantage as it is fed direct into the local 50-baud teleprinter which has more than sufficient margin to accept it.

Single-Parity Check Using a Start-Edge

An alternative means of introducing a redundant characteristic into a 7½-unit telegraph signal is to design the terminal equipment to commence a character cycle on the receipt of either (*a*) a start-to-stop transition or (*b*) a stop-to-start transition, instead of only on receipt of the latter. This would allow the usual stop element to be used as a parity element in the position previously described. However, for about half the code combinations the parity element would require to be of start polarity, and this would normally cause the receiving device to commence to re-cycle before the character cycle of 150 ms was completed. This can be avoided by arranging the receiving device to be sensitive to a start pulse only after the parity element has been received. The advantage of such a system is that it involves no loss of margin, but there are several disadvantages as indicated below.

(*a*) There is more chance of a loss of synchronism because a quiescent receiver would start on fortuitous stop-start transitions, this resulting in some increase in error indication when no error had occurred.

(*b*) The line signal cannot be interpreted using normal equipment.

(*c*) On the cessation of signals from the transmitting machine a steady-start condition will frequently be transmitted to line, and if this occurs on a telex connexion the call will be released. The release could be prevented by a delay circuit at the transmitting end which could restore the line to stop condition within a few milliseconds after the end of a signal sequence. The receiving unit could be designed to ignore this extra signal, which would normally be accepted as the start of a new character.

Combined System using Two Parity Elements

The two previous systems can be combined to provide two parity elements and this would allow improved error detection. The signal would be converted from 7½-unit to 8-unit and then a start-edge characteristic added. This combination would retain all the disadvantages of the individual systems with no additional advantage other than improvement in detection efficiency. No practical tests have been made and no further development was proceeded with on parity-check methods.

LOOP OR RETURN-PATH METHODS

Although the systems using parity methods have been described as single-path, a return circuit is usually required to transmit an error-indication signal back to the sending end. The systems now to be described, however, detect the error at the sending end. To do this the telegraph signal must be looped back on a return path, and this requires a return channel to carry the telegraph signals back to the sending terminal for checking. The signal is transmitted on the "go" channel to operate the receiving terminal, and at that point is transmitted back via the "return" channel to the transmitting terminal (see Fig. 2). The loop need not

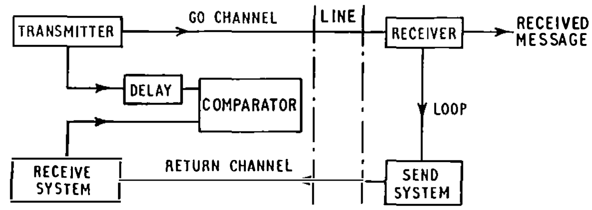


FIG. 2—BASIC REQUIREMENTS FOR LOOP ERROR DETECTION

be electrical but can be in the form of tape transmission; however, the method of looping has an important bearing on the efficiency of detection, as described later.

At the transmitting terminal, the two signals—one direct from the transmitter, the other from the loop return path—are compared. If they do not agree an error is indicated. Comparison can be either fully-electronic or electromechanical, but both methods require some type of adjustable signal-storage system to accommodate time differences between the incidence of the sent and received signals which occur on all types of telegraph circuits.

LOOP ERROR DETECTION USING A TAPE COMPARATOR

A simple method that can readily be used is to modify existing station terminal apparatus to permit duplex operation and retransmit the received signals back to the sending end by feeding the received punched tape through the automatic transmitter at the receiving station. The receiver at the transmitting station punches a tape from the returned signal, and this tape, together with the originating tape, are then fed into a mechanical tape comparator (see Fig. 3). The comparator consists of two tape-reading heads mechanically linked in

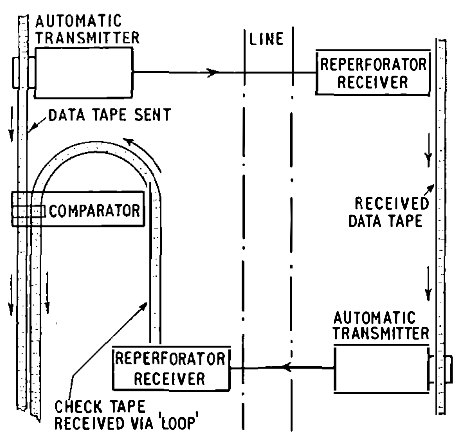


FIG. 3—LOOP ERROR CHECK USING TAPE COMPARISON

synchronism, with the outputs of the two heads being compared element by element. An error is indicated when the outputs differ, and this can bring in either a visual or audible alarm, or both, as well as suspend transmission. Several comparators of this type have been built and have performed satisfactorily.

This technique has been tested using the Post Office stores-requisitioning procedure over telex circuits, with Leeds and Bradford as the sending terminals and Studd Street Supplies Depot (London) as the receiving terminal. Although the detection of errors was satisfactory the correction procedure proved cumbersome. This was not such a drawback as it might appear, because the correction procedure was necessary, on average, only once every 2 hours on a connexion involving one v.f. telegraph circuit.

Although this method ensures that punching errors due to mechanical failure of the receiving-station reperforating machine are also detected, the operational procedure to set up the system at the commencement of each transmission or after an error has been detected is, however, complex. It is simplified at the receiving station if the telegraph signals are returned via an electrical loop, which is essential when electronic comparison devices are used at the transmitting station.

LOOP ERROR DETECTION USING MAGNETIC STORAGE

The tape comparator system suffers from the following two disadvantages.

(*i*) Lengths of tape long enough to feed from the reperforator into the automatic transmitter at the receiving end, and from the reperforator into the comparator at the sending end, have to be received before comparison can commence. Any error is therefore not detected until the transmission of a large number of subsequent characters has been completed.

(*ii*) The transmitting operator has to exercise great care when lining-up the two tapes in the comparator heads.

These difficulties can be eliminated if the signals are compared in their electrical state. It is still necessary to provide some form of storage but this need only be sufficient to accommodate the loop delay of the transmission path. Referring to Fig. 2, if the transmission time on each channel is d ms the storage unit must delay the transmitted signals by $2d$ ms before comparison takes place.

Transmission Times

A telegraph circuit may consist of tandem-connected cable pairs (a physical link) or a circuit in a multi-circuit voice-frequency telegraph system (v.f. channels), or a combination of both. For all practical purposes the transmission time of a 50-baud signal over an average physical link can be considered negligible (less than 1 ms)—hence, for a simple looped physical circuit, additional delay before signal comparison is unnecessary. However, if the loop is completed by means of a polarized relay a delay of about 2 ms will be introduced. Similarly, additional relays, as will exist on a "relayed" physical circuit, will add an extra 2 ms per relay. Since, in practice, the circuit loop may be regenerated (as discussed later) another 10 ms of delay will be introduced. Thus, it is possible for physical circuits to have loop delays between zero and 10–20 ms.

A v.f. channel introduces a maximum delay of 40 ms: since five v.f. circuits in tandem can be encountered on a telegraph switched network, a looped circuit can contain 10 channels in tandem with a possible total delay of 400 ms. To this must be added the transmission time of the telephone bearer circuits which can be taken as 7 ms/100 miles for audio circuits, and 1 ms/100 miles for circuits derived from high-frequency line plant. A 1,000-mile looped v.f. telegraph circuit, routed entirely on audio bearer circuits and with 10 v.f. channels in tandem, could have a loop delay of from 400 ms + 140 ms = 540 ms. A maximum delay of 550 ms has, therefore, been assumed for apparatus design as the rare occasions when this is exceeded do not justify the cost of the additional storage.

Summarizing: the delay ranges to be designed for are approximately 0–20 ms for physical links, and 60–540 ms for v.f. circuits of from one to five links. The storage is arranged to accommodate the data transmitted over the the complete range from 0–550 ms.

The Magnetic Store

Two possible methods of magnetic storage are (*a*) tape and (*b*) drum. From experimental work it soon became evident that distortionless storage on magnetic tape was not practicable unless a precision tape-transport mechanism was available to accurately control the tape speed.

The possibilities of using a magnetic drum were examined, but the available drum-storage systems were not suitable because the precision engineering required to ensure adequately-stable separation between head and drum surfaces made these systems very expensive. However, a cheaper device using in-contact heads and based on those used in a new design of magnetically recorded speaking clock[5] was built.

The equipment consisted of a solid-brass drum, 5 in. in diameter and 1 in. wide, driven synchronously via reduction gearing by a 50 c/s mains-driven motor. A neoprene band about $\frac{7}{8}$ in. wide and $\frac{1}{8}$ in. thick, impregnated with a magnetic oxide, is fitted around the drum circumference. The two heads, one for recording and one for replaying, are in contact with the band surface and are flexibly mounted to accommodate any drum eccentricity: the radial position of one head is fixed but the other is manually adjustable. Erasing is effected by a permanent magnet mounted just clear of the drum surface. Low-impedance heads were used for the initial tests but were replaced by standard high-impedance tape-recorder heads which provided improved output and matching.

Complete Storage Unit

The $\pm$ 80-volt telegraph signals could have been directly applied to the recording head, but, in order to ensure that the recording level is the same for all applications, a limiting and recording amplifier using transistors is employed. For recording purposes one of the signal polarities is inverted; the drum recording therefore consists of a train of unidirectional pulses, one pulse at each characteristic instant of the signal. The advantage of this arrangement is that only one magnetic state on the drum has to be considered: if both polarities are recorded there is also a significant magnetic state equivalent to a zero state, and it is not easy to establish this condition owing to the inevitable random noise associated with magnetic recording. The adopted method enables satisfactory operation to be obtained simply, even in the face of a low signal-to-noise ratio.

The replay head is coupled into the replay amplifier with linear early stages. As soon as the signal has sufficient amplitude it is heavily limited to produce a train of noise-free unidirectional pulses with fast rise times.

The adjustment of the delay between recording and replay so that it is equal to the transmission time round the looped circuit is effected by the manual control, which moves the replay head round the drum while a preliminary calibration signal is being sent from the transmitter.

Comparator

The signal received from line must be compared with the output from the storage unit element by element and this is achieved by processing the received signal so that it has the same form as that produced by the storage circuit, i.e. a train of single-polarity pulses. This is done by another amplifier-limiting circuit.

The comparator works on the principle that each change-over sent to line, as represented by a unidirectional pulse out of the storage unit, must be matched by a pulse received via the looped circuit; unmatched signals indicate an error. Since the returned signals may well be badly distorted, the comparator input must possess sufficient margin to accept such signals. Any return pulse is regarded as being correct if it is received within 18 ms of the corresponding send pulse, i.e. a maximum of ± 45 per cent distortion. Fig. 4 gives an indication

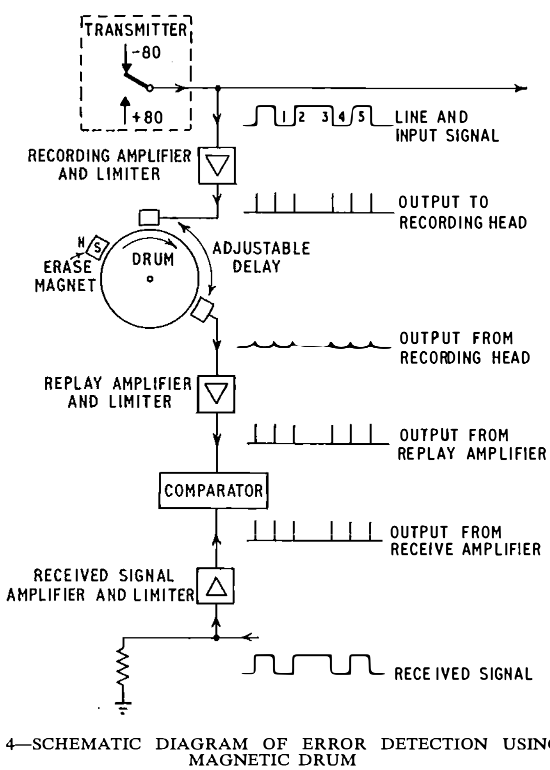


FIG. 4—SCHEMATIC DIAGRAM OF ERROR DETECTION USING A MAGNETIC DRUM

of the complete system. Fig. 5 shows the relative timing positions of the two trains of pulses. For explanatory purposes it is assumed that the transmitted signal is a square wave, as represented by A. This appears as a series of negative pulses, as shown at B. By a suitable manipulation of the delay control, using a calibration signal developed from the transmitter, the mean time of the incidence of the pulses derived from the perfect received signal, C, and producing the pulse train shown at D, is arranged to occur 10 ms later than the equivalent transmitted signal. The timing circuits of the comparator are so arranged that any received pulse appearing in the period x, i.e. between 1 ms and 19 ms after every change-over in the A signal, will be accepted as correct. A heavily-distorted received signal and the consequent pulse train are shown at E and F. The second transition falls outside the equivalent x period and an error would be signalled, as would the absence of the final transition. The margin of the comparator is 45 per cent but, by a suitable adjustment, this could be made to be any value up to 50 per cent. The significance of this margin is discussed later. A field trial of this device demonstrated its effectiveness, but it was found that the manual control of the delay feature was too meticulous an operation to be generally acceptable and further development embodied automatic adjustment.

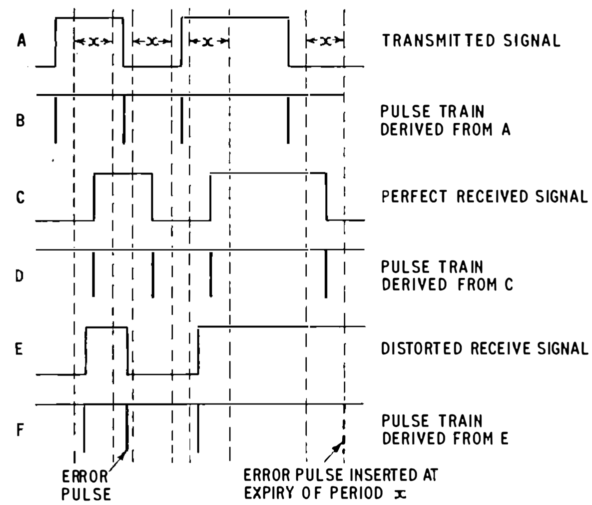


FIG. 5—WAVEFORMS OF COMPARATOR USED WITH MAGNETIC DRUM STORE

MAGNETIC DRUM WITH AUTOMATIC DELAY ADJUSTMENT

The design of an automatic drive to position the head on the drum required a different mechanical system because of the comparatively large mechanical power required to move an in-contact head against the friction between it and the drum surface. An out-of-contact head enables a simple low-power drive system to be used. The drum in this latest development consists of a brass disk 5 in. diameter and $\frac{1}{4}$ in. thick driven by a mains synchronous motor. The magnetic surface consists of a 0·0003 in. thick coating of an 80 per cent cobalt and 20 per cent nickel alloy. The heads are out-of-contact but adjustment is not critical as the working gap can be of the order of several thousands of an inch. Calibration is achieved by starting to send immediately after the loop at the distant end has been established, until a lamp indicates that the calibration is complete. Briefly, the electronic comparator indicates that calibration is not correct by producing error pulses which cause the head motor to drive until the delay adjustment is correct. To keep the calibration time to a minimum and also avoid mis-calibration due to a fortuitous correct matching of the two telegraph signals, a complex circuit has been necessary. Calibration time is kept short by assessing whether the replayed drum signal or the signal appearing from the receive line appears first and always driving the head in the correct direction. A fast drive takes the head to within a short distance of the correct position and then an intermediate, and finally a fine, drive completes the adjustment. The fine drive is retained as a correcting adjustment to the head position throughout the ensuing transmission, thus allowing the system to adjust for small variations of drum speed and loop delay.

LOOP ERROR DETECTION USING ELECTRONIC STORAGE

The development of the magnetic-drum equipment with automatic delay compensation enabled a device to be associated with the standard station apparatus used with a switched network, and it was, therefore, suitable for installation in a renter's premises.

However, development was continued with the aim of providing a fully electronic device which would give the same facilities and at the same time be free from the need to carry out a preliminary calibration. With this equipment comparison is made character by character so that the application is limited to operation with the standard telegraph 7½-unit 50-baud code.

This fully electronic error detector consists of an electronic store followed by a comparator unit. As the comparison takes place character by character the storage circuits must also store an integral number of characters. A store of four characters is sufficient to cover the maximum delay expected on the inland telegraph network.

Operation

A block schematic diagram of the essential units is shown in Fig. 6. Assume the system is idle, the stores

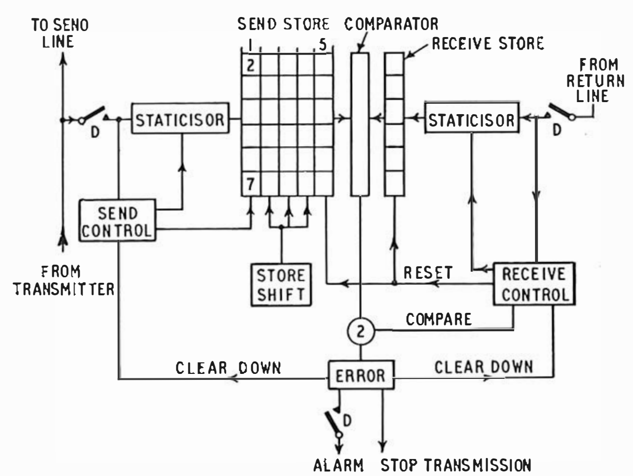


FIG. 6—SCHEMATIC DIAGRAM OF 50-BAUD ERROR DETECTOR WITH ELECTRONIC STORAGE

are cleared and no signals have been sent or received. The start of the first character transmitted to line is fed into the send side of the equipment and initiates the send-timing-control circuit which examines the signal elements. The resulting information is fed into column 1 of the send store after conversion from a serial to a parallel mode by a staticisor, and, in effect, a regenerated signal appears at this point. During the stop-element period fast drive pulses, of the order of 5 kc/s, shift the information in parallel form through the send store to column 5 where it awaits the return of the same character from the receive line. If the second character is transmitted before the first has appeared at the return-path receive input, i.e. the first character is still travelling around the looped transmission circuit, the sequence of events described is repeated, the second character being transferred to send store column 4. Similarly, transmitted characters three and four will fill columns 3 and 2. If the return signal still has not arrived, i.e. if the delay in receiving the return signal were to exceed the time of four characters, the fifth character transmitted would overload the store and bring in an error alarm.

In normal circumstances the return signal will appear within the maximum delay period of four characters. The start signal of the first character received on the return path operates the receive control circuit and this effectively regenerates the signal, each element being fed into the receive store of the comparator. During the stop-signal period a parallel comparison between this first received character and the first character in the send store occurs. If these are identical, column 5 of the send store and the receive store are emptied and any characters in columns 4, 3 and 2 are transferred into columns 5, 4 and 3, respectively, this transfer also taking place during the stop signal of the character which has just been assessed.

Character 2 is now ready for comparison and when character 2 appears on the receive line, the comparison sequence is repeated—if again correct all characters in the send store move along one step as before. The send store, therefore, maintains a running store of one, two, three or four characters as determined by the line delay. If the comparator detects any element difference an error alarm occurs, the transmitter is switched off and all stores are cleared. A photograph of this equipment, known as Unit, Telegraph, No. 37A, is shown in Fig. 7.

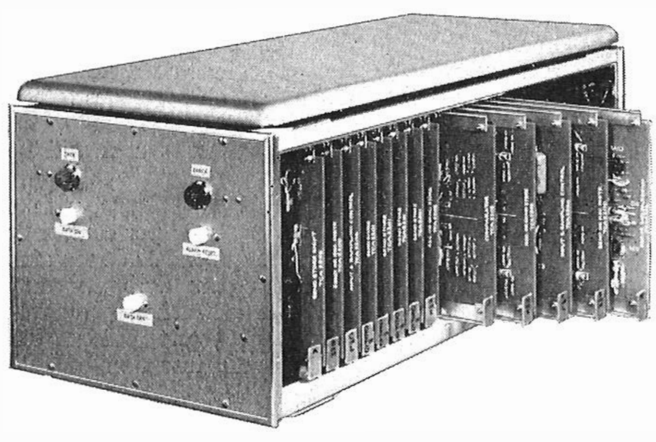


FIG. 7—ERROR-DETECTION UNIT SHOWING INTERNAL CONSTRUCTION

THE EFFECTIVENESS OF ERROR DETECTION

Telegraph circuits provided by the British Post Office have a normal error expectancy low enough not to cause undue operational difficulties, and the provision of even the most rudimentary form of error detection results in finding at least nine out of 10 of the errors. This was the experience of using the single-parity-element technique, and the effectiveness could be doubled by the addition of simple circuits to detect specific anomalies in the signal. The undetected error-rate could be reduced to 1 in 10^6 characters.

For the simple information-feedback methods the undetected error-rate can be of the same order, but unless the feedback loop is carefully designed there is a possibility of difficulty due to the correction of an error on the return path.

Two other factors may also cause unnecessary retransmission: (*i*) defects which affect only the return path can cause a signal that has been received correctly to be assessed as an error, and (*ii*) where a connexion is used which comprises a number of telegraph circuits in tandem, as with a switched network, the aggregate distortion of the signal received back at the sending end may be so high as to cause a signal to be assessed as faulty even though it was correctly transcribed at the receiving end. On one particular switched connexion formed of three v.f. telegraph circuits in tandem, i.e. with six channels round the loop, stoppages occurred every 5 minutes although the actual average error-rate was one each 100 minutes.

The equipment at the receiving station will possess a certain margin, normally not less than $\pm$ 35 per cent. Interruptions will result in occasional elements being distorted beyond the receiver margin, and a printed or punched error will be received. To give the best chance of this error being detected, the comparator must have a margin of less than $\pm$ 35 per cent, say $\pm$ 30 per cent, to allow some factor of safety.

The many false indications of error that occur with a simple loop can be eliminated if the signal is regenerated immediately before the looping point at the receiving terminal. The regenerator ensures that the distortion of all signals retransmitted to line is of the same low order as that of the signals originally transmitted. The probability of error correction on the return path is now so low that it can be considered negligible. The receiving equipment (regenerator) has a wide margin, nearly of 50 per cent, and the comparator margin can, consequently, be correspondingly wide. Hence, negligible stoppages will occur due to normal distortion, and all stoppages will be due to true errors either on the "go" or "return" or on both circuits. Stoppages due to other causes will be negligible.

The regenerator should be of a simple type, with a margin which, although set initially to 50 per cent, may be allowed to fall to 45 per cent over a period of 6 months. A simple temperature-compensated multivibrator may then provide the control-time element. The regenerator should be immune to very-short start pulses, but need not provide for the automatic insertion of stop elements.

The provision of a regenerator at the receiving end also allows the input circuit of the comparator to be simplified as this may now have a margin of 50 per cent which can be allowed to drift to 45 per cent. Such an input circuit avoids the need to design for a close-toleranced margin of 30 per cent, a design which would require the use of high-stability components and associated stages of frequency division.

COMPOSITION OF DATA ON PUNCHED TAPE

In all schemes of error control which involve detection only and not automatic correction, the error is present in the received information. The incidence of errors has not been reduced; notice has merely been drawn to their existence and some acceptable operational procedure has to be introduced to remove them from the system; two possibilities are suggested below.

The data can be divided into blocks, each block being separated from the next by a character sequence, such as a series of letter-shift characters, that is easily recognized by visual inspection of the tape. The data block could conveniently consist of up to 100 characters. When an error is detected transmission is stopped and the sending operator receives an error alarm. The sending operator attracts the attention of the receiving operator—perhaps by operation of the "J Bell"—and then moves the data tape back to the previous block-separation marker, while the receiving operator destroys, or suitably marks for subsequent removal, the partially completed faulty block.

This procedure can be modified if the received data is ultimately to be processed by equipment requiring block-start and block-end recognition characters before and after each block, thus avoiding the need for operator attention at the receiving station in the event of an error. The punched tape may be inserted tail-end first in the transmitter so that the transmitted sequence of characters is reversed; the received tape will then contain a series of blocks complete with block-start and block-end characters together with blocks containing errors but with no block-start characters. The received tape can then be reversed and fed in the correct way into the processing equipment, which is programmed to ignore any blocks not possessing a block-start character, i.e. those with errors.

CONCLUSIONS

Investigations into the incidence of errors on telegraph circuits and the development of a relatively simple means of detecting them has enabled a reliable service to be offered to users of Post Office telegraph circuits for the transmission of low-speed data using the standard form of subscribers telegraph installation.

Throughout the design attention has been paid to the stability of the equipment so that visits to subscribers' premises for maintenance purposes are as unfrequent as possible.

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Doorbell Warning Device for the Deaf-Blind

G. C. MARTIN and D. C. JONES†

U.D.C. 621.395.92:621.391.5

The difficulty of communicating with those people who are both deaf and blind can be readily imagined. The problem of providing a convenient means of drawing their attention when alone in the house to a caller pressing their front-door bell-push has been solved by using the inductive-loop method of energizing a combination of hearing aid and special tactile receiver worn on a finger.

INTRODUCTION

PERSONS who are both completely deaf and blind are deprived of two of their five senses. The Royal National Institute for the Blind (R.N.I.B.) has in the past experimented with methods of signalling which involve two of their remaining senses: smell and touch. Both have been tried in the present context, but the system described here has been the most successful to date. Based on a proposal made by the Post Office Research Station, it has been developed by the R.N.I.B., with the assistance of the Subscribers' Apparatus and Miscellaneous Services Branch of the Post Office Engineering Department in connexion with the special receivers used.

DESCRIPTION

The system utilizes a low-frequency mains-driven transmitter controlled by the door bell-push. The transmitter output is connected to an inductive-loop circuit, and the signal is detected by a hearing aid that, in turn, energizes a special tactile receiver. The apparatus provided is illustrated in Fig. 1, which shows the transmitter above and the hearing aid connected to the receiver below.

Transmitter

The transmitter is a saturable-core transformer operating from the domestic 250-volt 50 c/s mains supply. The output of the transformer is tuned to the fifth harmonic of the supply frequency, namely, 250 c/s. A current of 2 amp at 1 volt can be obtained with a load of 0·5 ohm.

Inductive-Loop Circuit

The inductive-loop circuit takes the form of loops of wire or copper strip fitted around each living room of the premises and of such gauge as will achieve a total resistance of approximately 0·5 ohm. All the loops and the bell-push are connected in series.

Hearing Aid

The Medresco hearing aid for bone-conduction receivers* is used with the 3-way function switch in the coil position.

Tactile Receiver

The receiver is basically a Medresco bone-conduction receiver modified mechanically by a change of armature

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*Rigby, D. F., and Jones, D. C. A Transistor Hearing Aid for Bone-Conduction Receivers. *P.O.E.E.J.*, Vol. 57, p. 86, July 1964.

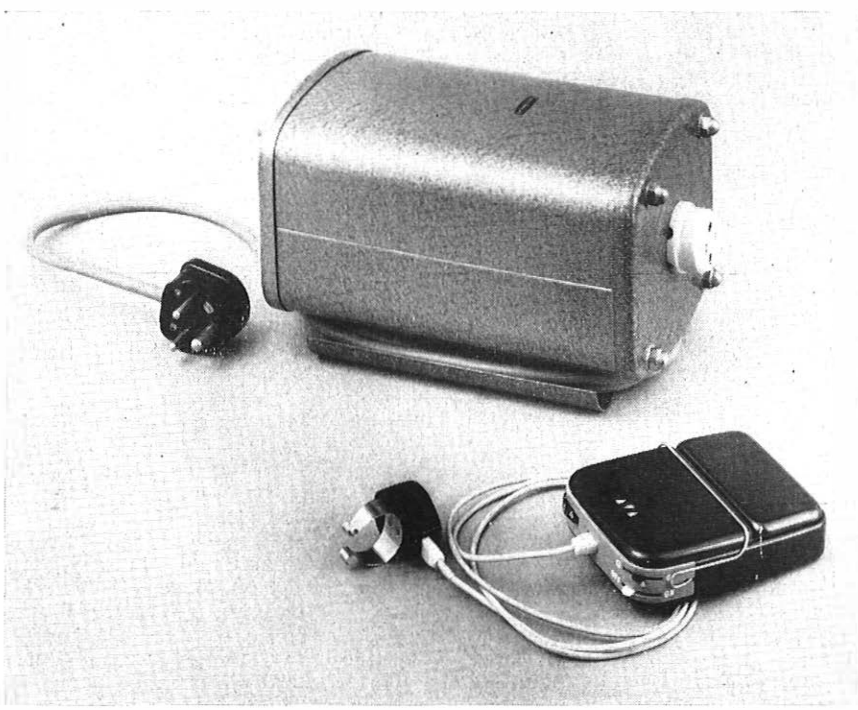

FIG. 1.—TRANSMITTER, HEARING AID AND RECEIVER

thickness and adjusted to achieve a high output at 250 c/s. The device used for securing the prototype to the finger can be seen in Fig. 1, but later models have extensible stainless-steel straps fixed to the sides of the receiver case. The finger was chosen as the best place for wearing the receiver, having regard to both sensitivity to vibrations and the ease of attachment. Such a position suffers from the disadvantage that the receiver is liable to be occasionally immersed with the hands in water. The risk of damage to the coil and motor-unit has, therefore, been reduced by sealing the receiver internally with a special adhesive. Fig. 2 shows the receiver being worn by a busy housewife.

FIG. 2.—RECEIVER IN USE

OPERATION

When the door-bell is pressed current flows in the inductive-loop system, which creates a magnetic field throughout the house. This energizes the hearing aid via its pick-up coil and this in turn causes the receiver to vibrate.

With the hearing aid switched to the microphone position, a similar sensation can be felt when an acoustic input at low audio frequencies is received. By this means the wearer can, if desired, be made aware when other persons in the room are speaking. In the third, coil-plus-microphone, position both magnetic and acoustic signals are capable of energizing the device.

ACKNOWLEDGEMENTS

Acknowledgements are made to the Ministry of Health who, with local authorities, are sponsoring a field trial of the system, and to Gardners Transformers, Ltd., for their work in connexion with the transmitter.

Books Received

"Work Examples in Advanced Electrical Engineering." K. S. Chapman, B.Sc.(Eng.), A.M.I.E.E., A.M.I.E.R.E. Edward Arnold (Publishers), Ltd. ix + 158 pp. 104 ill. 21s.

The title of this book, "Worked Examples in Advanced Electrical Engineering," explains succinctly what this book is about: it is indeed composed of fully-worked answers to questions set in Part III of the examination of the Institution of Electrical Engineers in the subject of Advanced Electrical Engineering.

The author points out in his preface that "the book does not contain all the questions set in the various papers. It is felt that the greatest need of the student is practice in examples in electrical circuit theory, and so standard bookwork on electric field theory has been omitted." The "various papers" referred to are those set during the period of November 1959 to November 1963, each paper representing a "chapter." A tenth "chapter" is composed of 20 unworked examples for which numerical answers are provided. There are also two short appendices: one contains a table of Laplace transforms and the other gives a classified list of references.

"Elphyma Tables." Compiled by E. Ingelstam and S. Sjoberg. John Wiley & Sons, Ltd. 99 pp. 27s.

This book of tables has been produced from a Swedish book, first printed in 1950 and now in its fourth edition, which is widely used in the scientific and technical education of that country. The title of the book is derived from the fact that it is a condensed handbook covering electricity, physics and mathematics—EL-PHY-MA. This English-language edition has been thoroughly revised and expanded, as well as adapted to cover U.S. nomenclature and systems.

The main purpose of the book is to provide a single convenient reference containing the most commonly used data in the three fields covered by the book title. For educative purposes this handbook will provide students with the information required for the solution of most numerical problems, and scientists and engineers will find it a useful compact reference for the solution of everyday problems.

The authors have tried to make the tables useful to readers accustomed to various systems of units, and have given guidance for conversion between systems. The abbreviations used generally follow the American Standards Association (A.S.A.) recommendations but some of the more condensed abbreviations recommended by the International Organization of Standardization (I.S.O.) are given as alternatives.

"Eurolec 1965 Pocket Guide to the Electronics and Instruments Industry in the U.K." Published by David Rayner Associates. 153 pp. 18s. 6d.

The main part of this pocket guide to the electronics and instruments industry in the United Kingdom is devoted to listing about 1,000 firms in, or associated with, that industry. Under each firm's name are given the products and services it offers, together with the name and telephone number of the sales contact of that company, as well as information relating to branch offices, names of distributors the company may have, the number of employees, and, if it has one, the company's parent.

Appendix 1 gives a broad classification of the number of people employed in the industry, arranged under four groups (over 10,000 employees, 3,000–10,000 employees, 1,000–3,000 employees, up to 1,000 employees) with firms' names included in the first three groups.

The remainder of the guide consists of an alphabetical list of non-British principals with agents in the United Kingdom, and a short appendix (Appendix 2) giving a breakdown of these principals with countries of origin.

The Use of Electronic Digital Computers for Telephone Traffic Engineering

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This article deals with the application of computers to some of the problems that arise in telephone traffic engineering. The problems are considered under four broad classifications: experimental data processing, evaluation of formulae, matrix operations, and simulation techniques.

INTRODUCTION

TELEPHONE traffic engineering has stimulated the interest of engineers and mathematicians from the very beginning of telephony, not only because of its application in running a telephone system efficiently and economically but also because of the wealth and range of interesting mathematical problems it embodies. Since the very first studies were made there have been many advances in probability and statistical theory, and some of these advances have undoubtedly been due to the progress of traffic theory itself. In a similar way, computers, which themselves have a strong affinity to telephone switching systems, have developed extremely rapidly in the past decade, and these, together with modern mathematical analysis techniques which have progressed in parallel with them, now provide new and powerful tools for continuing the advancement of traffic theory with renewed vigour. As traffic theories are used to calculate the quantities of equipment to be provided in telephone exchanges, there is a strong incentive to develop these theories because of the large capital investments currently being made in the rapidly expanding telephone network and the need to distribute this capital in the most effective way.

The purpose of this article is to describe, in very general terms, some of the ways in which computers are being used for traffic engineering and telephone-network management. To assist the description, it will be useful to consider briefly, in its application to traffic engineering, the most common procedure that is adopted whenever a practical situation is to be analysed scientifically.

As the practical circumstances themselves are far too complex to take all possible variables into account, a switching system, or, more usually, the particular part of interest, is examined by setting out a mathematical model to represent the system and deducing facts about the behaviour of the model which may be applied to the system itself. A mathematical model is composed of a logical description of the system that includes only those aspects of immediate interest and significance, together with a set of idealized assumptions about the telephone traffic offered to the system. For example, the following factors will need to be specified.

(*a*) The number of inlets to each switching stage, and the outlets that may be reached by each inlet.

(*b*) The interconnexion pattern of outlets, or trunks, i.e. the description of the way in which some outlets are shared by a number of inlets.

(*c*) A statement of the rules that must be obeyed whenever a call is being generated in order to set up a free path through the system.

(*d*) A mathematical description of the way in which calls arrive at the system, and of their destination.

(*e*) A description of the way in which calls terminate.

The mathematical model chosen to solve a particular problem will be a compromise between two conflicting requirements: first, the model must be sufficiently realistic for useful conclusions to be drawn, and, secondly, the model must be amenable to analysis. Thus, a relatively simple model, which may be useful for illustrating the general behaviour of a system under limited conditions, might prove to be of little value for actually deciding how much equipment should be provided in a particular telephone exchange. On the other hand, a more complex model, which more closely approximates to actual conditions, may be very difficult to analyse satisfactorily.

It is convenient to group the problems that occur in traffic engineering into four broad classifications which tend to reflect the different properties of computers. Each of these classes of problem is concerned either with providing information for designing suitable mathematical models, or with carrying out the actual analyses on these models. Computers provide traffic engineers with the facility for greatly improving the techniques for operating both on more complex models or on simpler, existing, models, with greater accuracy or under more onerous conditions.

The four classifications, discussed and illustrated in subsequent paragraphs, are as follows.

(*a*) *Experimental Data Processing*. Previously, it has been difficult, because of the time and the manpower effort that would be involved, to collect and to analyse sufficient information from working telephone exchanges to test properly many important assumptions that are used, or would ideally be used, in models of telephone switching systems. Emphasis is now being given to the design of automatic equipment with which to collect statistics in a suitable form for immediate processing by computers.

(*b*) *Evaluation of Formulae*. The end result of the analysis of a model is usually a formula which describes some relationship between a dependent variable of interest and the independent parameters of a type of system; for example, the traffic capacity of a switching stage of a system for particular probabilities of congestion may be expressible by some relationship of the number of circuits in the switching stage. Even for simple models many of these formulae are complex, and, in any event, many different values may need to be tabulated: a computer is an ideal instrument for evaluating formulae for differing values of the parameters, and printing the results in tabular form.

(*c*) *Matrix Operations*. Matrix algebra is a branch of

†Telephone Exchange Systems Development Branch, E.-in-C.'s Office.

mathematics with widespread applications; for example, it may be used for solving sets of simultaneous linear equations with many unknowns, for solving linear programming problems concerned with the most economical allocation of resources between alternative schemes, and for solving various types of network problem. Solving problems of this sort with matrix methods usually involves large numbers of simple calculations, which are eminently suitable for a computer. These problems normally arise from analytic treatments of models, i.e. by the deduction of formula from stated assumptions using the laws and definitions of algebra, calculus, etc.

(*d*) *Simulation Techniques.* Analytic studies of switching systems soon become exceedingly difficult when the models are expanded both by including more complex behaviour in the logical description and by the addition of certain assumptions which may need to be examined. Perhaps the most valuable method made available by a computer is the simulation of a complex switching system—that is, storing a logical description of the model in a computer, generating thousands of simulated calls and feeding them into the model, and measuring, for example, the calls carried in various parts of the system. In other words, large-scale statistical sampling experiments are carried out on the model.

EXPERIMENTAL DATA PROCESSING

The assumptions that are used in any particular model of a switching system may be of various types and complexities, depending on the type of problem being considered and the accuracy required. For example, consider that very well-known formula, the Erlang lost-call formula for full-availability groups. This expresses the probability that all N trunks are engaged, if A erlangs are offered to the group, as

$$E(N,A) = \frac{\dfrac{A^N}{N!}}{\sum_{i=0}^{N} \dfrac{A^i}{i!}},$$

This formula is derived on the basis of the following assumptions.

(*a*) Calls originate in accordance with pure chance about a constant mean value. This assumption may be expressed mathematically, as the number of calls, X, that arrive in an interval t is a random variable that obeys a Poisson distribution, i.e. the probability that x calls arrive in time t is equal to

$$P[X = x] = \frac{(\lambda t)\ e^{-\lambda t}}{x!},$$

where λ = mean number of calls arriving in unit time. Alternatively, the time, T, between successive calls is a random variable obeying a negative-exponential distribution, i.e. the frequency distribution of T is given by

$$f(T) = \lambda(T) = \lambda e^{-\lambda t}$$

The assumption of pure-chance arrivals implies that there are an infinite number of sources and that no repeated attempt is made if a call is lost. For other models, it may be desirable to depart from these implied assumptions.

(*b*) The holding time of a call is a random variable that follows a negative-exponential distribution. For other models, e.g. in considering certain types of register, it might be more appropriate to assume that holding times are constant.

(*c*) Statistical equilibrium conditions exist, i.e. the number of calls leaving the system during any time interval is, on average, equal to the new calls arriving during that interval. Other models may deal with dynamic conditions, i.e. the behaviour of a system during a period when the traffic intensity is increasing or decreasing.

Theoretically, it is easy to test each of these assumptions against the conditions that exist with actual telephone traffic as each assumption has a simple mathematical interpretation, and it is only necessary to test whether a set of sampled values differ significantly from the values expected under the theoretically ideal conditions or whether any differences that exist should, more properly, be attributed to chance. In the past it has not been possible to adequately test these assumptions because of the effort involved in collecting the special statistics from large enough samples, and the even greater effort involved in the processing required to analyse them.

In the same way, assumptions can be formulated for other models that are equally or even more difficult to test. For example, in the application of traffic theory to the dimensioning of a network, equipment quantities for each exchange are calculated according to estimates of traffic during the busy hour at some future date, to allow time for the stores to be ordered, manufactured and delivered. In connexion with this aspect of traffic engineering, a large-scale series of surveys has been carried out during the past year at 54 exchanges of differing types and size in every part of the United Kingdom, to analyse in detail the traffic originated by the subscribers in each exchange. The survey has been conducted by taking a special traffic record for the five days Monday to Friday on the first week of every month, the record covering each half-hour period from 9.00 a.m. to 12.00 noon, a longer period than usual. By examining the variations between times of day, between days of the week, and between months of the year for each exchange, valuable information will be made available for subsequent investigations into methods of estimating future levels of traffic, into more workable definitions of an exchange busy-hour, to provide data for investigating dynamic models, etc.

It will be realized that a survey of this size would have been unacceptably costly to carry out without using a computer. It is not generally appreciated that although computers enable certain problems to be examined that would not otherwise be possible to manage, a great deal of work may still have to be performed in writing programs, collecting basic data and assembling it for processing, etc. So it was with this survey. To enable results to be obtained in the earliest possible time, it was decided not to design special equipment to collect the data (traffic-meter readings or their equivalent) directly on to, say, paper tape but to enter it on to forms. These forms, an example of which is illustrated in Fig. 1, were designed so that, after a limited amount of editing, they could be used by a punch operator to prepare the data paper tapes for feeding into the computer. The survey involved punching a total of approximately 4 million characters.

Two programs have been written so far. The first

AUTOMATIC TRAFFIC RECORD – METER READINGS – THREE HOURLY RECORD. E-in-C 4484

1 ıp² = KNEBWORTH ŀr² EXCHANGE
PRESELECTED DAYS 235 ıp² HOURS 234 ıp²
WEEK COMMENCING 7 ıp² 12 ıp² 64 ıp²
CONNECTING KEY POSITION 1 ıp²

TIME OF RECORD
START 9.0
FINISH 12.0

METER CODE	GROUP CODE	0	1	2	3	4	5	6	
TEST CYCLE	0	2765	2815	2865	2915	2965	3015	3065	M
		3065	3115	3167	3217	3268	3319	3369	Tu
		3369	3419	3470	3520	3570	3634	3684	W
		3684	3736	3786	3836	3886	3936	3986	Th
		3986	4050	4100	4150	4200	4250	4300	F
A1 PF GR. 1	1	9137	9209	9330	9419	9504	9564	9664	M
		9664	9769	9847	0003	0054	0090	0181	Tu
		0181	0264	0397	0506	0637	0743	0785	W
		0785	[illegible]					[illegible]	

METER CODE	GROUP CODE	0	1	2	3	4	5	6	
WELWYN O/G	9	8409	[illegible]		8468	8471	8498	[illegible]	
		8551	8590	8618	8641	8670	8675	8680	Tu
		8680	8717	8729	8736	8751	8770	8784	W
		8784	8793	8835	8895	8904	8921	8946	Th
		8946	8968	9013	9041	9051	9069	9077	F
WELWYN I/C	10	8600	8637	8659	8683	8709	8715	8757	M
		8757	8799	8886	8915	8974	8989	9047	Tu
		9047	9080	9097	9167	9228	9237	9249	W
		9249	9295	9351	9401	9408	9458	9488	Th
		9488	9531	9553	9581	9607	9624	9680	F

FIG. 1—TYPICAL ENTRIES ON THE FORM DESIGNED TO OBTAIN TRAFFIC METER READINGS FOR SUBSEQUENT PUNCHING ON TO PAPER TAPE

merely converts the original meter readings into the mean traffic offered to each circuit group for every half-hour of the record, and provides paper-tape output of the complete set of traffic measurements for each exchange, the tape commencing with characters identifying the exchange and the time of the record. For the complete experiment, over 1,000 circuit groups have been analysed, giving a total of about 400,000 separate half-hour traffic measurements. A typical output is shown in Fig. 2, Table 1. The tape for this table, consisting of the raw traffic measurements, now replaces the original punched tapes as the basic-data tape for subsequent analysis programs. The second program was written to provide information for immediate use, the output being in the forms of two tables: Fig. 2, Table 2 is similar to Table 1 but shows the mean traffic evaluated for intervals of 1 hour; Fig. 2, Table 3 gives weekly figures, the mean traffic values being calculated in various ways.

The analysis proper is at present being planned, and will consist of a number of statistical tests to examine the variability of the traffic measurements, the correlations between measurements, comparisons between the various methods of calculating the weekly average values, etc.

EXCH NO 1 = TABLE 1

MONTHLY ANALYSIS OF ORIGINATING TRAFFIC

KNEBWORTH EXCHANGE PRESELECTED DAYS 235 = HOURS 234 =
WEEK COMMENCING 7 12 64 = CONNECTING KEY POSITION 1

GROUP NO.	1/2 =HR ENDING	TRAFFIC CARRIED MON	TUE	WED	THU	FRI
1	9.30	16.640	18.780	20.560	18.788	19.125
	10.00	20.560	16.885	21.333	22.420	21.680
	10.30	18.060	17.440	19.660	21.880	16.600
	11.00	14.480	15.275	23.680	18.480	13.200
	11.30	15.580	12.725	17.547	17.440	13.140
	12.00	17.220	13.740	14.440	16.320	14.380
2	9.30	1.380	0.800	1.100	0.712	1.187
	11.30	0.340	[illegible]	[illegible]	0.340	0.300
	12.00	1.060	0.100	0.280	0.500	0.160
10	9.30	0.740	0.840	0.660	0.885	0.672
	10.00	0.440	1.673	0.333	1.120	0.440
	10.30	0.480	0.580	1.400	1.000	0.560
	11.00	0.520	1.157	1.220	0.140	0.520
	11.30	0.120	0.294	0.141	1.000	0.340
	12.00	0.840	1.160	0.240	0.600	1.120

EXCH NO 1 TABLE 2

MONTHLY ANALYSIS OF ORIGINATING TRAFFIC

KNEBWORTH EXCHANGE PRESELECTED DAYS 235 HOURS 234
WEEK COMMENCING 7 12 64 CONNECTING KEY POSITION 1

GROUP NO.	ONE HR ENDING	TRAFFIC CARRIED MON	TUE	WED	THU	FRI
1	10.00	18.600	17.833	20.946	20.604	20.402
	10.30	19.310	17.163	20.497	22.150	19.140
	11.00	16.270	16.357	21.670	20.180	14.900
	11.30	15.030	14.000	20.614	17.960	13.170
	12.00	16.400	13.233	15.994	16.880	13.760
2	10.00	1.630	1.717	1.511	1.146	1.904
	10.30	[illegible]	2.507	[illegible]	1.360	2.470
						[illegible]
	[illegible]	0.250	[illegible]	[illegible]	[illegible]	
	11.30	0.300	0.333	0.298	0.260	0.280
	12.00	0.800	0.099	0.288	0.420	0.230
10	10.00	0.590	1.257	0.496	1.003	0.556
	10.30	0.460	1.127	0.867	1.060	0.500
	11.00	0.500	0.869	1.310	0.570	0.540
	11.30	0.320	0.726	0.681	0.570	0.430
	12.00	0.480	0.727	0.191	0.800	0.730

TABLE 3

MONTHLY ANALYSIS OF LOCAL ORIGINATING TRAFFIC

EXCHANGE NO. 1

	TIME CONSISTENT			PRESELECTED	POST SELECTED	
GROUP NO.	HOUR ENDING	5-DAY MEAN ERLANGS	MAXIMUM ERLANGS	TRAFFIC ERLANGS	3-DAY MEAN ERLANGS	5-DAY MEAN ERLANGS
1	10.00	19.677				
	10.30	19.652				
	11.00	17.875				
	11.30	16.155				
	12.00	15.253	19.677	19.324	21.408	20.273
2	10.00	1.582				
	10.30	1.904				
	11.00					
	11.30	0.294				
	12.00	0.367	0.573	0.488	0.850	0.739
10	10.00	0.780				
	10.30	0.803				
	11.00	0.758				
	11.30	0.545				
	12.00	0.586	0.803	0.992	1.209	0.989

FIG. 2—THREE TYPICAL TABLES SHOWING THE PRESENTATION OF TRAFFIC DATA OUTPUT AFTER ELEMENTARY ANALYSIS

EVALUATION OF FORMULAE

The end product of a traffic study is frequently a formula expressing the probability of congestion as a function of the traffic offered and the number of circuits in the group. For practical use in a design table one requires the traffic offered to be expressed as a function of the number of circuits and the probability of congestion.

In general, it is difficult to transform the original formula so that an explicit function for the traffic offered is obtained. Very often, however, the congestion formula can be rearranged in such a way that, even though calculation by hand would still be laborious and slow, an iterative calculation by digital computer can easily be programmed.

The Erlang lost-call formula, which is shown at the beginning of the previous section, is required frequently in traffic theory both by itself as the probability of loss of the model described previously, and as a term in the Jacobaeus formula for the probability of congestion in multi-stage link switching systems. The advent of digital computers has permitted an extensive tabulation.

Since it is fairly easy to produce a sophisticated page layout with a digital computer it is possible to produce a table in a form suitable for direct photographic reproduction. Fig. 3 shows one page of an experimental production of a traffic-capacity table in the format of an Engineering Instruction.

P.O. ENGINEERING DEPT.
ENGINEERING INSTRUCTIONS

TELEPHONES
TRAFFIC
B 3545

TRAFFIC CAPACITY TABLE C/45

NO OF TRUNKS	TRAFFIC OFFERED (ERLANGS) AT GRADE OF SERVICE OF:- .1000	.0333	.0200	.0100	.0050	.0020	TRAFFIC CARRIED .1000	.0333	.0200
	TABLE A, THEN:-								
46	45.1	38.4	36.4	34.2	32.4	30.5	40.6	37.1	35.7
47	46.0	39.3	37.3	35.1	33.2	31.2	41.4	38.0	36.6
48	47.0	40.2	38.2	35.9	34.0	32.0	42.3	38.9	37.4
49	48.0	41.1	39.0	36.7	34.8	32.8	43.2	39.7	38.2
50	48.9	42.0	39.9	37.5	35.6	33.6	44.0	40.6	39.1
51	49.9	42.8	40.7	38.4	36.4	34.3	44.9	41.4	39.9
52	50.9	43.7	41.6	39.2	37.2	35.1	45.8	42.3	40.8
53	51.8	44.6	42.5	40.0	38.0	35.9	46.6	43.1	41.6
54	52.8	45.5	43.3	40.9	38.8	36.6	47.5	44.0	42.4
55	53.7	46.4	44.2	41.7	39.6	37.4	48.4	44.8	43.3
56	54.7	47.3	45.0	42.5	40.4	38.2	49.2	45.7	44.1
57	55.7	48.1	45.9	43.3	41.2	39.0	50.1	46.5	45.0
58	56.6	49.0	46.7	44.2	42.0	39.7	51.0	47.4	45.8
59	57.6	49.9	47.6	45.0	42.8	40.5	51.8	48.2	46.6
60	58.6	50.8	48.5	45.8	43.6	41.3	52.7	49.1	47.5
61	59.5	51.7	49.3	46.6	44.4	42.0	53.6	50.0	48.3
62	60.5	52.6	50.2	47.5	45.2	42.8	54.4	50.8	49.2
63	61.5	53.4	51.0	48.3	46.0	43.6	55.3	51.7	50.0
64	62.4	54.3	51.9	49.1	46.8	44.4	56.2	52.5	50.8
65	63.4	55.2	52.7	50.0	47.6	45.1	57.0	53.4	51.7
66	64.3	56.1	53.6	50.8	48.5	45.9	57.9	54.2	52.5
67	65.3	57.0	54.5	51.6	49.3	46.7	58.8	55.1	53.4
68	66.3	57.9	55.3	52.4	50.1	47.4	59.7	55.9	54.2
69	67.2	58.7	56.2	53.3	50.9	48.2	60.5	56.8	55.0
70	68.2	59.6	57.0	54.1	51.7	49.0	61.4	57.6	55.9
71	69.2	60.5	57.9	54.9	52.5	49.8	62.3	58.5	56.7
72	70.1	61.4	58.7	55.7	53.3	50.5	63.1	59.3	57.6
73	71.1	62.3	59.6	56.6	54.1	51.3	64.0	60.2	58.4
74	72.1	63.2	60.5	57.4	54.9	52.1	64.9	61.1	59.3
75	73.0	64.0	61.3	58.2	55.7	52.9	65.7	61.9	60.1
76	74.0	64.9	62.2	59.1	56.5	53.6	66.6	62.8	60.9
77	75.0	65.8	63.0	59.9	57.3	54.4	67.5	63.6	61.8
78	75.9	66.7	63.9	60.7	58.1	55.2	68.3	64.5	62.6
79	76.9	67.6	64.7	61.5	58.9	55.9	69.2	65.3	63.5
80	77.8	68.5	65.6	62.4	59.7	56.7	70.1	66.2	64.3
81	78.8	69.3	66.5	63.2	60.5	57.5	70.9	67.0	65.1
82	79.8	70.2	67.3	64.0	61.3	58.3	71.8	67.9	66.0
83	80.7	71.1	68.2	64.9	62.1	59.0	72.7	68.7	66.8
84	81.7	72.0	69.0	65.7	62.9	59.8	73.5	69.6	67.7
85	82.7	72.9	69.9	66.5	63.7	60.6	74.4	70.4	68.5
86	83.6	73.8	70.8	67.3	64.5	61.3	75.3	71.3	69.3
87	84.6	74.6	71.6	68.2	65.3	62.1	76.1	72.2	70.2
88	85.6	75.5	72.5	69.0	66.1	62.9	77.0	73.0	71.0
89	86.5	76.4	73.3	69.8	66.9	63.7	77.9	73.9	71.9
90	87.5	77.3	74.2	70.6	67.7	64.4	78.7	74.7	72.7

PAGE 1

ISSUE 2, 25.10.63

FIG. 3—EXAMPLE OF A TRAFFIC-CAPACITY TABLE PRODUCED BY PHOTOGRAPHING THE COMPUTER OUTPUT

MATRIX OPERATIONS

Although it is not within the scope of this article to deal with matrix methods in any detail, it may be instructive to briefly set out the steps of the solution of a set of simultaneous equations. Consider the equations

$$a_{11}\,x_1 + a_{12}\,x_2 = b_1, \text{ and}$$
$$a_{21}\,x_1 + a_{22}\,x_2 = b_2.$$

This is written in matrix form as follows:

$$\mathbf{AX} = \mathbf{B},$$

$$\text{where } \mathbf{A} = \begin{bmatrix} a_{11}\,a_{12} \\ a_{21}\,a_{22} \end{bmatrix}, \mathbf{X} = \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} \text{ and } \mathbf{B} = \begin{bmatrix} b_1 \\ b_2 \end{bmatrix}.$$

Now if $\mathbf{A}^{-1}$ is the inverse of matrix $\mathbf{A}$, by definition,

$$\mathbf{A}^{-1}\,\mathbf{A} = \mathbf{I}$$

$$\text{where } \mathbf{I} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}.$$

For example, for the matrix $\mathbf{A}$ above, it can be shown that the inverse matrix is

$$\mathbf{A}^{-1} = \frac{\begin{bmatrix} a_{22} & -a_{12} \\ -a_{21} & a_{11} \end{bmatrix}}{a_{11}a_{22} - a_{12}a_{21}}.$$

Performing the rules of matrix multiplication, the solution of the set of simultaneous equations is given by

$$\mathbf{A}^{-1}\,\mathbf{A}\,\mathbf{X} = \mathbf{A}^{-1}\,\mathbf{B}.$$

$$\text{Because } \mathbf{A}^{-1}\,\mathbf{AX} = \mathbf{IX} = \mathbf{X},$$

$$\mathbf{X} = \mathbf{A}^{-1}\,\mathbf{B}.$$

For example, the equations $x + y = 5$, and

$$2x + 3y = 13$$

$$\text{may be written } \begin{bmatrix} 1 & 1 \\ 2 & 3 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} 5 \\ 13 \end{bmatrix}.$$

$$\text{Now } \mathbf{A}^{-1} = \frac{\begin{bmatrix} 3 & -1 \\ -2 & 1 \end{bmatrix}}{3 - 2} = \begin{bmatrix} 3 & -1 \\ -2 & 1 \end{bmatrix}.$$

$$\therefore \begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} 3 & -1 \\ -2 & 1 \end{bmatrix} \begin{bmatrix} 5 \\ 13 \end{bmatrix} = \begin{bmatrix} 15 - 13 \\ -10 + 13 \end{bmatrix} = \begin{bmatrix} 2 \\ 3 \end{bmatrix}.$$

$$\therefore\ x = 2,\ y = 3 \text{ is the solution.}$$

A set of simultaneous equations may, therefore, be solved by performing a repetitive routine to invert a matrix, $\mathbf{A}$, and then multiplying the resulting inverse matrix, $\mathbf{A}^{-1}$, by $\mathbf{B}$ using another repetitive routine.

An example of a problem in traffic theory solved by these methods relates to a both-way switching stage to which a small group of subscribers is connected with full-availability, and through which they originate and receive calls both between themselves and to other groups of subscribers. The model is shown diagramatically in Fig. 4.

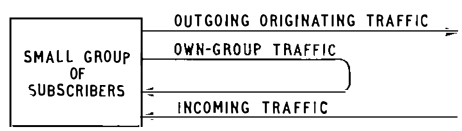


FIG. 4—SIMPLE DIAGRAM OF THE MODEL FOR A SMALL GROUP OF SUBSCRIBERS

In a particular problem, there may be 20 subscribers having access to five trunks. A feature of the problem is that as there are only a small number of subscribers, when one subscriber originates a call the probability that another call will be originated will be reduced. The problem is to determine, for different proportions of own-group traffic, the probabilities that no trunks are busy, [0], 1 trunk is busy, [1], and so on, up to, say, the probability that all five trunks are busy, [5]. The system may, therefore, be in one of six possible "states," and the problem is to determine the "state probabilities" at any instant.

Each state as defined above, other than [0], may be obtained in a number of ways, each corresponding to a "sub-state" for which an equation may be formulated in terms of "sub-state probabilities." Thus, the system will be in state [2] at a particular point in time for each of the four following sub-states:

(*a*) two outgoing calls in progress simultaneously,
(*b*) one own-group call,
(*c*) one outgoing and one incoming call, and
(*d*) two incoming calls.

If vector $[n_1, n_2, n_3]$ represents a sub-state of the system at a particular instant where n_1, n_2 and n_3 are, respectively, equal to the number of outgoing calls, the number of own-group calls, and the number of incoming calls, the sub-states equivalent to each state are as follows:

State	*Sub-States*
[0]	[0,0,0]
[1]	[0,0,1] [1,0,0]
[2]	[0,0,2] [1,0,1] [2,0,0] [0,1,0]
[3]	[0,0,3] [1,0,2] [2,0,1] [3,0,0] [0,1,1] [1,1,0]
[4]	[0,0,4] [1,0,3] [2,0,2] [3,0,1] [4,0,0] [0,1,2] [1,1,1] [2,1,0] [0,2,0]
[5]	[0,0,5] [1,0,4] [2,0,3] [3,0,2] [4,0,1] [5,0,0] [0,1,3] [1,1,2] [2,1,1] [3,1,0] [0,2,1] [1,2,0]

It will be seen that although a relatively simple system is being analysed, for each different set of conditions examined a set of 35 simultaneous equations has to be solved to calculate the 34 sub-state probabilities and, thence, the six state probabilities; the final equation of the 35 arises from the fact that the sum of the sub-state probabilities is unity. The solution would be an exceedingly lengthy process by hand, even using a sophisticated desk-type calculating machine.

A graph is given in Fig. 5 showing how each state probability varies with the probability that a call originated in the group is to another subscriber in the group, for the particular case where each subscriber offers 0·035 erlangs and there are 0·676 erlangs of incoming traffic. The points on the graph were obtained by solving four different sets of 35 equations. Similar graphs are obtainable for different values of originating and incoming traffic by formulating and solving other sets of equation.

The state probabilities themselves may be used to calculate other probabilities, e.g. probabilities of congestion for incoming and outgoing calls, probabilities of time congestion and call congestion for own-group calls.

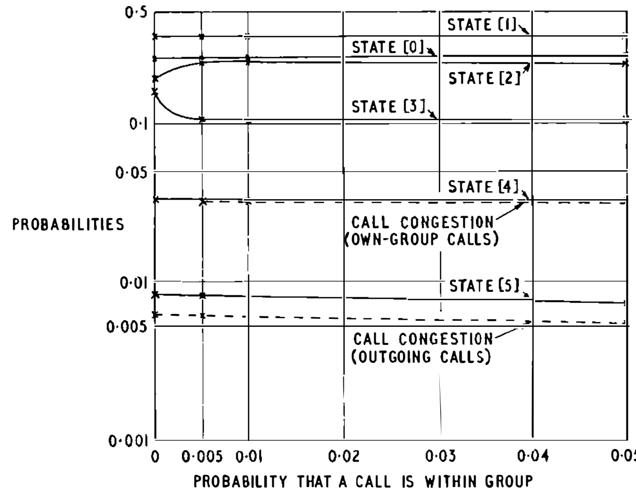


FIG. 5—GRAPH SHOWING THE VARIATION OF STATE AND CONGESTION PROBABILITIES WITH DIFFERENT PROPORTIONS OF OWN-GROUP TRAFFIC

SIMULATION TECHNIQUES

There are two distinct methods used in the simulation of systems by digital computers. These are:

(*a*) roulette simulation—Kosten model, and
(*b*) event-by-event simulation.

Roulette method

In the roulette method the system being simulated is examined at regularly spaced instants in the time scale, and changes are made to the state of the system in accordance with probabilities that depend only on the state of the system at the instant being considered. The model so formulated is, therefore, a discrete Markov process and can be used when the call inter-arrival times and durations have a negative-exponential distribution.

Although a telephone system having Poisson arrivals and negative-exponential distribution of holding times is a continuous Markov process the simulation, as a discrete process, does not introduce any errors for the characteristics which are usually of interest in a system study. This is because the system is studied in a state of statistical equilibrium and the transition probabilities of the simulated or discrete-time system are related to the average rates of recurrence of events in the continuous system.

The basic requirements of such a program are that it shall have sections which provide the following facilities.

(*a*) A source of pseudo-random numbers.

(*b*) Rules for deciding from these numbers whether a call arrival or a call termination is required.

(*c*) Rules for deciding which trunks are concerned if a call termination is indicated.

(*d*) Rules for deciding which groups of trunks must be examined for a free path if a call arrival is indicated.

(*e*) Means for counting the number of calls offered and lost in the system, and also for deciding when other statistics are to be collected, when results are to be printed and when the test is to stop.

Fig. 6 shows a simplified flow chart of such a simulation program which has been used to examine the behaviour of a 320-trunk O'Dell grading of 20 availability and 32 groups, operating as a lost-calls cleared system.

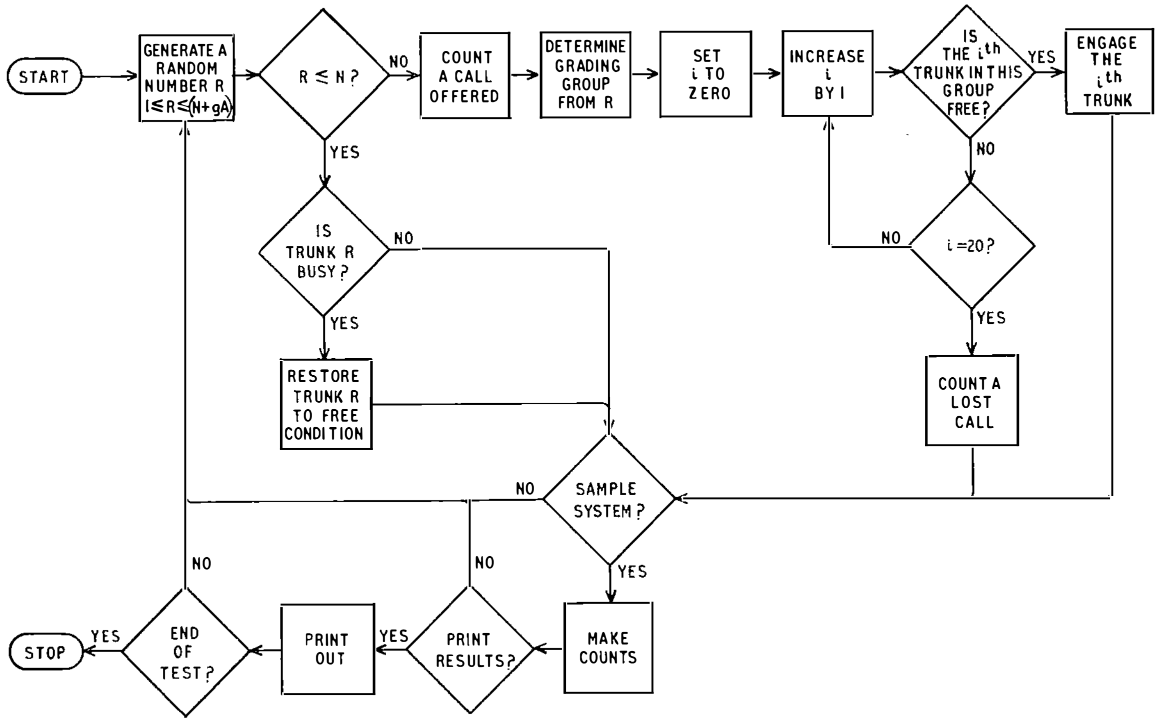


FIG. 6—FLOW CHART FOR A ROULETTE SIMULATION OF A GRADING

The table gives a summary of 100 tests, each terminated at the end of 50,000 computer events, and shows the number of calls offered and the number of calls lost. The variability of the results demonstrates one of the chief handicaps of the simulation technique for estimating the probability of congestion, namely, the large number of calls which must be processed to obtain a statistically reliable result.

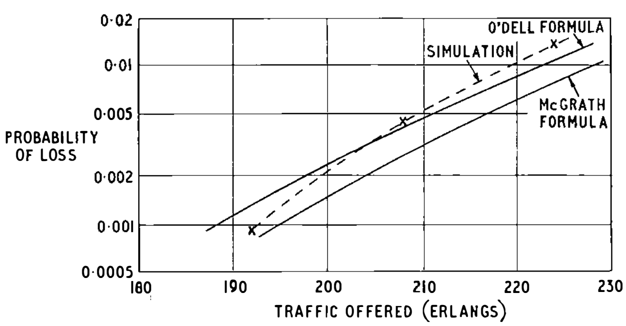


FIG. 7—GRAPH COMPARING THE PERFORMANCE OF THE 320-TRUNK O'DELL GRADING AS PREDICTED BY THREE METHODS

Fig. 7 is a graph which shows the performance of this grading as predicted by the well-known O'Dell formula, by the formula due to McGrath,[1] and by the simulation study. The curves for the O'Dell and McGrath formulae have been obtained by extrapolation well beyond the range of trunks investigated. The discrepancies which exist between these curves and the simulation results indicate the need for further investigation of large gradings.

Event-by-event simulation

For event-by-event simulation the functioning of the system must be broken down into a number of actions which occur at separate instants of time but which are themselves regarded as instantaneous. There must, therefore, be some form of master time record included

[1]McGRATH, H. T. The Electronic Traffic Analyser—a Survey of its Use and Limitations. *P.O.E.E.J.*, Vol. 52, p. 19, Apr. 1959.

Results of a Roulette Simulation Test of a 320-Trunk 32-Group 20-Availability O'Dell Grading

Number of Calls Offered in Test Period	Number of Test Periods in Which the Number of Calls Lost Lay Within the Following Ranges													Total Number of Test Periods
	21–30	31–40	41–50	51–60	61–70	71–80	81–90	91–100	101–110	111–120	121–130	131–140	141–150	
19,401–19,450	0	0	0	0	1	0	0	0	0	0	0	0	0	1
19,451–19,500	1	0	0	1	1	0	0	0	0	0	0	0	0	3
19,501–19,550	0	0	0	1	2	1	2	0	0	0	0	0	0	6
19,551–19,600	0	0	0	2	2	2	0	1	0	0	0	0	0	7
19,601–19,650	0	2	2	2	3	4	1	1	1	1	0	0	0	17
19,651–19,700	0	1	0	1	2	5	7	3	1	1	1	1	1	24
19,701–19,750	0	0	0	0	2	1	4	3	2	1	1	0	0	14
19,751–19,800	0	0	0	2	2	2	0	1	0	2	1	1	0	11
19,801–19,850	0	0	0	0	0	1	0	0	1	1	1	1	1	6
19,851–19,900	0	0	0	0	0	0	3	1	0	1	0	0	3	8
19,901–19,950	0	0	0	0	0	0	0	2	0	0	1	0	0	3
Total Number of Test Periods	1	3	2	9	15	16	17	12	5	7	5	3	5	100

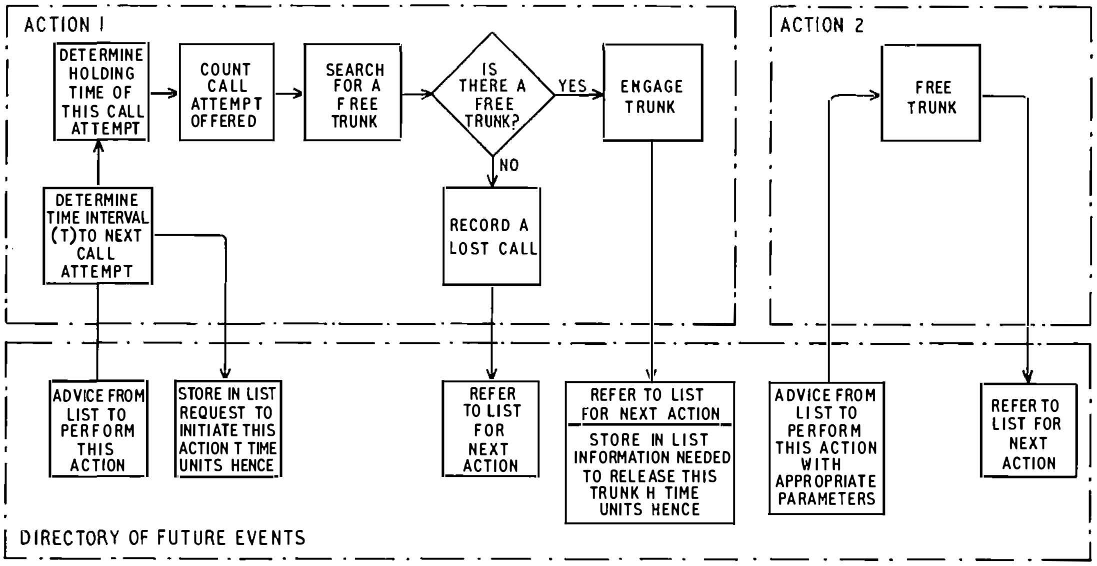


FIG. 8—FLOW CHART FOR AN EVENT-BY-EVENT SIMULATION OF A GRADING

in the program. This "clock" need not have a uniform motion but may move forward in one step to the time of the next happening; the only restriction is that it must never go backwards.

The actions are sets of rules which govern the behaviour of the simulation system in all possible circumstances. For a model of an O'Dell grading there are only two basic actions, which are as follows.

Action 1: A call arrives and a search is made for a free outlet. If there is none the call is lost, otherwise an outlet is chosen and busied.

Action 2: A busy trunk is made free at the expiry of the holding time of the call.

Even with such a simple model the sequence of actions will not be "set-up a call," "release this call," "set-up another call," etc., but will be a number of such pairs of actions interleaved with one another. Consequently, the program must include a directory of future events to ensure that the actions occur in the correct sequence and at the correct moments in the time scale. There will, of course, be other actions which set up the initial state of the system, sample the state of the system, print out results, etc. Fig. 8 illustrates a simplified flow chart showing the basic actions and the directory.

The technique described has been used in the study of a variety of traffic and trunking problems, of which the following are examples.

(*a*) The behaviour of interconnecting patterns in lost-call and delay systems.

(*b*) The traffic capacity of groups of bothway circuits when heavily loaded and with significant unguard times.

(*c*) The performance of electronic switching systems.

(*d*) The performance of link switching systems.

CONCLUSIONS

The Engineering Department computer No. 2[2] will be used to solve many traffic engineering problems of the types described in this article. In particular, a large program of simulation work is under preparation to compare the traffic capacities of various types of interconnexion pattern, which may lead to the adoption of more efficient grading designs for relieving congestion on heavily-loaded routes; to obtain general information on the performance, of link switching systems, and, in particular, cross-bar systems and certain types of electronic systems. Also, it is intended to develop computational methods for the economic design of networks for both inland and international routes.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the work done by Elliott Brothers (London), Ltd., in developing a simulation language (ESP), which is used as the basis for programming many simulation problems. Also, thanks are due to members of Telephone Areas, the Engineering Department Exchange Equipment and Accommodation Branch and the Inland Telecommunications Department for their co-operation in the planning and conduct of surveys of telephone traffic.

[2]McGRATH, H. T. New Computing Facilities for the Post Office Engineering Department. *P.O.E.E.J.*, Vol. 58, p. 38, Apr. 1965.

Notes and Comments

Birthday Honours

The Board of Editors offers congratulations to Mr. G. W. J. Sharp, Draughtsman, Reading Telephone Area, whose name should have been included in the list published in the July 1965 issue of the Journal. He was honoured by Her Majesty the Queen in the Birthday Honours List with the British Empire Medal.

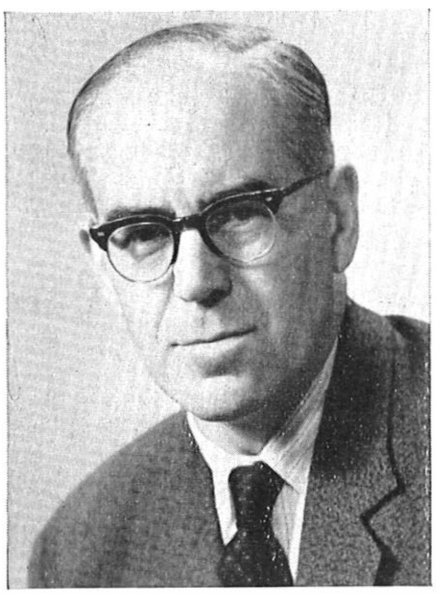
R. E. Jones, M.B.E., M.Sc.(Eng.), D.I.C., M.I.E.E.

Mr. R. E. Jones, previously an Assistant Engineer-in-Chief of the Post Office, has been appointed head of the advisory unit concerned with telecommunications in the Ministry of Technology. This unit is one of a number of specialized units with responsibility for conducting an appraisal in depth of their subject: they are the focal points in the Ministry for technical questions and for the co-ordination of intra-mural and extra-mural research and development.

Mr. Jones' wide experience in the Post Office and the Services, together with his capacity for leadership, make him eminently suitable for his new duties, and his many friends, both in the Post Office and in the telecommunications industry, will wish him every success in his new field of activity.

S. D. Mellor, B.Eng., M.I.E.E.

Although his friendly, helpful, presence will be greatly missed in the North Western Region the appointment of Mr. S. D. Mellor as Chief Regional Engineer in the



Directorate of Wales & Border Counties is welcomed by his friends and colleagues everywhere.

A 1st Class Honours graduate of Liverpool University he entered the Post Office in 1933, and was posted to the Telephone Branch of the Engineer-in-Chief's Office. For 7 years he carried out valuable work there in the field of maintenance procedures and automatic routiners, and theoretical and practical investigations into traffic and switching problems for telephone exchanges.

In the early years of the war he was loaned to the North Eastern Region and engaged on the planning of war-emergency schemes within that Region. Subsequently, he was appointed Area Engineer in the Newcastle-on-Tyne Area, where he spent several years on external and internal planning. This was followed by a period, in a similar capacity in the same Area, on the internal side in charge of maintenance and installation.

Promotion to Regional Engineer, External, North Western Region, came in 1952. It is interesting to note that here also his services were divided between the external and internal fields: for 6 years he was responsible for the full range of external planning and works in the Region, and then transferred to be Regional Engineer, Internal, in charge of planning (including accommodation aspects) and execution of exchange design and works.

Throughout this period in the North Western Region the impact of Mr. Mellor's ability and drive, together with his careful attention to detail, has been appreciated by all who worked with him. These qualities, and the scope of his experience, have caused him to be in demand for several Headquarters Committees and Working Parties set up to deal with special problems, and to these also he has given able and unstinting service.

Apart from his official activities, Mr. Mellor has taken a keen and active part in matters relating to the Institution of Electrical Engineers, particularly in the North West Centre where he was a committee member for some years, and for a time was Chairman of the Electronics and Communications Section. In addition, he has contributed articles to the *Post Office Electrical Engineers' Journal* relating to both external and internal activities of the Post Office Engineering Department.

Mr. Mellor's reserved nature conceals, on first acquaintance, a strong and purposeful character which, together with his wide knowledge and experience, will ensure success in his new appointment. His friends and colleagues offer him sincere congratulations.

A.W.H.

W. A. Humphries, T.D., A.M.I.E.E.

The recent appointment of Mr. Humphries to Staff Engineer of the Exchange Equipment and Accommodation Branch of the Engineering Department has been welcomed by his staff and all who know him.

Mr. Humphries entered the Post Office as a Youth-in-Training in 1933 in the London Telecommunications Region, and there he received his first introduction to automatic-exchange maintenance work. In 1936 he was successful in the Probationary Inspectors' examination, being appointed to the Telephone Branch of the Engineer-in-Chief's Office, where he became concerned with maintenance procedures. In 1938 he passed the Probationary Assistant Engineers' examination and then joined the Exchange Equipment and Accommodation Branch, where he dealt with repeater-station costs and economics, until, as with so many, the coming of the second world war interrupted his Post Office career.

As a Territorial Officer he was called up for military service immediately before the outbreak of hostilities. He served variously with London A.A. Signals during the blitz, and as a staff officer at the Ministry of Supply, and at the War Office. He was also Lines Officer to a Chief

Signal Officer on the Continent, during which period he was mentioned in dispatches.

On demobilization he rejoined the Telephone Branch and was engaged on automatic-exchange circuit develop-

ment for the next 2 years. In 1948 he was promoted to Senior Executive Engineer and returned to the Exchange Equipment and Accommodation Branch. In the ensuing 10 years he acquired valuable experience in a wide field which embraced exchange-equipment costs and economics, consultative services and publicity, accommodation, and exchange design and trunking.

In 1957 Mr. Humphries was promoted to Assistant Staff Engineer, still in this same branch. Now began a period of concentration on exchange standards and programmes, during which time he became heavily involved with the introduction and build-up of the provision of subscriber trunk dialling throughout the country. He also served on a joint C.C.I./I.E.C. Working Party on Graphical Symbols, as a representative of the C.C.I.T.T. Recently he visited the U.S.A. as a member of a team which studied American methods of provision of telephone-exchange equipment.

Early in his career he was the recipient of an Institution of Post Office Electrical Engineers' prize for the City and Guilds Intermediate Telephony examination, and was awarded a silver medal in the City and Guilds Final Telephony (Auto) examination.

This Journal is indebted to Mr. Humphries for his services: first as Assistant Editor, and then as Managing Editor during the period when two special issues were produced—in 1956 on the occasion of the Jubilee of the Institution of Post Office Electrical Engineers, and in 1957 to commemorate the laying of the first transatlantic telephone cable (TAT-1). He was also responsible for restyling the Journal in its present form.

In earlier days he was a footballer and a keen participator in various athletics, gaining a number of successes in field events. These days he enjoys the quieter pleasures experienced in exploring the more beautiful corners of this country on foot.

He is unfailingly courteous and good humoured, and engenders wholehearted loyalty from his staff. With his widely varied experience success in the future is undoubtedly assured; we all wish him well.

H.K.

J. K. S. Jowett, B.Sc.(Eng.), M.I.E.E.

Mr. Jowett, who has been appointed Staff Engineer in the Space Communication Systems Branch, began his career in 1936 when he entered the Post Office Engineering Department as a Probationary Inspector. He was appointed to the Radio Branch in 1937, and has remained in one or other of the radio branches throughout the period up to the present time. For some years after 1937 he was engaged in the planning and provision, first, of high-frequency radio links and, later, of very-high-frequency (v.h.f.) radio links such as those used for communication with the Scottish islands. Immediately after the war he was responsible for planning the first microwave radio-relay links for television in the United

Kingdom. Between 1950 and 1958 he was in charge of a group concerned with the development of v.h.f. sound and television broadcasting, as well as with radio propagation.

In 1958 he was appointed Assistant Staff Engineer in the Overseas Radio Branch, and was in charge of system studies, radio-propagation work, and frequency planning. He has published several articles on the propagation of radio waves, a subject which has interested him throughout his career. His work has included studies of the optimum ways of utilizing high-frequency waves for intercontinental communication, v.h.f. and microwaves for various forms of terrestrial communication, and microwaves for communication between points on the earth by the use of artificial satellites.

He has represented the United Kingdom at a number of C.C.I.R. meetings at home and abroad, and played an important part in the technical work of the I.T.U. Administrative Radio Conferences at Geneva in 1959 and 1963, at which the Regulations governing the uses of radio were revised and extended to meet present-day requirements, including space communications.

On transfer to the Space Communication Systems Branch at the time when it was formed in 1961, Mr. Jowett was engaged in the study of the relative merits and potentialities of the various types of communication-satellite system. Alternatives such as passive and active satellites, polar and equatorial orbits of various altitudes, and many varieties of modulation system, had to be considered. This work led to his appointment last year as Chairman of the C.C.I.R. United Kingdom Study Group IV on Space Communication Systems, and, now, as Staff Engineer in the Space Communication Systems Branch. His present duties include United Kingdom representation at meetings in Washington of the Advisory Technical Committee concerned with the planning of a global communications satellite system and at other international meetings.

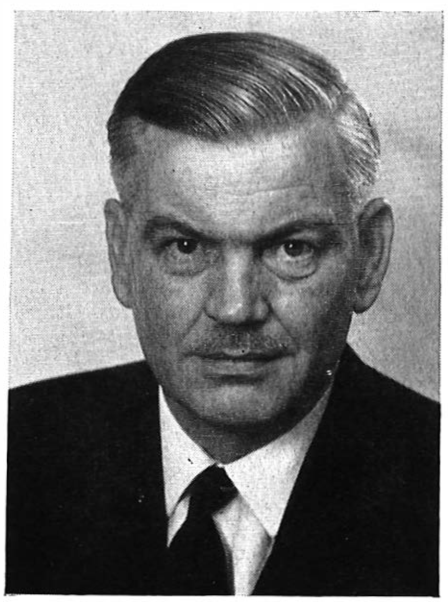
Kenneth Jowett is known for his sincerity and for his keen interest in the engineering problems with which he deals. His new work, involving much travelling, could go some way towards satisfying his interest in travel and people, but may leave less time for his many other activities at home. His co-operative and friendly attitude is much appreciated by his colleagues, and by the many others, both at home and overseas, with whom his work has brought him into contact. He has the good wishes of his friends and colleagues in this arduous but interesting appointment.

D.B.B.

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

The announcement of the promotion of Mr. A. E. Jemmeson to Staff Engineer in charge of the Organization and Efficiency—Work Study and Stores (OWS) Branch of the Engineering Department was welcomed by his many friends and colleagues in all sections of the Post Office.

Arthur Jemmeson brings to this post a very wide experience. He received his engineering education at Durham University, and his early interest was in heavy



electrical engineering. He was for a time a technical apprentice with the Lancashire Dynamo and Crypto Company, where he was engaged on testing all types of electrical machinery.

He was attracted to the Post Office in 1937, entering on the traffic side by open competition for Assistant Traffic Superintendent. During the following 5 years he not only had experience of many aspects of traffic work but was fortunate in gaining his experience in a wide range of Telephone Area organizations and working conditions covering the Manchester, Southend and Scotland West Areas. He returned to engineering in 1942 when he was successful in the open competition for Probationary Assistant Engineer (old style). His Area experience was further widened by 2 years on automatic telephone-exchange and subscribers' apparatus maintenance in Glasgow.

In 1944 he came to the Engineer-in-Chief's Office and was employed in the Research Branch, where he made a valuable contribution in the telegraph field on distortion measurements and was responsible for the design of the telegraph-distortion monitor. He later returned to the north and served in the Edinburgh and Newcastle Telephone Areas, gaining experience on external development and construction. During this period he was seconded to the Burmese Government for a special assignment as a member of a three-man team to design a telephone system for Rangoon.

In view of his wide experience of Telephone Area work, it is not surprising that on promotion to Senior Executive Engineer in 1952 he was appointed to the Central Training School (C.T.S.). Here, he took a very active part in the development of engineering, technical, and management training, and was appointed Deputy Principal of the school in 1953. His period at the C.T.S. brought him into close touch with all Branches of the Engineering Department, and his wide knowledge of Regional and Headquarters work and organization stood him in good stead when in 1961 he was promoted to Assistant Staff Engineer in the Organization and Efficiency Branch. He has since been engaged on problems of engineering organization and complementing, and in important negotiations with Staff Associations. He was actively concerned in the expansion and reorganization of efficiency work in the Engineering Department and with the setting up of the Management Services Division.

His all-round ability and wide experience of work in the field was recognized when he was placed in charge of the newly formed OWS Branch. Here he faces his most challenging task in the direction of method and work studies of construction work and stores, on the success of which will depend much of the productivity improvement necessary to the continued expansion of the telecommunications service.

Arthur Jemmeson brings to his new post ability and a wealth of experience, and we wish him every success.

F.W.J.W.

A. J. Thompson

Mr. A. J. Thompson, who has been appointed Chief Regional Engineer, Planning and Works, in the London Telecommunications Region, started his Post Office career in London in 1925 as a Youth-in-Training in the old C.T.O. Engineering. In 1927 he became a Draughtsman-in-Training and then a Draughtsman in West Area, and is thus perhaps unique amongst C.R.E.s in having had personal experience as a Post Office draughtsman in his younger days.

In 1932 Mr. Thompson was successful in the Limited Competition for Probationary Inspector, and left London for the Eastern District, as it was then, to take up

an Inspector appointment at Cambridge. He was successively promoted to Chief Inspector and Assistant Engineer (old style), and was engaged on exchange and line maintenance, and local-line and main-cable development in the Eastern District Technical Section, where he also carried out precision-testing and cable-balancing duties.

During the second world war Mr. Thompson volunteered for flying duties in the R.A.F. and, after receiving training in South Africa as a navigator, he was posted to operational duties. He took part in the "D-day" operations and the subsequent invasion of Europe, including Arnhem and the Rhine crossing, and was "Mentioned in Dispatches."

After returning to Post Office duties Mr. Thompson was promoted in 1949 to Senior Executive Engineer in the Equipment Branch of the Engineering Department, and then in 1957 he was promoted to Assistant Staff Engineer in the same Branch. During this period he dealt with the general equipment planning for the introduction of trunk mechanization in the early 1950s, and later he was closely concerned with the introduction of subscriber trunk dialling. He has also played a leading part in telecommunications buildings design and accommodation standards. He has participated in the presentation of papers on several of these subjects at meetings of the Institution of Post Office Electrical Engineers.

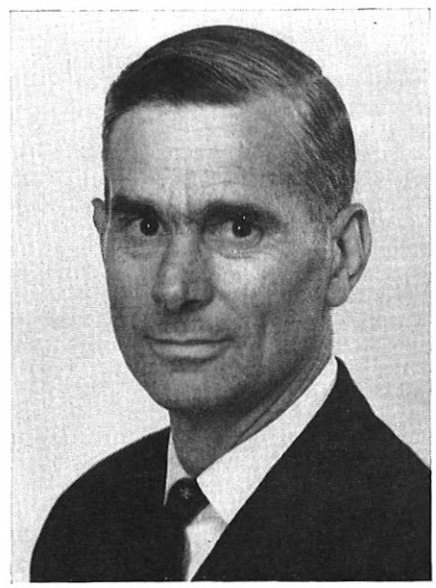
In 1964 Mr. Thompson moved to the London Telecommunications Region to take up the post of Deputy Chief Regional Engineer, and was appointed Chief Regional Engineer in March 1965. Mr. Thompson's long and particularly varied career, and his wide knowledge of the work of the engineering staff in the Post Office, have undoubtedly fitted him well to take over the responsibilities of Chief Regional Engineer for Planning and Works in London.

Outside his official duties Mr. Thompson is always ready to participate in social activities. He served for a number of years in his local Civil Defence unit as Rescue Officer. In his early days he was keenly interested in, and took an active part in, a number of sports, and was a founder member and secretary of the Cambridge Area Sports and Social Club. His many friends and colleagues wish him well in his new appointment.

J.R.

A. J. Forty, B.A., A.M.I.E.E.

Mr. A. J. Forty enters upon a new field of activity in an already varied career, by his recent promotion to Staff Engineer in charge of the Technical Support Unit, which deals through the Ministry of Technology with the application of computers in both Government Departments and industry. Born in Oxford, he was educated at the City of Oxford School from which he obtained an Open Mathematical Scholarship to The Queen's College, where he graduated in 1937 with 1st Class Honours in Engineering Sciences. His academic training was followed by a year as a pupil engineer in Rolls-Royce, Derby, and in 1938 he entered the Post Office by the Open Assistant Engineer Competition. After field training he was posted to the Telegraph Group of the Research



Branch, but in 1941 he was transferred to the Acoustics Group where he was concerned with military application of electro-acoustics, his duties taking him to several foreign countries.

After a period with the Postal Engineering Group Mr. Forty returned to the Acoustics Group where he was intimately concerned with the development of speaking clocks, announcing machines and other recording devices. In 1957 he was promoted to Assistant Staff Engineer in the Subscribers' Apparatus and Miscellaneous Services Branch where he was responsible for the development of, among other things, a range of modern P.M.B.X.s, P.A.B.X.s and loud-speaking telephones. In particular, he made the first application in the Post Office of critical path methods to the control of the development and installation of a large electronically-controlled P.A.B.X. of exceptional complexity.

John Forty is a man whose equable temperament belies his energy and capacity: he is never daunted by a task before him. Needing an unobtainable house after the war he became his own architect and builder in his spare time, and with the aid of his wife he designed and erected an attractive house in the Chilterns. More recently, needing holiday accommodation for his family, which was growing beyond the capacity of his caravan, he acquired a derelict Cornish cottage which he has enlarged, modernized and provided with all normal services. He is now enquiring about boat building!

Although Forty's new responsibilities are in unfamiliar fields of equipment, industry and users, there is little doubt that with his ready adaptability he will make a lasting contribution to the task before him.

W.H.M.

Board of Editors

Mr. J. A. Povey has resigned from the post of Assistant Editor and Mr. N. J. H. Ninnim has been appointed to take his place. The Board of Editors takes this opportunity of thanking Mr. Povey for his services.

Institution of Post Office Electrical Engineers

Essay Competition 1965–66

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

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

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

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

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

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

Name (in block capitals).............................

Signature ....

Rank ....

Departmental Address...............................

....

Date ....

The essays must reach
The Secretary,
The Institution of Post Office Electrical Engineers,
G.P.O.,
2–12 Gresham Street,
London, E.C.2,
by 15 January 1966.

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

J. W. Hotham, M.B.E.

The death of Mr. Hotham, Executive Engineer, Tunbridge Wells Telephone Area, is noted with regret.

Mr. Hotham had for many years taken a very keen and active interest in the affairs of the Institution, including the Tunbridge Wells and Hastings Associate Section Centres. He will particularly be remembered by his colleagues, not only for his work as a member of Council, but as the London Centre Assistant Local Secretary, South-East Group, for some 13 years and, at the time of his death, as a committee member.

S. WELCH,
General Secretary.

Additions to the Library

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

2814 *Space Physics*. H. Massey (Brit. 1964).
Discusses the techniques and methods involved in space research, and the results so far achieved. Some knowledge of mathematics is desirable, but not essential.

2815 *Photo-Electric Devices in Theory and Practice*. H. Carter and M. Donker (Dutch 1963).
Relates the principles to practical industrial applications in a manner which will be of value to engineers and technicians.

2816 *Fundamentals of Electric and Electronic Circuits*. M. Mandl (Amer. 1964).
Assumes a basic grounding in algebra and trigonometry, and a knowledge of slide-rule applications is useful though not essential.

2817 *ABC's of Boolean Algebra*. A. Lytel (Amer. 1963).
Explains the principles of symbolic logic, logical statements, and electronic circuits used for logical functions. A mathematical background is not required.

2818 *Rapid Car-Fault Diagnosis*. G. C. Sneed (Brit. 1964).
Suggests procedures by which faults that develop in cars may be pinpointed swiftly, accurately and scientifically with the aid of test equipment cheaply built from government surplus components.

2819 *Cold Cathode Tube Circuit Design*. D. M. Neale (Brit. 1964).
Presents information on a wide range of cold-cathode tubes and their application.

2820 *Earth, Moon and Planets*. F. L. Whipple (Amer. 1963).
A non-mathematical and up-to-date book written in non-technical language by the Director of the Smithsonian Astrophysical Observatory.

W. D. FLORENCE,
Librarian.

Regional Notes

London Telecommunications Region

A NEW CALL-OUT SYSTEM FOR FIREMEN

On 14 June a new communication network was introduced for the London Fire Brigade to speed mobilization of fire appliances and to alleviate staff shortages. The successful opening was accomplished by the collaboration of all the London Areas.

The focal point of the new system is a specially-designed P.A.B.X. No. 4 installation at the Brigade's Albert Embankment headquarters. Mobilization of fire engines in the inner London area is now achieved by an integrated telephone-teleprinter system. Some 65 stations are connected to the network, which provides telegraph lines for operational requirements and administrative facilities via the P.A.B.X.

A teleprinter broadcast switchboard is associated with each cordless P.A.B.X. position. Emergency "999" calls from auto-manual exchanges and fire telephones are received by the telephonist. The calls are monitored by the teleprinter operator and, when the address of a fire is given, he refers to a card-index street directory to obtain the predetermined number of appliances to be sent. In London, fires are attended by at least three appliances from different stations, to reduce the risk of traffic hold-ups. While the telephonist confirms details with the caller, the teleprinter operator rings the fire bells at the selected stations by signalling from the broadcast panel. The signal, applied over the administrative lines, can open the station doors and switch on lights in the appliance room. By the time the appliances are ready, full details have been sent by teleprinter broadcast for the local fire officers to remove from the machines as they leave the stations.

The administrative private wires from the headquarters are used, in addition, for the telephones outside the fire stations (known as running-call telephones) which are also used by the public for emergency calls. Calls from the running-call telephones have priority over administrative traffic, and when the handset is lifted an earth-loop signal is extended to the P.A.B.X. to divert the line to a special key-ended display panel.

The fire brigade anticipate that considerable manpower savings will be made with the selective teleprinter broadcast system as it will now allow fire-station watchrooms to be left unattended.

J.L.D.

Scotland

WOODCROFT TRUNK NON-DIRECTOR EXCHANGE

Woodcroft trunk exchange in Edinburgh was formally opened by the Director General, Sir Ronald German, on 9 July 1965. Building work started in February 1961, and was completed in September 1964. Equipment installation started in July 1963, before building work was complete so that conditions were far from ideal. Installation was completed on 3 June 1965, and the exchange was brought into service on 26 June.

The exchange equipment includes a trunk switching unit with 4,000-type and motor-uniselector-type group selectors, a trunk signalling unit, with mainly S.S.A.C. No. 9 and S.S.D.C. No. 2 relay-sets, an originating and incoming subscriber trunk dialling (S.T.D.) unit, a 40-position auto-manual switchboard, a 24-position directory-inquiry suite, a 10-position monitorial suite, a 7-position centralized service-observation suite, a 6-position trunk-test suite and a 7-position maintenance-control suite.

Woodcroft replaces the incoming trunk unit at Rose Street in Edinburgh and the trunk non-director exchange at Fountainbridge in Edinburgh, and allows S.T.D. facilities to be given to the remainder of the Edinburgh director exchanges as well as extension of existing S.T.D. access.

All zone and group centre circuits were transferred to Woodcroft from Fountainbridge and Rose Street, with the exception of forced overflow routes to Glasgow and London (Kingsway) from the Talisman and Edinburgh auto-manual exchanges.

Signalling systems have been changed from S.S.A.C. No. 1 to S.S.A.C. No. 9 on the majority of the zone and group centre routes. S.S.D.C. No. 2 signalling was also extended to many group centre routes. Incoming register-translator access is provided on all incoming zone and foreign group centre routes.

The transfer of circuits to Woodcroft was effected instantaneously by transfer-switching arrangements provided at Edinburgh and at distant exchanges where a change of signalling or routing was involved. Pre-transfer rearrangements at Edinburgh included, whenever practicable, the interception or diversion of trunk and junction cables via the M.D.F. or M.R.D.F. at Woodcroft. Many circuits were permanently routed via Woodcroft before the transfer and were extended temporarily to Fountainbridge or Rose Street via transfer-switching keys, the operation of which disconnected the temporary extension. Circuits which were not routed via Woodcroft were diverted or extended at the time of transfer, switching arrangements having been provided at some 25 other Edinburgh exchanges.

To simplify the transfer arrangements at director exchanges by avoiding the need for massive translation changes at the time of transfer, the majority of remote non-director (R.N.D.) and unit automatic exchange (U.A.X.) codes had been changed and translations provided in advance. It was not possible to do this for eight codes and these had their translations changed at the time of transfer. The changes were effected by taking a number of directors out of service at each exchange before transfer, recovering the existing translations for the codes concerned, and providing the new translations. At the time of transfer the directors with the new translations replaced the working directors, which were then taken out of service and their translations changed. The 9XX service codes were replaced at this time with the standard 19X codes, and the "ASK" service was introduced.

The provision of new magnetic-drum register-translators at Woodcroft allowed the new translations for existing and extended S.T.D. access to be provided in advance of transfer. At three group centres and R.N.D.s with S.T.D. service already in existence, new translations were made available at each exchange by taking one translator out of service before the transfer, providing new translations, and replacing the working translator by the modified translator at transfer. The translator replaced was immediately modified after transfer and then restored to service.

A transfer control and fault-reporting centre was established at Woodcroft. Only a minimum of direct control of outstation work was exercised by this transfer control. Officers in charge of outstations proceeded independently with their pre-transfer, transfer and post-transfer operations. This arrangement worked extremely satisfactorily.

W.G.C.

Midland Region

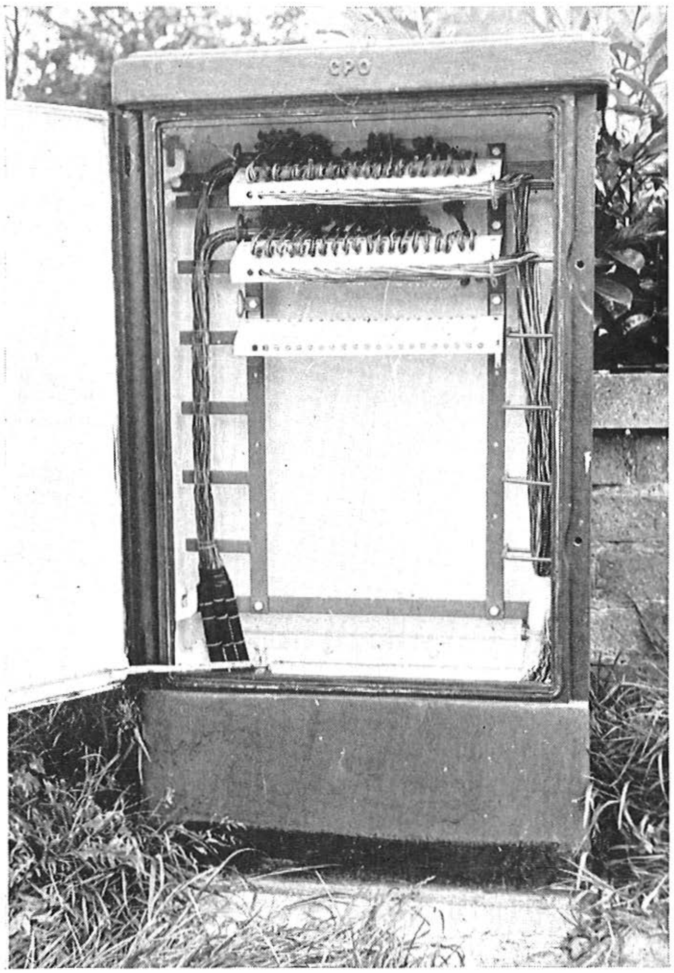
EXPERIMENTAL FLEXIBILITY UNITS

A review of the means of providing flexibility in external plant has recently been undertaken in the Midland Region. This was brought about by worsening maintenance conditions in cabinets, by changing circumstances such as increasing telephone density and higher labour costs, and by the introduction of new materials such as polythene-insulated cable and insulated conductor joints.

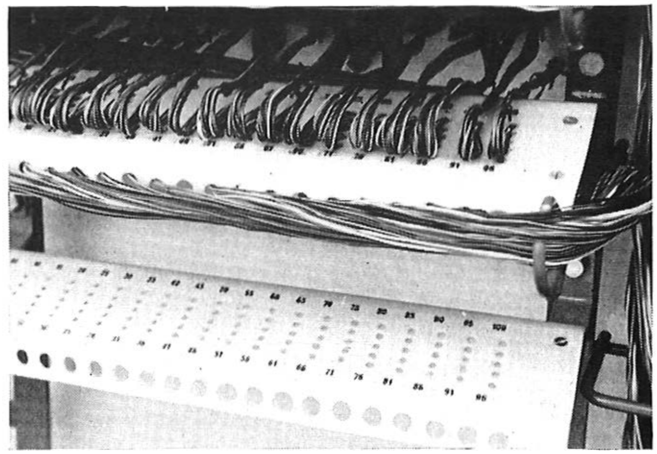
The existing cabinet area, based on the number of tenancies rather than on a forecast, appeared to constitute the most economic size of flexibility unit, and a method of leading polythene-insulated cables directly into cabinet shells and jointing them by means of grease-filled compression sleeves was considered.

It was desirable to adhere as closely as possible to the existing method of recording allocation of pairs, and to enable individual E-side and D-side pairs to be readily identifiable. Thus, a system was developed in the Midland Region that employs plastic shelves having numbered holes through which the D-side pairs are passed to correspond to D-side terminations. E-side pairs are collected in a numbered sequence to form the equivalent of E-side terminations.

A prototype was constructed in August 1964, and at a meeting with the Engineering Department, in January 1965, the Midland Region was asked to undertake a field trial, as the External Plant and Protection Branch and the Local Lines and Wire Broadcasting Branch, Engineering Department, were considering similar methods.



MODIFIED CABINET FOR CROSS-CONNECTING POLYTHENE-INSULATED CABLES



CABINET SHELF DETAILS

The trial is being restricted to the Birmingham Area at present, and the photographs show a cabinet installed at Solihull and the type of mounting which has been introduced to accommodate the cabling and the shelves. The capacity of such cabinets is 50 per cent higher than when assemblies are installed.

Scotchlok UR connectors are used to joint the conductors. All D-side cable pairs are taken to the numbered holes in the shelves, whereas only those E-side pairs which are to be connected at that time are taken through jumper rings to the corresponding holes for jointing. D-side to D-side (and, exceptionally, shared service) connexions can be provided by means of a polythene-insulated jumper. After jointing the required pairs at the front of the shelves, the pairs are folded over so that the Scotchlok connectors lie at back of the cabinet.

Although main cables are provided in instalments, exchange pairs will be put through to distribution poles (D.P.) only in sufficient numbers to meet two or three years' growth at any one time. Relief of a shortage of pairs at any D.P. (or pillar) will be undertaken by the external planning group upon advice from Installation Control, or when shown to be necessary at the review of spares in cabinets when the 6-monthly spare-plant return is compiled. A further allocation of pairs will then be made by the planning group. It is not intended that a shortage of exchange pairs at a D.P. should be corrected by the diversion of pairs from another D.P. within the cabinet. Once a pair has been put through in the cabinet it will not normally be changed. The conductors are, however, of sufficient length to enable them to be re-jointed several times, if essential.

The cabinets will be equipped with locks requiring special keys, and will be under the control of the maintenance supervising officer.

H.G.G., R.G.T., and L.G.C.B.

Associate Section Notes

Bedford Centre

From 29 April until 2 May the Bedford Centre visited the Belgian Telecommunications Department in Brussels. Mr. A. H. C. Knox, C.R.E., led the Party, which consisted of 36 members and wives from various parts of the Home Counties Region.

Friday, 30 April, was spent visiting the telex centre, an automatic exchange and the accounting department. Mr. Knox, the Chairman and the Secretary were presented to the Lord Mayor of Brussels, and handed to him a letter of greetings from the Mayor of Bedford. The visit ended with tea beside Lake Groënendahl some miles from Brussels. All day Saturday and Sunday morning were spent sightseeing, and the party returned home Sunday afternoon.

D.A.C.

Canterbury Centre

The annual general meeting and dinner of the Canterbury Centre was held on Friday, 14 May 1965, at the County Hotel, Canterbury. The following officers and members of the committee were elected: *Chairman:* Mr. H. Shugrue; *Vice-Chairman:* Mr. M. S. J. Green; *Treasurer:* Mr. D. W. Wainwright; *Secretary:* Mr. B. Clapson; *Assistant Secretary:* Mr. P. Croucher; *Committee Members:* Messrs. D. Medhurst, W. Heath, J. Simpson, C. Cox, B. Fletcher, P. L. Johnson, L. M. Wadey, J. Read and W. Gretton.

The dinner was attended by approximately 60 members, senior members and guests. The guest speaker was Mr. E. Hoare, President of the Associate Section. The guests present included Mr. A. H. C. Knox, Chief Regional Engineer, Mr. A. H. Watkins, Regional Liaison Officer, and Messrs. S. T. E. Kent and J. Bluring, Area Engineers. Mr. C. W. A. Kent, Telephone Manager, presided.

B.C.

Inverness Centre

The annual general meeting was held on 28 April and the following officers were elected for the 1965–66 session: *Chairman:* Mr. J. W. Innes; *Vice-Chairman:* Mr. B. W. Fieldsend; *Secretary:* Mr. W. Catto; *Treasurer:* Mr. D. Neave; *Librarian:* Mr. R. Russell; *Committee:* Messrs. L. G. Nuttall, R. Pirrie, A. Ross, I. Stewart, R. H. Inglis and R. Russell; *Auditors:* Messrs. K. Hall and S. Fraser.

After the meeting a debate followed on the motion that "The Telephone Service Presents a Poor Image to the General Public." With Mr. J. J. Loughlin acting as chairman, Mr. J. W. Innes spoke for the motion, which was seconded by Mr. W. Catto. Against the motion was Mr. J. W. P. Miller, seconded by Mr. J. Barron. On a show of hands the motion was carried by a large majority.

The program for the 1965–66 session is at present being compiled and the subjects offered range from "Communications Satellites" to "Gardening for the Amateur."

W.C.

Aberdeen Centre

In April many of our members enjoyed a visit to the British Motor Corporation factory at Bathgate where commercial vehicles and tractors are produced. The assembly lines were seen from start to finish, and at various points many of the "off-line" activities were explained. The engine production unit of the factory was perhaps the most interesting in that progress could more readily be seen to be occurring on the smaller product. A multitude of different types of machines were seen, including an automated one for producing cylinder blocks. Most of the members felt that the 2½-hour visit was insufficient but extremely interesting.

The 1964–65 annual general meeting was held on the 7 May. The following office bearers were elected: *President:* Mr. J. B. Duff; *Vice-President:* Mr. J. McLeod; *Chairman:* Mr. R. T. Ross; *Secretary and Treasurer:* Mr. D. White; *Assistant Secretary:* Mr. G. D. Adam; *Librarian:* Mr. P. McAnulty; *Auditors:* Messrs. E. D. Petrie and G. Milne; *Committee:* Messrs. A. Forster, G. Fox, R. M. Hill, R. Kemp, D. C. McLean, R. Matthewson, J. B. Michie, J. S. M. Morrison, J. T. Pike, J. H. Robertson, R. Sandison, J. H. Simpson, J. A. Stephen, A. Webster, W. Williamson and A. E. Yule.

Following directly after the formalities of the meeting, associate and senior members enjoyed an excellent dinner and social evening.

D.W. and G.D.A.

Edinburgh Centre

The Centre rounded off the winter session with the annual general meeting and dinner which was held in the Leamington Hotel, on Thursday, 15 April. The dinner was well attended; our guest was Mr. R. Burns, the Associate Section Liaison Officer. The evening, as usual, was a great success. The following officers were elected for the 1965–66 session: *Chairman:* Mr. H. Donaldson; *Secretary:* Mr. J. A. Coghill; *Treasurer:* Mr. R. Elder; *Assistant Secretary:* Mr. J. Duncan; *Librarian:* Mr. R. L. Harris; *Committee:* Messrs. T. A. Woolard, H. R. Phillip, J. H. King, I. A. Barkley and D. Stenhouse; *Auditors:* Messrs. R. Cockburn and L. Young.

We wish to thank Mr. J. Dickson, our outgoing Secretary, for his past work and effort on behalf of the Centre and to wish him success in his new appointment.

J.A.C.

Dundee Centre

At the annual general meeting of the Dundee Centre, held in Dundee on Tuesday, 18 May, the following office bearers and committee members were elected: *Chairman:* Mr. R. L. Topping; *Vice-Chairman:* Mr. R. C. Smith; *Secretary:* Mr. R. T. Lumsden; *Treasurer:* Mr. D. L. Miller; *Committee:* Messrs. Bannerman, Bunt, Hennesey, Mackie, Patrick and Pirie.

Attendances at meetings during the 1964–65 session show an increase and enthusiasm seems to be increasing amongst new members. A tentative program for the next session was drawn up and hopes are high that a most interesting syllabus can be arranged.

R.T.L.

Bath Centre

In January a presentation was made to Mr. L. Vranch, ex-Chairman of the Centre, for his success in the 1963–64 Associate Section Members Papers Competition, in which he gained 1st prize. The presentation was made by Mr. C. A. L. Nicholls, C.R.E., South Western Region, at a senior-section meeting.

Also during January, Daystrom of Gloucester gave a demonstration of the high-fidelity equipment which they produce in kit form.

In February we held our annual telephone dance. This was, as usual, a popular event and very well supported. In March we were the guests of the Bristol Centre for a general knowledge quiz, of which we were the winners; we hope to entertain the Bristol Centre at a return match in March 1966. Thanks are due to Mr. Povey of Taunton, for the use of items of telephone equipment of historical interest from the Telephone Museum. These items provided a round of particular interest to participants and audience.

April saw the annual general meeting, the election of officers, and the planning of future programs. A visit took place during April to the B.B.C. Western Region Studios at Whiteladies Road, Bristol, which was well attended. Members found plenty to interest them in the sound and television studios.

During June, members visited the R.A.F. station at Colerne. There they were shown ground and airborne communication and navigational equipment, and were conducted round the air-traffic control centre, meteorological office and the Hastings aircraft.

R.R.D.

Sheffield Centre

On 16 January some 70 members and friends attended the annual Christmas social. Entertainments included a film show, games and dancing, and an enjoyable supper was served.

In February, Messrs. Brooks and Allen of the Main Lines Planning and Provision Branch, Engineering Department, gave an excellent lecture on "Cable Pressurization." Demonstrations and slides added considerable interest to the talk.

On 4 March, an afternoon visit was arranged to "Denby Pottery" at Ripley, near Derby. All stages of pottery working from mixing the various clays to the painting and finishing processes were seen by 30 members. Line insulators were being made for the Post Office, along with famous brands of kitchenware.

In early April a fire prevention officer from Sheffield City Fire Brigade addressed the centre on "Fires and their Prevention." He showed a film strip of notable fires which had occurred in the city and explained their causes and how they could have been prevented.

On 22 April members visited the Post Office Supplies Department stores at Birmingham, where they were shown the punched-card unit, and the progress of a requisition through the stores.

The annual general meeting was held on the 14 May, and the following officers and committee were elected: *Chairman:* Mr. A. Knowles; *Vice-Chairman:* Mr. H. S. Beddus; *Secretary:* Mr. D. Ashton; *Assistant Secretary:* Mr. B. A. Sargent; *Financial Secretary:* Mr. C. S. Shepherd; *Committee:* Messrs. F. Bough, F. S. Bracher, J. G. Buckley, S. Cottage, T. Duncum, C. B. Gray, A. E. Jewitt, R. B. Lines, J. E. Poulton, J. K. Tomlinson and B. Woodhouse.

B.A.S.

Liverpool Centre

The first attempt to start an Associate Section in Liverpool was begun early this year, and an ad-hoc committee was set up under the Area Engineer, Mr. W. K. Dunn, with Messrs. R. N. Ross, C. Marooth and W. Brown. A recruiting campaign was developed over several months and by June the Centre consisted of 160 members. The Committee was elected by ballot, and meetings were held to work out the details of the first session, 1965–66. A program of meetings and visits has been drawn up and for the first year, at least, meetings will take place in the Welfare Room at Lancaster House, Liverpool, at 6 p.m. on the last Thursday in the month. The session started in September 1965 and summer visits will be made at the end of this session. Several suggestions have been made for these visits which met with general approval. Almost a year's notice is required for some of these visits, and a selection is being made from the following: Ford or Vauxhall motor companies, Pilkington's glass works, television studios, John Summers iron works.

The inaugural meeting was held on Thursday, 30 September 1965, when Mr. E. Hoare, President of the Associate Section, talked about "The Next 40 Years." A total of six papers has been arranged for the session.

The elected Committee is as follows: *Chairman:* Mr. R. N. Ross, Maintenance, Stoneycroft; *Vice-Chairman:* Mr. D. M. Murray, External Construction, Birkenhead; *Secretary-Treasurer:* Mr. W. Brown, Internal Planning, Liverpool; *Committee Members:* Messrs. J. R. Finney, Maintenance, St. Helens; G. A. Gallagher, Training School, Liverpool; W. Hilton, Maintenance, Anfield; Barbara Hughes, Telephone Manager's Office, Liverpool; D. J. Lyon, Internal Construction; J. H. Stephenson, Maintenance, Trunk Non-Director Exchange.

Committee members will serve for 2 years and the retiring members at the end of the first year will be selected by ballot. They will be eligible for re-election on this occasion. Nominations will be called for at the annual general meeting in April 1966. The Vice-Chairman will go up to Chairman and the Chairman will serve on the Committee for a further 2 years as Past-Chairman.

A target of 400 members is aimed at over the next three or four sessions to ensure a substantial and steady attendance at meetings.

W.K.D.

Preston Centre

The first annual general meeting was held on the 26 April following a successful first year of the Centre.

The following officers were elected: *Chairman:* Mr. J. Catterall; *Secretary:* Mr. B. Worswick; *Treasurer:* Mr. M. Hood; *Committee:* Messrs. J. Mahon, R. Flitcroft, F. Ponsonby and G. Sharples.

Our President, Mr. Saunders, has now left us to become Telephone Manager in Norwich and we wish him every success. Mr. Houldsworth, Area Engineer, has kindly agreed to accept our invitation to be President.

One of our members, Mr. E. Byron, has been promoted to A.E.E. and we wish to congratulate him.

On 15 April 1964 the program was opened by a visit to the Ribble Generating Station. This expedition was well attended.

The September meeting consisted of a film show: "M1 Motorway," and "Transistors" by Mullards.

On 20 October 1964 a visit was made to the Premium Bonds office at Lytham St. Annes. This proved to be most interesting and consisted of a short film, "The Importance of Being ERNIE," which dealt with the organization, both during the draw and the subsequent search for the winning number. A demonstration was then given of ERNIE in action and questions were answered by the Draw Controller and the maintenance officers present.

The visit on 10 November 1964 to a brewery at Blackpool was a great success. The whole process of brewing and bottling was explained and members were invited to sample the finished product.

On 26 January 1965 the Lancaster Centre kindly invited us to a lecture by a British Aircraft Corporation expert on "High-Speed Flight."

Members visited the new S.T.D. equipment at Preston on 23 February.

We now have 40 members and look forward to another successful session.

B.B.W.

London Centre

The second Annual Conference took place on 26 May 1965 in the Council Room of the Institution of Electrical Engineers, Savoy Place, London. The Conference was presided over by Mr. E. Hoare. Our Liaison Officer, Mr. F. C. Greening with Mr. A. Welling, the Chairman, and other officers of London Centre were present. Mr. Hoare opened the Conference at 2.0 p.m. and welcomed representatives from all areas. Mr. Hoare then presented the C. W. Brown award and the Associate-Section cheque to Mr. D. C. Peddleston of Long-Distance Area for "devoted service towards the aims of the I.P.O.E.E. Associate Section" in his area. A special C. W. Brown award and a cheque were also presented to Mr. W. C. Peck for outstanding service to London Centre. Mr. Peck has had to retire from the Treasurer's post.

The winners of the London Telecommunication's Region Quiz this year were S.W. Area, and Mr. Hoare was pleased to present the trophy to the team captain Mr. R. A. Hammond. The captain of East Area, Mr. G. Hunt, received from Mr. Hoare the runners-up trophy.

The 1965–66 session opened with a talk by Captain F. Walton of B.O.A.C. on 21 September entitled "The Work of an Airline Pilot," and this will be followed on 19 October by a talk on "TV Developments with Colour on 625 Lines" by Mr. A. W. Welsh.

R.W.H.

Staff Changes

Promotions

Chief Regional Engineer to Assistant Engineer-in-Chief

Name	Region, etc.	Date
Blair, D. C.	W.B.C. to E.-in-C.O.	7.6.65

Deputy Chief Regional Engineer to Chief Regional Engineer

Name	Region, etc.	Date
Thompson, A. J.	L.T. Reg.	29.4.65

Assistant Staff Engineer to Staff Engineer

Name	Region, etc.	Date
Humphries, W. A.	E.-in-C.O.	18.3.65
Forty, A. J.	E.-in-C.O. to T.S.U.	14.6.65
Jowett, J. K. S.	E.-in-C.O.	21.6.65
Jemmeson, A. E.	E.-in-C.O.	11.3.65

Regional Engineer to Chief Regional Engineer

Name	Region, etc.	Date
Mellor, S. D.	N.W. Reg. to W.B.C.	21.6.65

Regional Engineer to Regional Engineer and Telecommunications Controller

Name	Region, etc.	Date
Haliburton, F. C.	N.E. Reg. to N.I.	23.6.65

Area Engineer to Regional Engineer

Name	Region, etc.	Date
Pooley, E. H.	Mid. Reg.	1.4.65

Area Engineer to Telephone Manager

Name	Region, etc.	Date
Saxby, F. H.	Mid. Reg.	25.5.65
Gilbey, P. D.	N.E. Reg.	1.4.65
Stanier, J. H.	N.W. Reg.	11.3.65
Saunders, J. C.	N.W. Reg. to H.C. Reg.	29.3.65

Senior Executive Engineer to Assistant Staff Engineer

Name	Region, etc.	Date
Chapman, K. J.	E.-in-C.O.	14.6.65
Combridge, J. H.	E.-in-C.O.	2.6.65
Morton, J. Y.	E.-in-C.O.	14.6.65
Turner, D.	E.-in-C.O.	14.6.65
Judson, J. E.	E.-in-C.O.	25.6.65

Senior Executive Engineer to Deputy Principal

Name	Region, etc.	Date
Bellew, T. K.	E.-in-C.O.	20.4.65

Senior Executive Engineer to Deputy Telephone Manager

Name	Region, etc.	Date
Rogers, D. M.	L.T. Reg.	25.5.65

Senior Executive Engineer to Regional Engineer

Name	Region, etc.	Date
Tomlinson, H.	N.E. Reg. to N.W. Reg.	22.6.65

Executive Engineer to Area Engineer

Name	Region, etc.	Date
Holloway, K.	E.-in-C.O. to L.T. Reg.	20.4.65
Allen, J. M.	Scot. to H.C. Reg.	31.5.65
Corby, P. D.	L.T. Reg.	11.6.65

Executive Engineer to Senior Executive Engineer

Name	Region, etc.	Date
Mellors, W. J.	L.T. Reg. to H.C. Reg.	20.4.65
Fielding, H.	E.-in-C.O.	27.5.65
Vicary, P. F.	E.-in-C.O.	27.5.65
Westcott, R. J.	E.-in-C.O.	27.5.65
Bates, S.	Mid. Reg. to E.-in-C.O.	28.6.65
Haines, G. E.	E.-in-C.O.	28.6.65
Foster, H. A. L.	E.-in-C.O.	2.6.65
Smith, C. S. A.	E.-in-C.O.	21.6.65
Knox, K. A. T.	E.-in-C.O.	3.6.65
Ithell, A. H.	E.-in-C.O.	1.6.65
Cosier, J. E. H.	E.-in-C.O.	3.6.65
Hunt, C. S.	E.-in-C.O.	8.6.65
Chatwin, W.	N.W. Reg. to E.-in-C.O.	14.6.65
Chesterman, D.A.	E.-in-C.O.	17.6.65
Turner, G. (in absentia)	E.-in-C.O.	17.6.65
Allen, J. A. W.	C.E.S.D.	1.6.65

Executive Engineer (Open Competition)

Name	Region, etc.	Date
Evans, J. H.	E.-in-C.O.	14.6.65
Waring, B.	E.-in-C.O.	19.5.65

Executive Engineer (Limited Competition)

Name	Region, etc.	Date
Yeates, B. L. E.	E.-in-C.O.	8.6.65
Palmer, G. B.	E.-in-C.O.	24.5.65
Harry, R. J.	E.-in-C.O.	24.5.65
Jones, R. A.	E.-in-C.O.	8.6.65
Stichbury, R. L.	T.S.U.	13.5.65
Comber, G.	E.-in-C.O.	18.5.65
Nye, P. J.	E.-in-C.O.	24.5.65
Medcraft, D. H. F.	E.-in-C.O.	8.6.65
Finden, R. E.	E.-in-C.O.	8.6.65
Childs, R.	E.-in-C.O.	10.5.65
Phillips, J. L.	E.-in-C.O.	24.5.65
Clow, D. G.	E.-in-C.O.	1.6.65
Stayton-Davis, A. M.	T.S.U.	21.6.65
Soames, S. T.	E.-in-C.O.	21.6.65
Brooks, M.	E.-in-C.O.	24.5.65
Gibbs, R. C.	E.-in-C.O.	19.5.65
Wicken, C. S.	E.-in-C.O.	24.5.65
Gibbons, A. K.	L.T. Reg.	1.6.65
Yates, R. F.	E.-in-C.O.	10.5.65
Hurcom, J. G.	E.-in-C.O.	1.5.65
Henly, H. R.	E.-in-C.O.	24.5.65
Brownlee, G.	T.S.U.	14.5.65
Kirby, A.	E.-in-C.O.	19.5.65
Godden, B. F.	E.-in-C.O.	31.5.65
Risbridger, J. N. A.	E.-in-C.O.	24.5.65
Myhill, R. P.	E.-in-C.O.	19.5.65
Peacock, R. D.	E.-in-C.O.	12.5.65
Skingle, G. D.	E.-in-C.O.	8.6.65
Golesworthy, H. M. G.	E.-in-C.O.	12.5.65

Assistant Executive Engineer to Executive Engineer

Name	Region, etc.	Date
Graham, R. J.	L.T. Reg.	31.3.65
Rooker, H. M.	L.T. Reg.	31.3.65
McLennan, A. W.	L.T. Reg.	31.3.65
King, F. A.	L.T. Reg.	31.3.65
Overton, S. E.	L.T. Reg.	31.3.65
Rowe, R. P.	L.T. Reg.	31.3.65
Sudbery, A. J.	L.T. Reg.	31.3.65
Hart, B. N.	E.-in-C.O.	29.4.65
Hall, B.	E.-in-C.O.	29.4.65
Forster, J. F. S.	E.-in-C.O.	29.4.65
Simpson, E. C.	E.-in-C.O.	29.4.65
Bromilow, T. G. E.	Mid. Reg.	31.3.65
Hinks, C. T.	Mid. Reg.	31.3.65
Goldie, H. G.	Mid. Reg.	31.3.65
McGilvray, D. A.	E.-in-C.O.	15.4.65
Donaldson, G. T.	N.I.	29.4.65
Campbell, A. T.	E.-in-C.O.	29.4.65
Davis, W. B.	E.T.E.	29.4.65
Hutchinson, W. A. W.	L.T. Reg.	31.3.65
Barry, M.	E.T.E.	3.5.65
Emery, T. M.	E.-in-C.O.	10.5.65
Sales, D. A.	H.C. Reg. to E.-in-C.O.	24.5.65
Robinson, A. J.	L.T. Reg. to E.-in-C.O.	31.5.65
Roe, N. J.	E.-in-C.O.	25.5.65
Mackie, J. R.	E.-in-C.O.	24.5.65
Sparrow, D. H.	H.C. Reg.	10.5.65
Hood, J. W.	L.T. Reg.	10.5.65
Brand, F. R.	L.T. Reg.	10.5.65
Clark, L. C. J.	L.T. Reg.	10.5.65
Hodges, C. A.	L.T. Reg.	10.5.65
Patrick, G. R.	L.P. Reg. to E.-in-C.O.	28.5.65
Robinson, J.	E.-in-C.O.	28.5.65
Bartlett, L. W.	E.-in-C.O.	28.5.65
Jones, A. T.	N.W. Reg.	27.5.65
Brown, A. H.	E.-in-C.O.	1.6.65
Edmonds, J. G.	E.-in-C.O.	1.6.65
Ridgway, W. L.	E.-in-C.O.	10.6.65
Fisher, J.	E.-in-C.O.	10.6.65
Treasure, S. D.	E.-in-C.O.	10.6.65
Marchant, L. W. K.	L.T. Reg. to E.-in-C.O.	10.6.65
Young, K. W.	E.-in-C.O.	10.6.65
Skinner, P. H.	E.-in-C.O.	10.6.65
McCann, D. B.	Scot. to H.C. Reg.	28.6.65

Name	Region, etc.	Date
Assistant Executive Engineer to Executive Engineer—continued		
Waters, F. J.	H.C. Reg. to L.T. Reg.	14.6.65
Popham, D. A. E.	E.-in-C.O.	15.6.65
Smith, B. B.	E.-in-C.O.	21.6.65
Stokes, A. E.	E.-in-C.O.	23.6.65
Coleman, R. F.	W.B.C.	17.5.65
Goodwin, W. J. A. L.	H.C. Reg.	1.6.65
McDonald, D.	Scot.	25.5.65
Bowdidge, W. L.	E.-in-C.O.	29.6.65
Lock, D. C. A.	L.P. Reg. to L.T. Reg.	28.6.65
Giblett, K. G.	S.W. Reg.	21.6.65
Assistant Executive Engineer (Open Competition)		
Gambling, R. S.	E.-in-C.O.	24.11.64
Park, I. D. C.	E.-in-C.O.	7.12.64
Jamison, M. L.	E.-in-C.O.	24.11.64
Anderson, G. W.	E.-in-C.O.	24.11.64
Turner, E. A.	E.-in-C.O.	7.12.64
Wilson, C. P. T.	E.-in-C.O.	24.11.64
McKeown, J. H. A.	E.-in-C.O.	24.11.64
Quaintance, V. G.	E.-in-C.O.	24.11.64
Hearfield, J. K.	E.-in-C.O.	24.11.65
Brown, R. A.	E.-in-C.O.	24.11.64
Gerrard, J.	E.-in-C.O.	24.11.64
Smith, T. W.	E.-in-C.O.	24.11.64
West, N. V.	E.-in-C.O.	24.11.64
Piachand, A. R.	E.-in-C.O.	5.7.65
Assistant Executive Engineer (Limited Competition)		
Wilson, J. W.	E.-in-C.O.	20.4.65
Bennett, H. A. J.	E.-in-C.O.	29.4.65
Inspector to Assistant Executive Engineer		
Johnston, N.	Scot.	16.4.65
Davey, R. E.	H.C. Reg.	5.4.65
Sutherland, J. S.	N.W. Reg.	22.4.65
Pritchard, H. S.	W.B.C.	5.4.65
Restorick, S. I.	H.C. Reg.	6.4.65
Besant, D. A.	H.C. Reg.	6.4.65
Hughes, W.	N.W. Reg.	5.4.65
Horan, F. G.	N.W. Reg.	3.5.65
Mansell, R. J.	S.W. Reg.	26.4.65
Newberry, L. G. W.	S.W. Reg.	10.5.65
Clark, J.	Scot.	4.5.65
Plumridge, A. E.	H.C. Reg.	3.6.65
Purton, S. G.	Mid. Reg.	4.6.65
Technical Officer to Assistant Executive Engineer		
Dunn, D. J.	Scot.	14.4.65
Service, J. L.	Scot.	8.3.65
Lloyd, L. D. G.	S.W. Reg.	12.4.65
Simms, M. W.	H.C. Reg.	6.4.65
Dawkins, T. A.	H.C. Reg.	6.4.65
Foxley, J. G.	N.W. Reg.	1.4.65
Eyre, R. H.	N.W. Reg.	26.4.65
McGregor, D.	Scot.	1.4.65
Carmichael, D. L.	Scot.	22.3.65
Brown, A.	Scot.	22.3.65
Neary, J.	Scot.	5.4.65
Lloyd, H.	W.B.C.	23.4.65
Mitchell, A. D.	N.E. Reg.	29.4.65
Hudd, N. T.	S.W. Reg.	2.4.65
Adams, G.	Mid. Reg.	8.4.65
Wheatcroft, A. W. R.	Mid. Reg.	8.4.65
Kirk, L.	H.C. Reg.	29.4.65
King, D. J.	H.C. Reg.	29.4.65
Gurney, G. A.	H.C. Reg.	29.4.65
Rayner, M. D.	H.C. Reg.	29.4.65
Archer, R. J. E.	S.W. Reg.	2.4.65
Alderton, P.	H.C. Reg.	29.4.65
Gouldson, D. R.	N.W. Reg.	20.4.65
Proctor, E.	N.W. Reg.	2.4.65
Moss, N. T.	N.W. Reg.	5.4.65
Woodhouse, E. W.	N.W. Reg.	2.4.65
Jones, M.	W.B.C.	23.4.65
Beardsworth, T.	N.W. Reg.	29.4.65
Technical Officer to Assistant Executive Engineer—continued		
King, E. F.	L.P. Reg.	15.4.65
Beaver, F. N.	S.W. Reg.	23.4.65
Smith, H. S.	S.W. Reg.	10.5.65
Tuck, R. A.	Mid. Reg.	20.5.65
Dolby, A. K.	Mid. Reg.	20.5.65
Knight, A. P.	H.C. Reg.	5.5.65
Davies, T. M.	W.B.C.	5.5.65
Gowing, D. D.	H.C. Reg.	5.5.65
Atkinson, J. A. M.	N.I.	7.5.65
Tolerton, W. H.	N.I.	7.5.65
Lyons, J.	N.I.	17.5.65
Beggs, R. A.	N.I.	17.5.65
Speed, D. J.	Mid. Reg.	26.5.65
Miller, R. S.	Scot.	3.5.65
Ronaldson, I. M.	Scot.	4.5.65
Gilmore, A. G.	Scot.	3.5.65
Nicol, J.	Scot.	17.5.65
Gray, J.	Scot.	31.5.65
Mason, A. H.	L.T. Reg.	8.4.64
Harley, B. W.	L.T. Reg.	8.4.65
Fraser, D. E.	L.T. Reg.	8.4.65
Smith, M. A.	Scot.	8.4.65
McKenna, L. E.	Scot.	8.4.65
Hitchman, G. M.	E.-in-C.O.	26.5.65
Armstrong, C.	W.B.C.	2.6.65
Owen, R. W. B.	H.C. Reg.	3.6.65
Grave, D. M.	H.C. Reg.	21.6.65
Webb, G. H.	S.W. Reg.	11.6.65
Elias, R. R.	W.B.C.	2.6.65
Martin, N. F.	H.C. Reg.	14.6.65
Fitzgerald, T. E.	L.P. Reg.	26.5.65
Burt, J. A.	H.C. Reg.	14.6.65
Duffy, J.	H.C. Reg.	14.6.65
Engeham, H.	N.W. Reg.	8.6.65
Doyle, W.	N.W. Reg.	8.6.65
Armistead, J. H.	N.W. Reg.	8.6.65
Ball, J. D.	N.W. Reg.	8.6.65
Mulford, B. J.	H.C. Reg.	23.6.65
Ridsdale, K.	Mid. Reg.	30.6.65
Cave, R.	Mid. Reg.	30.6.65
Martin, J.	Mid. Reg.	30.6.65
Brameld, K. C.	Mid. Reg.	30.6.65
Melbourne, J. R.	Mid. Reg.	30.6.65
Flett, A. J.	Scot.	14.6.65
Hook, G. L.	E.T.E.	1.6.65
Jenkins, M. I.	E.T.E.	1.6.65
White, J. N. B.	E.T.E.	1.6.65
Bristow, P. R.	E.T.E.	1.6.65
Foxley, K. J.	E.T.E.	1.6.65
Hassan, A.	E.T.E.	1.6.65
Powell, D. J.	E.T.E.	1.6.65
Newton, C. J.	E.T.E.	1.6.65
Burford, J. R.	E.T.E.	1.6.65
Evans, P. J. R.	H.C. Reg.	23.6.65
Gracey, A. W.	H.C. Reg.	23.6.65
Grossell, D. C.	H.C. Reg.	23.6.65
Draughtsman to Assistant Executive Engineer		
Kirkpatrick, T. J.	H.C. Reg.	9.3.65
Duffield, N. S.	H.C. Reg.	9.3.65
Technical Officer to Inspector		
Haining, R.	Scot.	15.2.65
Banks, J.	Scot.	22.2.65
Alderman, R. W.	H.C. Reg.	6.4.65
Buckley, B. S.	N.W. Reg.	2.4.65
Graham, J. H.	N.I.	17.5.65
Cornelius, P. A.	H.C. Reg.	3.6.65
Lawrence, B.	Mid. Reg.	30.6.65
Friday, J. L. G.	Mid. Reg.	30.6.65
Groves, W.	Mid. Reg.	30.6.65
Harrison, R. D.	Mid. Reg.	30.6.65
Allen, C. E.	Mid. Reg.	30.6.65
List, C. F.	Mid. Reg.	30.6.65
Pinches, D. W.	Mid. Reg.	30.6.65

Name	Region, etc.	Date
Senior Technician to Inspector		
Rigby, F.	H.C. Reg.	29.4.65
Crow, J. W.	H.C. Reg.	24.3.65
Gibb, E. E.	H.C. Reg.	29.4.65
Foster, R. P.	H.C. Reg.	5.5.65
Knight, A. C.	H.C. Reg.	28.5.65
Harrison, A. S.	H.C. Reg.	14.6.65
Technician I to Inspector		
Smith, M. E.	H.C. Reg.	6.4.65
Bemkin, F. N.	W.B.C.	20.4.65
Berry, D. J.	H.C. Reg.	29.4.65
Swain, W. R.	S.W. Reg.	20.5.65
Johnson, H. R.	S.W. Reg.	20.5.65
Scotts, D. W. P.	S.W. Reg.	17.5.65
Hinchcliffe, F.	N.E. Reg.	26.5.65
Miller, J. J.	N.I.	7.5.65
Whitaker, J.	N.E. Reg.	3.6.65
Whitelow, R.	Scot.	8.4.65
Beech, P.	Mid. Reg.	11.6.65
McGregor, I. A.	Scot.	30.4.65
Bosworth, J.	Mid. Reg.	4.6.65
Bullock, G. C.	Mid. Rcg.	11.6.65
Mullens, J. R.	Mid. Reg.	4.6.65
Croucher, G.	N.E. Reg.	28.6.65
Smart, W. J.	Mid. Reg.	30.6.65
Cockerill, R.	H.C. Reg.	23.6.65
Senior Scientific Officer to Principal Scientific Officer		
Baker, D.	E.-in-C.O.	11.6.65
Experimental Officer to Senior Scientific Officer		
Hollins, G. T.	E.-in-C.O.	11.5.65
Scientific Officer to Senior Scientific Officer		
Mellor, P. J. T.	E.-in-C.O.	6.4.65
Experimental Officer (Open Competition)		
Wilson, K. J.	E.-in-C.O.	25.6.65
Assistant Experimental Officer to Experimental Officer		
Fudge, A. D.	E.-in-C.O.	5.4.65
Booth, A. J.	E.-in-C.O.	5.4.65
Assistant Experimental Officer to Experimental Officer—continued		
Geden, D.	E.-in-C.O.	5.4.65
Johnson, C. B. C.	E.-in-C.O.	5.4.65
Scientific Officer (Open Competition)		
Porter, M. A. G. (Miss)	E.-in-C.O.	29.3.65
Assistant (Scientific) to Senior Assistant (Scientific)		
Brooker, J. E.	E.-in-C.O.	1.6.65
Assistant Experimental Officer (Open Competition)		
Stace, W. E.	E.-in-C.O.	28.6.65
Assistant (Scientific) (Open Competition)		
Evans, L. H.	E.-in-C.O.	5.4.65
Perkins, G. W.	E.-in-C.O.	14.4.65
Ali, A. S. M.	E.-in-C.O.	17.6.65
Workshop Supervisor II to Technical Assistant		
Goodhind, R.	N.E. Reg. to S.W. Reg.	19.3.65
Leading Draughtsman to Senior Draughtsman		
Johnson, F. C.	E.-in-C.O. to Mid. Reg.	12.4.65
Draughtsman to Leading Draughtsman		
Burnard, A. E.	E.-in-C.O.	7.4.65
Wakeling, G. A. C.	E.-in-C.O.	7.4.65
Strickland, D. C.	L.T. Reg. to E.-in-C.O.	3.5.65
Draughtsman (Open Competition)		
Scoggins, R. E. A.	E.-in-C.O.	3.5.65
Draughtsman (Limited Competition)		
Buck, D. E.	E.-in-C.O.	2.4.65
Lucas, D. G.	E.-in-C.O.	14.5.65
Executive Officer (Open Competition)		
Lodge, J. R.	E.-in-C.O.	26.4.65
McMurdo, M.	E.-in-C.O.	29.4.65
Fleming, R. W.	E.-in-C.O.	12.5.65

Retirements and Resignations

Name	Region, etc.	Date
Assistant Staff Engineer		
Chapman, R. H.	E.-in-C.O.	24.5.65
Regional Engineer		
Summers, F.	Mid. Reg.	1.4.65
Executive Engineer		
May, E. G. A.	H.C. Reg.	7.4.65
Bentley, W. C. B.	Mid. Reg.	9.4.65
Hills, J. E.	H.C. Reg.	12.4.65
Archer, E. W.	L.T. Reg.	1.6.65
Keep, J. F.	E.-in-C.O.	30.6.65
Assistant Executive Engineer		
Denney, R. F.	N.E. Reg.	1.4.65
Roberts, J.	N.W. Reg.	4.4.65
Pearce, H. T.	H.C. Reg.	11.4.65
Forbes, B. R. D.	Scot.	15.4.65
Kilgour, A. A.	N.W. Reg.	23.4.65
Lewry, W. R.	H.C. Reg.	29.4.65
Wilson, A. L.	L.T. Reg.	30.4.65
Miles, D. V. (*Resigned*)	E.-in-C.O.	30.4.65
Anderson, P. C. (*Resigned*)	E.-in-C.O.	30.4.65
Assistant Executive Engineer—continued		
Stechman, D. F. (*Resigned*)	E.-in-C.O.	30.4.65
Elkin, W. L.	Mid. Reg.	9.5.65
Hindson, G. V.	N.E. Reg.	16.5.65
Turner, J. V.	H.C. Reg.	22.5.65
Jones, W. L.	W.B.C.	24.5.65
Corkett, R. H.	H.C. Reg.	31.5.65
Cross, R. A. (*Resigned*)	E.-in-C.O.	5.5.65
Helm, J. T.	L.T. Reg.	5.5.65
Sitton, A. A. C.	L.T. Reg.	31.5.65
Head, J. E.	E.-in-C.O.	6.6.65
Chapman, H. L.	E.T.E.	12.6.65
Tennyson, A.	W.B.C.	18.6.65
Teesdale, R. J. (*Resigned*)	E.-in-C.O.	4.6.65
Murray, R. W. (*Resigned*)	H.C. Reg.	5.6.65
Keith, J. F. (*Resigned*)	L.T. Reg.	22.6.65
Inspector		
Newbery, A. W. J.	S.W. Reg.	21.4.65
Moorman, E. E.	L.T. Reg.	26.4.65
Butten, J. T.	N.I.	30.4.65
Brims, H. W.	L.T. Reg.	18.5.65

Retirements and Resignations—*continued*

Name	Region, etc.	Date	Name	Region, etc.	Date
Senior Scientific Officer			*Draughtsman*		
Young, D. A.	E.-in-C.O.	10.5.65	Taylor, J. H. .. .. (*Resigned*)	E.-in-C.O.	9.4.65
Assistant (Scientific)			Knibb, H. W. . . .. (*Resigned*)	E.-in-C.O.	23.4.65
Scott, S. E. .. .. (*Resigned*)	E.-in-C.O.	30.4.65	Wright, A. S. .. .. (*Resigned*)	E.-in-C.O.	31.5.65
Cunningham, P. W. H. (*Resigned*)	E.-in-C.O.	30.6.65	Bonnett, G. W. .. (*Resigned*)	E.-in-C.O.	18.6.65
			Thomsett, J. H. .. (*Resigned*)	E.-in-C.O.	30.6.65
Technical Assistant					
Kemp, A. R.	S.W. Reg.	8.3.65	*Executive Officer*		
Leech-Brown, D. C. ..	S.W. Reg.	17.3.65	O'Brian, M.E.M. (Miss)*	E.-in-C.O.	11.5.65
Brown, G.	Mid. Reg.	31.5.65	Ward, W. H.	E.-in-C.O.	11.5.65
Leading Draughtsman			Reeder, M. E. (Miss) ..	E.-in-C.O.	18.6.65
Theobald, E. S. ..	E.-in-C.O.	25.6.65			

* Miss M. E. M. O'Brian is continuing as a disestablished officer in E.-in-C.O.

Transfers

Name	Region, etc.	Date	Name	Region, etc.	Date
Assistant Engineer-in-Chief			*Experimental Officer*		
Jones, R. E.	E.-in-C.O. to Ministry of Technology	17.5.65	Howard, J. B. (Miss) ..	E.-in-C.O. to Ministry of Aviation	3.5.65
Staff Engineer					
Rhodes, J.	E.-in-C.O. to Home Office	14.6.65	*Assistant Experimental Officer*		
			Viveash, J. P. (Miss) ..	Ministry of Aviation to E.-in-C.O.	1.4.65
Executive Engineer					
Bell, C.	Nigeria to E.-in-C.O. ..	1.4.65	*Leading Draughtsman*		
Lelliott, S. R.	E.-in-C.O. to Ministry of Aviation	26.4.65	Gilbert, T. P.	E.-in-C.O. to C.E.S.D. ..	1.4.65
Davies, G. T.	E.-in-C.O. to N.W. Reg. ..	26.4.65			
Price, A. H.	E.-in-C.O. to L.T. Reg. ..	3.5.65	*Draughtsman*		
Senior Scientific Officer			Young, A. F. C. ..	E.-in-C.O. to H.C. Reg. ..	1.4.65
Rapsey, A. N.	E.-in-C.O. to Home Office	27.6.65	Cook, J.	L.T. Reg. to E.-in-C.O. ..	20.4.65

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

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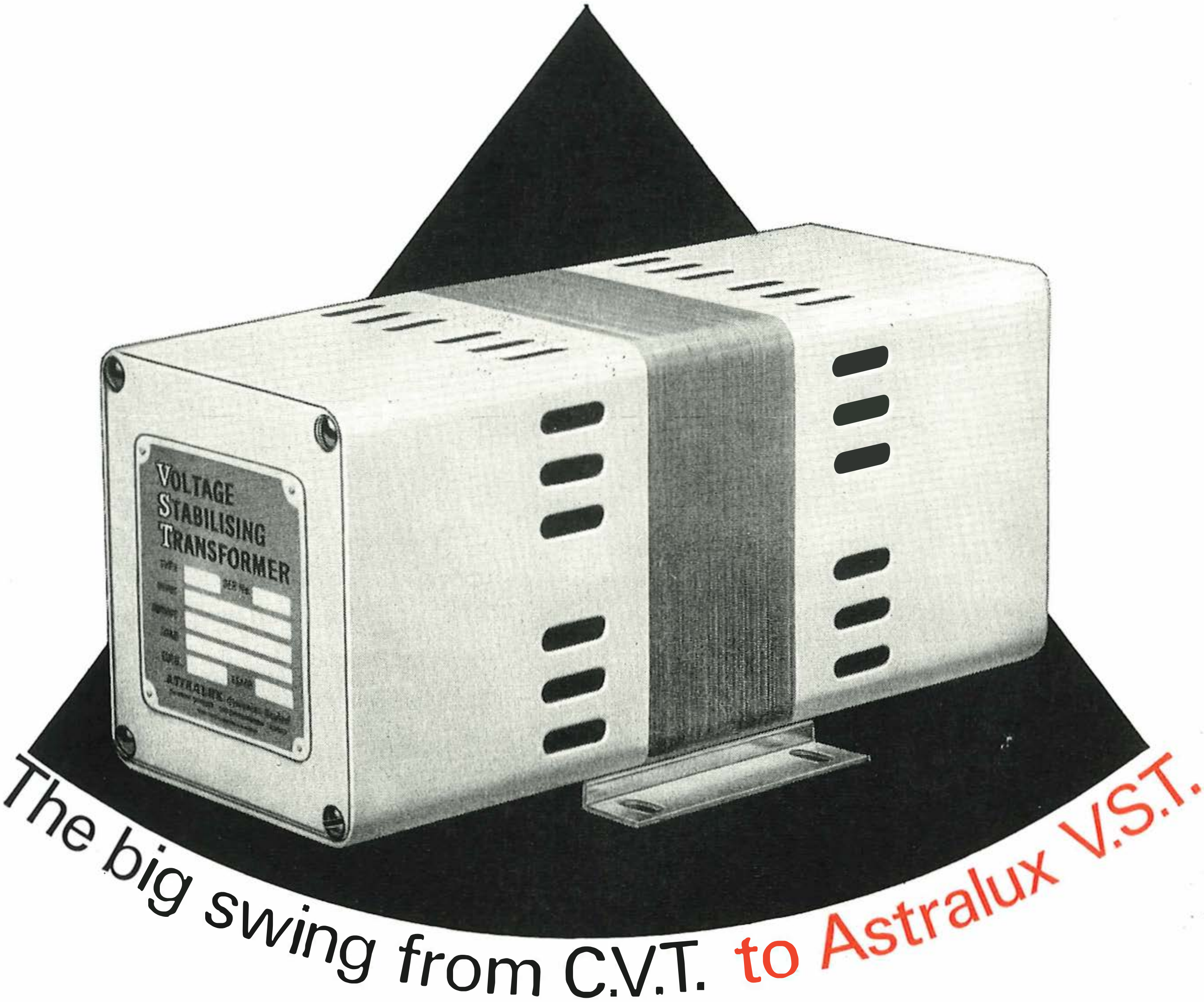
Model Answer Books

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

WHAT'S TRANSFORMERMATION?



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Improved Output Voltage Stability. Output voltage maintained within ±0.5% for input voltage changes of +10% —20%. Even when the input voltage fluctuation is as great as +10% —30% the V.S.T. will maintain the output voltage to within ±1%.

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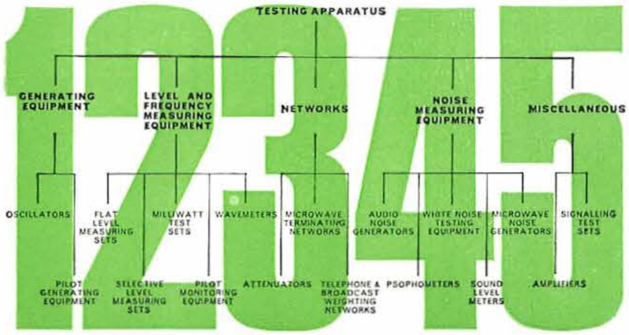
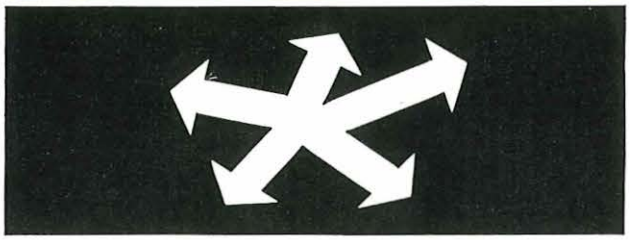
STC TELECOMMUNICATIONS REVIEW

OCTOBER 1965





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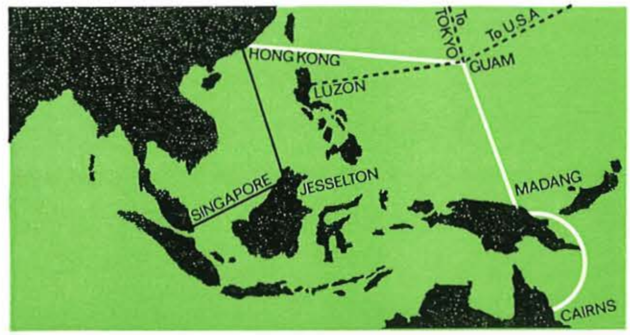
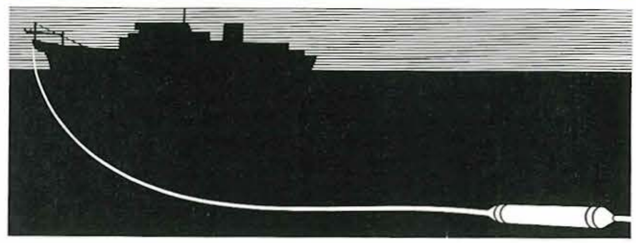
Standard Telephones and Cables Limited, Testing Apparatus Division, Corporation Road, Newport, Mon. Telephone: Newport 72281 (STD ONE3 72281). Telex: 49367. London Office: Telephone: CLErkenwell 4511.





STC and the final SEACOM link

With the orders placed with STC for the final phase of the South-East Asia section of the round-the-world Commonwealth telephone cable, STC will have contributed over £8,000,000 worth of equipment to the SEACOM project. This includes more than 2,600 miles of lightweight and shallow water armoured submarine telephone cable, 265 submerged repeaters, 35 submerged equalizers and shore terminal equipment for both phases of the project. Phase 1, linking Singapore, Jesselton and Hong Kong is now in service and cable laying operations for the final phase are well advanced for linking Hong Kong, Guam, Madang (New Guinea) and Cairns (Australia). Landing SEACOM at Guam permits interworking with the USA-Japan submarine cable (for which STC supplied 2,000 miles of cable) and provides through circuits to the Philippines, Japan and USA.

160-circuit equipment is being used for the Guam-Madang-Cairns route to cope with increasing telephone traffic between Japan and Australia. STC are supplying all the 160-circuit terminal equipment and submerged equalizers and 75% of the submerged repeaters. Its use marks a significant departure from the 80-circuit design of the round-the-world cable so far laid between the UK, Canada, New Zealand and Australia.

From Cairns an overland link will extend the system to Sydney. Here it will connect with the COMPAC and CANTAT systems to provide clear and reliable telephone communications for the first time between South-East Asia and Europe.

Standard Telephones and Cables Limited, Submarine Cable Division, West Bay Road, Southampton, Hants. Telephone: Southampton 74751. Transmission Systems Group, Basildon, Essex. Telephone: Basildon 3040. Telex: 99101.

Talking point

Design conscious but supremely functional—the new STC Deltaphone represents an entirely new approach to telephone design. A choice of restrained colours, lightweight handset, electronic tone caller with volume control, optional dial illumination, compactness . . . everything new!

The STC Deltaphone is particularly suited for use in homes, hotels, reception lounges and 'front offices', where harmony of design, functional elegance and prestige are essential. As well as its superb modern appearance, fit to grace any expensive service flat, the basic economies of space and effort give this new telephone utmost utility in offices and other business premises.

High technical specifications match the trend-setting symmetry of this truly new telephone.

Standard Telephones and Cables Limited, Telephone Switching Division, Oakleigh Road, New Southgate, London, N.11. Telephone: ENTerprise 1234. Telex: 21612.

Lightweights ahead!

STC lightweight headsets are designed for use by private and public telephone operators. These are fast superseding the use of the older breast-type instruments. Main advantages are: extraordinary light weight, high degree of comfort, stability and manoeuvrability and constant level of transmission regardless of head movement. Made of nylon plastic, and virtually unbreakable, the headsets are available in black and grey (colours approved by the British Post Office) and also in ivory. The "Rocking Armature" principle—an important STC development in telephone receiver design—which gives improved sensitivity and frequency response, has been incorporated into these instruments.

Standard Telephones and Cables Limited, Telephone Switching Division, Oakleigh Road, New Southgate, London, N.11. Telephone: ENTerprise 1234. Telex: 21612.

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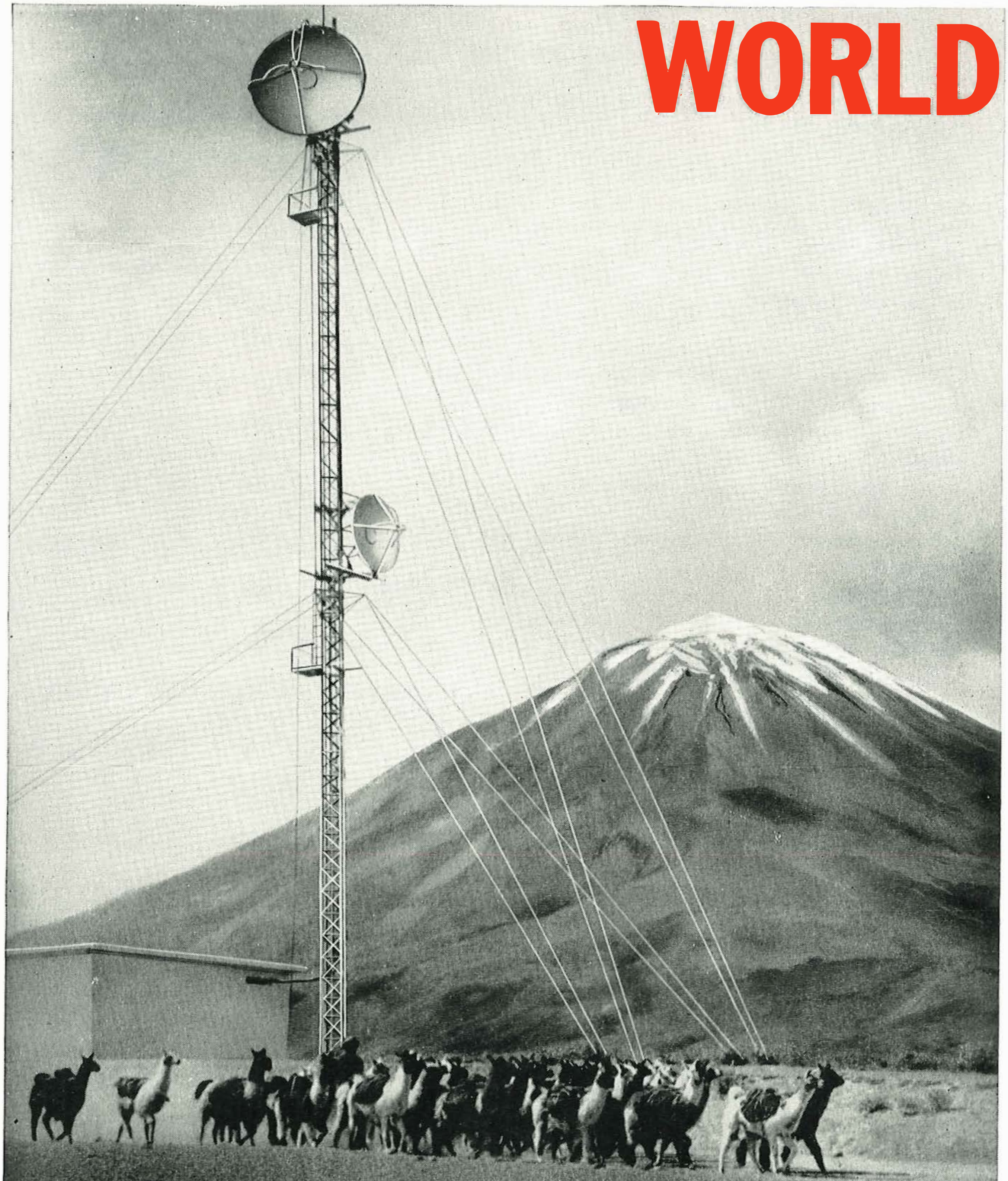
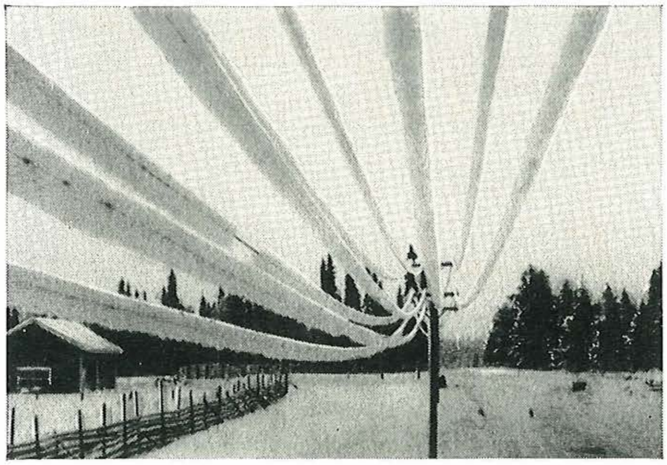
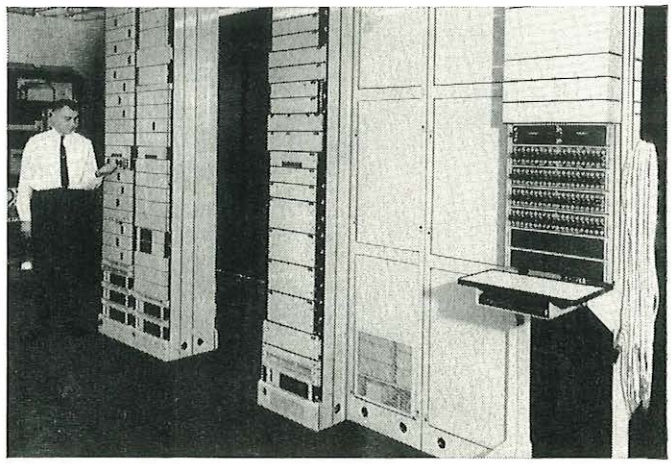
TRANSMISSION SYSTEMS FOR THE WORLD





Open-wire line route in Finland.



Carrier Multiplex Equipment at Toronto Terminal, Canada.

G.E.C. OFFERS A COMPLETE TELECOMMUNICATION SERVICE BY LINE AND RADIO

The wide range of transmission equipment manufactured by G.E.C. enables integrated national and international networks to be built up, catering for all traffic requirements. Ease of future expansion is an inherent feature of the equipment.

Backed by more than 40 years of experience, Transmission Division can offer a complete service including surveying, system planning, engineering, manufacturing, installation and commissioning. Where necessary, customers' engineers are trained by the Company locally or at the G.E.C. Telephone Works, Coventry.

G.E.C. transmission equipment is in operation throughout the world, in climatic conditions which range from arctic to equatorial. Throughout the range of equipment, semiconductors are used wherever possible.

Left: UHF Radio Repeater Station at Caima, Peru.

HIGH CAPACITY SYSTEMS

The Company manufactures a comprehensive range of completely transistored carrier multiplex equipment with capacities of up to 2700 channels, for use over coaxial cable or microwave radio routes. Six types of broadband radio equipment are available; four in the SHF 6000 Mc/s and 7000 Mc/s frequency bands and two in the UHF 2000 Mc/s band. These equipments have maximum capacities varying between 300 and 1800 speech circuits per radio channel according to type. Alternatively, monochrome or colour television signals may be transmitted.

A small-bore coaxial cable system with a maximum capacity of 960 speech circuits is also available.

All these equipments conform to the recommendations of the C.C.I.T.T. and C.C.I.R.

SMALL CAPACITY SYSTEMS

Small capacity systems available include completely transistored 3 and 12-circuit open-wire and 12+12-circuit carrier-on-cable equipments. A transistored rural carrier system is also manufactured which provides up to ten stackable subscriber circuits in rural areas or up to ten junction circuits. This equipment can be operated over the same pole route as a 3 or 12-circuit system.

Junction radio equipments, operating in the VHF and UHF bands with capacities of 5 or 9 speech circuits, are supplied.

Below: Maxwell's Hill Repeater Station, part of the 6000 Mc/s system in Malaya.

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* ZT87 (CV8615), ZT88, ZT89 designed for ELECTRONIC TELEPHONE EXCHANGES

Rating or Characteristic	Symbol	ZT80 ZT110	ZT81 ZT111	ZT82 ZT112	ZT83** ZT113	ZT84** ZT114	ZT86** ZT116	**ZT87 ZT117**	**ZT88 ZT118**	**ZT89 ZT119**	Test Conditions
Collector Base Voltage	V_{CBO}	25	45	45	60	60	100	25	100	70 volts	$I_E = 0$
Collector Emitter Sustaining Voltage	$V_{CEO(Sus)}$	25	35	35	45	45	80	25	80	70 volts	$I_B = 0$ $I_C = 5mA$
Emitter Base Voltage	V_{EBO}	4	4	4	5	5	5	4	5	5 volts	$I_C = 0$
Collector Peak Current	I_{Cpk}	500	500	500	500	500	500	500	500	500 mA	
DC Collector Current Gain	h_{FE}	38-162	38-162	78-250	35-85	75-170	35-85	78-250	75-170	75-250	$I_C = 10mA$ $V_{CE} = 6V$
Collector Base Reverse Current	I_{CBO}	0·5	0·5	0·5	0·05	0·05	0·05	0·5	0·05	0·5 μA	$V_{CB} = V_{CBO}$ $T_{AMB} = 25°C$
Collector Saturation Voltage	$V_{CE(Sat)}$	0·4	0·4	0·4	0·4	0·4	0·4	0·4	0·4	0·4 volts	$I_C = 50mA$ $I_B = 5mA$ / $I_C = 10mA$ $I_B = 2mA$
AC Current Gain (typical)	h_{fe}	10	10	10	10	10	10	10	10	10	$f = 20Mc/s$ $I_C = 10mA$
Power Dissipation	P_{tot}	300	300	300	300	300	300	300	300	300 mW	at 25°C ambient temperature
Minimum Burn-In Period	t_{BPmin}	48	48	48	48	48	48	48	48	48 hrs	$P_{tot} = 150mW$ $T_{AMB} = 100°C$

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FE 258

SOLARTRON DIGITAL SIGNAL GENERATORS A MAJOR BREAKTHROUGH IN STANDARD ACCURACY SIGNAL SOURCES

The essential characteristics of a precision signal generator is combined with – crystal accurate incremental tuning – ultra low noise sidebands – precision modulation facilities – accurately controlled output level Complemented by a modular design concept, any required combination of frequency range, tuning resolution and modulation facilities can be selected from a wide range of compatible units, giving maximum performance with economy.

FS30

Transistorized Digital Signal Generator Provides 6 decades of crystal-locked tuning in 10 c/s increments over the frequency range 10 kc/s–32 Mc/s. (See FS 30-7 and FS 500 below). A 7th decade provides fine tuning calibrated to 0.01 c/s. Maximum Output level is 1.3V from 50 Ω, stable to within 3dB of setting over the whole frequency range and for all loads > 50 Ω, using interchangeable modular sub-units.

The built-in 1 Mc/s crystal reference has a 24 hour stability of 3 parts in 10^9 and can be synchronised to an external standard.

The noise modulation sidebands at the output are exceptionally low –90dB w.r.t. carrier.

The power consumption is only 10 watts and an optional sealed-cell battery provides 6 hours operation (24 hours standby).

Provision is made for interconnecting a range of modulator sub units now being developed.

- ✳ Basic Frequency Range **10 kc/s – 32 Mc/s**
- ✳ Crystal Stability **3 parts in 10^9**
- ✳ Crystal-accurate tuning increments every **10 c/s**
- ✳ Fine Tuning Calibrated every **1 c/s**
- ✳ Noise Modulation Sidebands less than **–90dB**
- ✳ High Output Level **1.3 V r.m.s. from 50 ohms**
- ✳ Power consumption only **10 watts** **6 hours** operation by built in battery
- ✳ Fully **solid state printed circuit** engineering with interchangeable modules.

In the same series: – FS30-7 – As FS30 with 1 c/s crystal-accurate increments.
FS2 – As FS30-7 but frequency range 0 - 2 Mc/s.
FS500 – 27 Mc/s-500 Mc/s with crystal-accurate increments every 1 Mc/s. Fine-tuning by FS30.

DO 1001

Precision Signal Generator System The DO 1001 is a precision signal generator system providing outstandingly comprehensive facilities.

Carrier The basic carrier source covers the frequency range 50 kc/s – 52 Mc/s in 10 kc/s crystal–accurate increments, with fine tuning calibrated to 50 c/s.

Noise modulation sidebands, also spurious AM and FM, are all below –80dB w.r.t. carrier

This frequency range can be extended in 6 stages by plug-in units as follows :-

0250 27 – 250 Mc/s
0500 220 – 500 Mc/s
0800 470 – 860 Mc/s
01500 800 – 1550 Mc/s
02500 1500 – 2700 Mc/s
04000 2600 – 4000 Mc/s

Incremental tuning can be improved to 1 c/s crystal–accurate increments using the FS2 Digital Signal Generator.

Output level is 1 V r.m.s. from 50 Ω, stable within 0.1dB from open circuit to short circuit and over complete frequency range.

Precision output attenuator B 1200 provides 0-99dB attenuation in 1dB steps over frequency range D.C. – 1000 Mc/s.

Modulation Precision AM, FM, PAM, Video and SSB modulation are provided as optional sub units.

- ✳ Precision crystal-controlled output frequency ± 10 cps (or ± 0.1 cps **on** request)
- ✳ Automatic output-level control (1 volt r.m.s.) constant to 0.1 dB
- ✳ Precision output attenuator
- ✳ Comprehensive modulation facilities (AM, FM, PAM, Video, SSB)
- ✳ Negligible spurious modulation and radiation
- ✳ Plug-in units for extension of applications

These Digital Signal Generators are manufactured by Schlumberger (SOMV) Munich, an associated Company within the Schlumberger Group and are distributed by The Solartron Merchandising Division. They carry the usual one-year guarantee.

SOLARTRON

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M&P S211

These are designed and manufactured to meet C.C.I.T.T. recommendations or any other specific requirements. They are the products of modern plant, specialist engineers and over sixty years of experience—backed by extensive research and development facilities. BICC undertake the manufacture and installation of cables for every type of telecommunication system anywhere in the World.

BICC TELEPHON

Technical information on BICC Telephone Cables is contained in our publications—freely available to Telephone Administrations.

BRITISH INSULATED CALLENDER'S CABLES LIMITED
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Branches and Agents throughout the World.

QUAD TRUNK CABLE

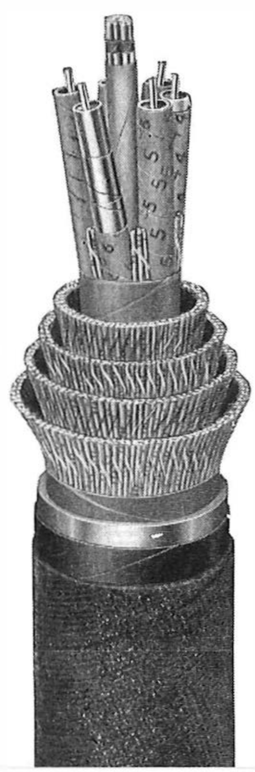
This cable, manufactured to a British Post Office specification, is produced in large quantities for audio frequency junction circuits. In common with other types of cable, they can be made to comply with any national or private specification.

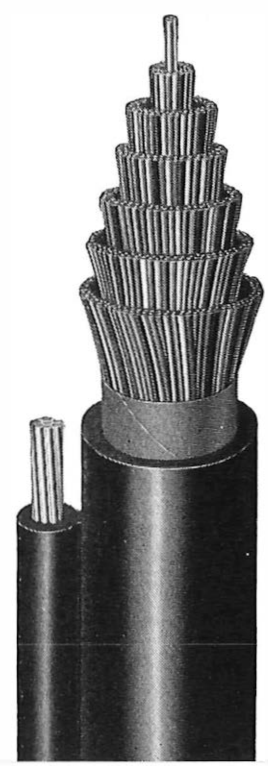
TYPE 174 AND TYPE 375 COAXIAL CABLE

For television circuits and multichannel telephony, BICC manufacture cables containing coaxial pairs meeting the C.C.I.T.T. recommendations. These can be combined with symmetrical pairs for audio frequency or short-haul carrier circuits.

POLYTHENE INSULATED DISTRIBUTION CABLE

Because of their ease of installation, reliability and low cost, polythene insulated distribution cables are widely used, particularly in sizes up to 100 pairs. They may be installed underground or, as in the case of the type illustrated, used with an integral suspension strand wherever aerial installation is preferred.





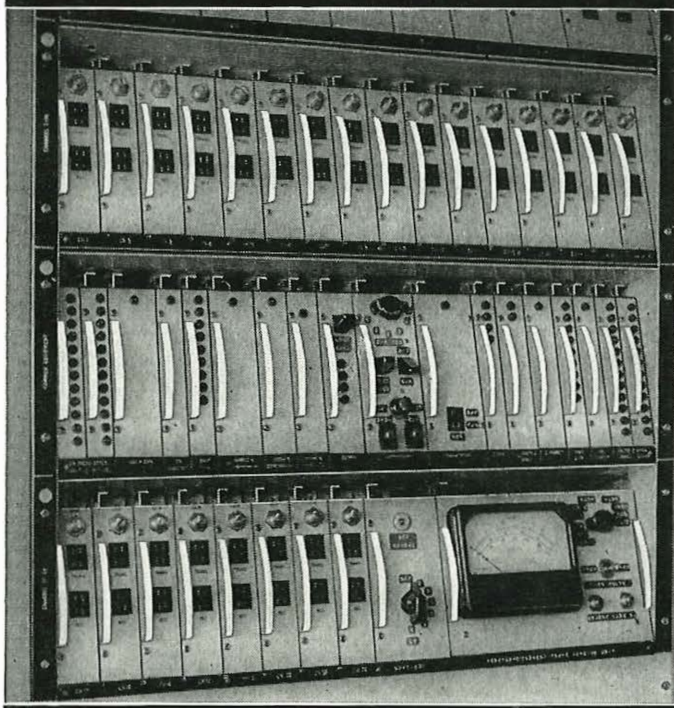
CABLES

UNIT TWIN CABLES

Large cables of unit construction are specially suited to the systematic arrangement of a dense telephone subscriber network. Units of 25, 50 or 100 pairs are first assembled, then the required number of units are combined and sheathed to form the complete cable Paper insulated, lead or polythene sheathed cables or all-polythene types are available.

2421

INCREASE CAPACITY OF EXISTING JUNCTION CABLE ROUTES ECONOMICALLY WITH



The new G.E.C. 24-circuit Pulse Code Modulation Equipment, Type SPO 1800, provides a new and economic means of increasing the capacity of existing junction cable routes.

The equipment provides 24 high-quality 300c/s-3400c/s speech circuits, with signalling facilities, over two pairs of an audio cable.

Fully transistored and manufactured to C.A.S.E. (GPO 62-Type) techniques, the compactness of the equipment enables three 24-circuit terminals, together with test equipment and repeater power feeding equipment, to be mounted in one 9ft (2744mm) rack.

The repeaters, spaced at 2000 yard (1828 metres) intervals corresponding to the normal cable joint spacings on junction routes, are mounted in sealed, corrosion resistant boxes. Each box houses equipment for up to twelve bothway 24-channel systems.

For further information write for Standard Specification SPO 1800.

A 24-circuit P.C.M. terminal equipment

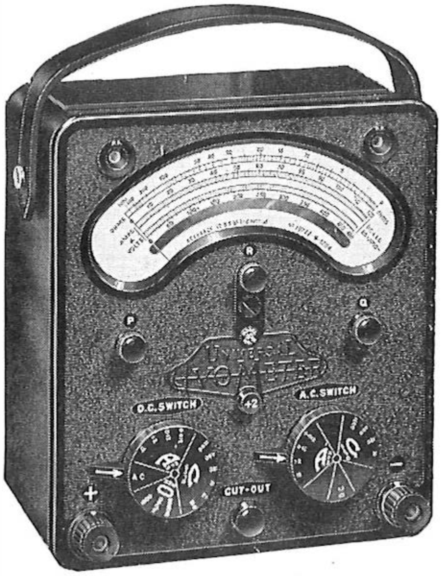
G.E.C. 24-CIRCUIT P.C.M. EQUIPMENT

G.E.C. everything for telecommunications

Transmission Division, G.E.C. (Telecommunications) Ltd., Telephone Works. Coventry · England

SP34

Model 40 Universal AVOMETER



A self-contained multi-range a.c./d.c. instrument providing 40 ranges of direct readings of current, voltage and resistance on a 5-inch hand calibrated scale fitted with an anti-parallax mirror. Range selection is accomplished by two rotary switches, for a.c. and d.c. respectively, and a press button provides additional ranges by halving the current and voltage ranges shown on the switch knobs. Full scale deflection on voltage ranges is obtained with a consumption of 3mA. or 6mA. according to whether the press button is used or not. The total resistance of the meter is 200,000 ohms.

The instrument meets the accuracy requirements of B.S.S. 89/1954 for 5-inch scale length portable industrial instruments. It also complies with the requirements of the U.K. Air Registration Board and the Merchant Shipping (Radio) Rules 1952.

It is a robust, compact and portable instrument, and is protected by an automatic cut-out against damage through inadvertent application to overload.

Size: 8 × 7¼ × 4½ in. Weight: 6¼ lb.

A leather carrying case is available, if required.

CURRENT: a.c. and d.c. 0 to 12 amps.
VOLTAGE: a.c. and d.c. 0 to 1,200 volts.
RESISTANCE: Up to 1 megohm.

Write for fully descriptive brochure, or for complete Catalogue of Avo Instruments.

Power Factor and reactive kV.A. can be measured in a.c. circuits by means of an external accessory, the Universal Avometer Power Factor & Wattage Unit.

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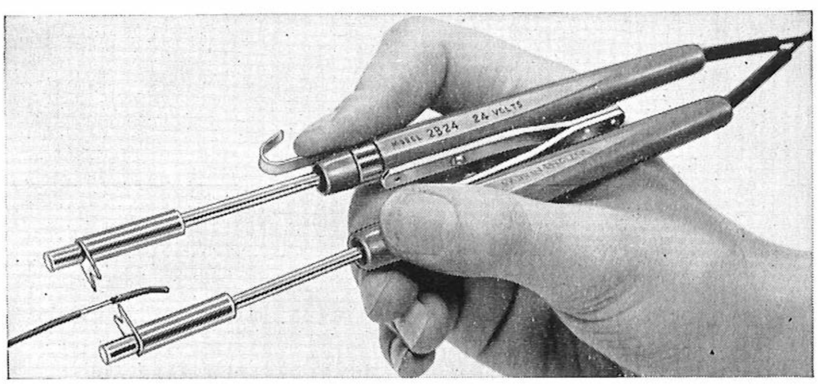
A40/8

ADAMIN THERMAL STRIPPERS



The new ADAMIN thermal wire strippers allow one-handed operation, using a simple tweezer action.

They strip coverings of up to about $\frac{5}{32}$in. dia. with absolutely no risk of damaging the conductors.

FOR *PTFE* INSULATION use Model 2B24 (illustrated), available for 24 volts only.

FOR *PVC* INSULATION and similar low temperature materials, use Model 2B6, available for 12 or 24 volts.

LITESOLD TRANSFORMERS permit safe operation from any mains power point.

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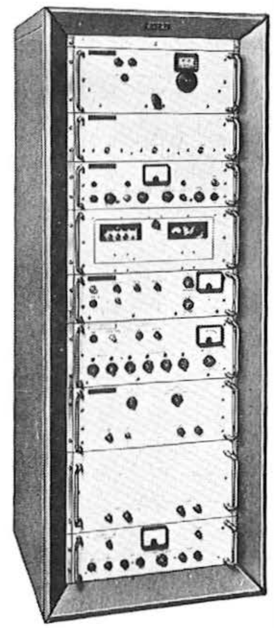
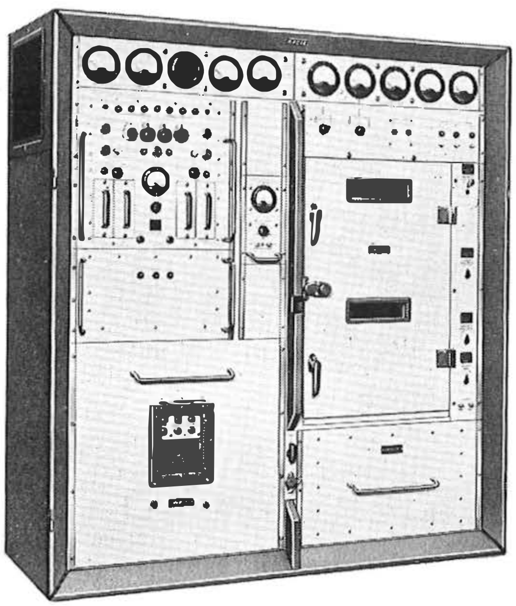
3 **change mode or operational state RAPIDLY**

4 **adapt to new requirements RAPIDLY**

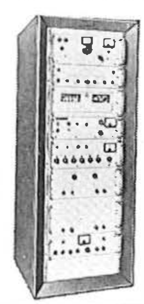


RTA. 191 Receiver te·minal



TA. 184 10 kW linear amplifier

LA 304 Remote Control Console



MA. 228 Exciter Unit

"Speedrace" satisfies nearly all HF communications requirements, being assembled from standard sub-units into remotely-controlled, automatically-tuned reliable systems. Static or transportable installations. Available with output powers 1 kW to 10 kW. Incorporating most modes of operation. 280,000 synthesiser-controlled operating frequencies of unsurpassed accuracy and stability.

RACAL

a name to communicate

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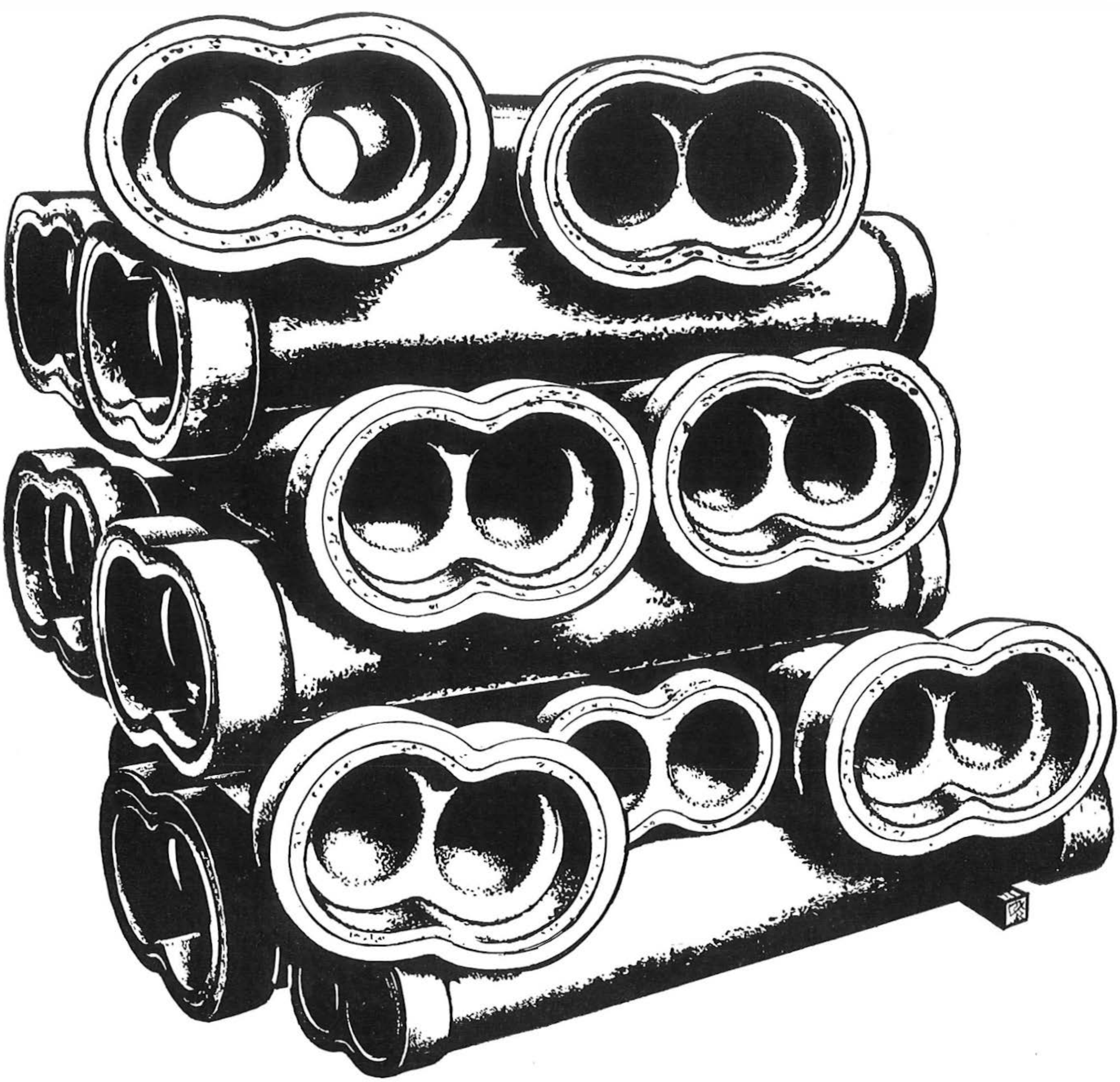
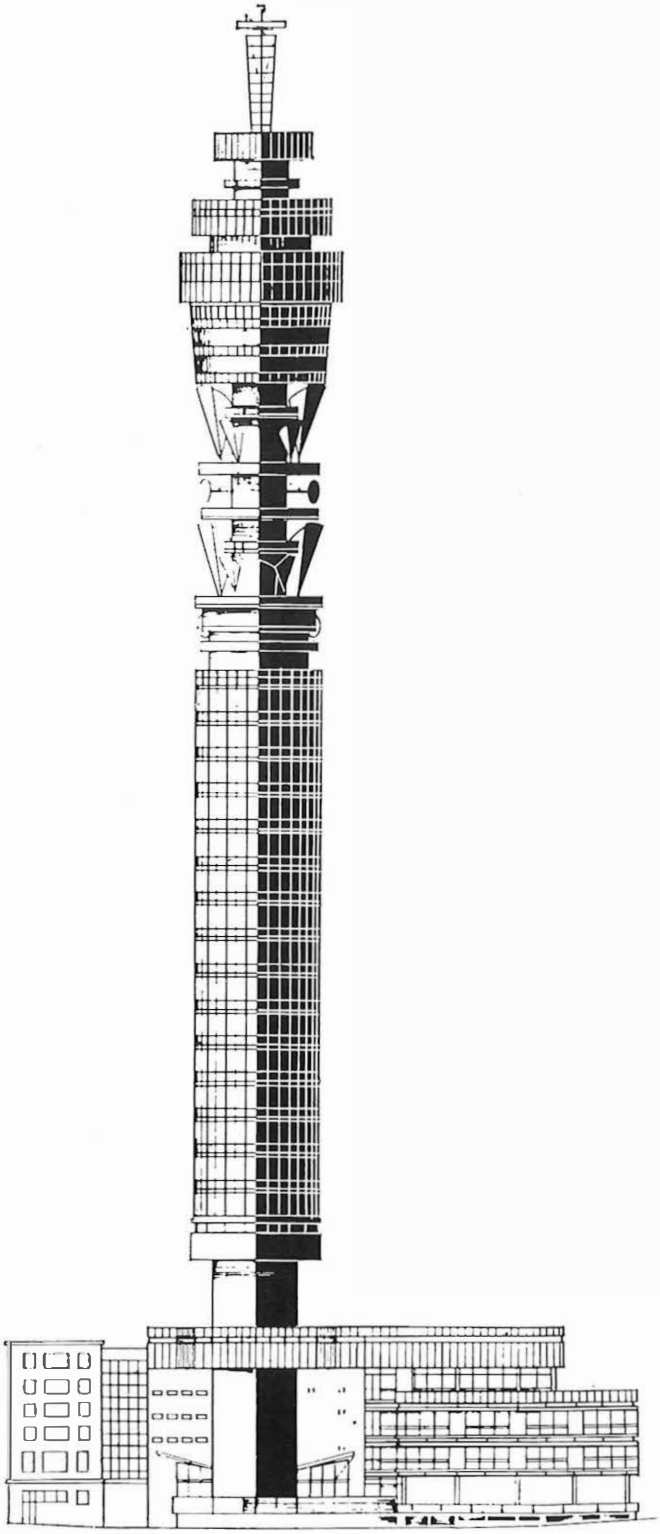
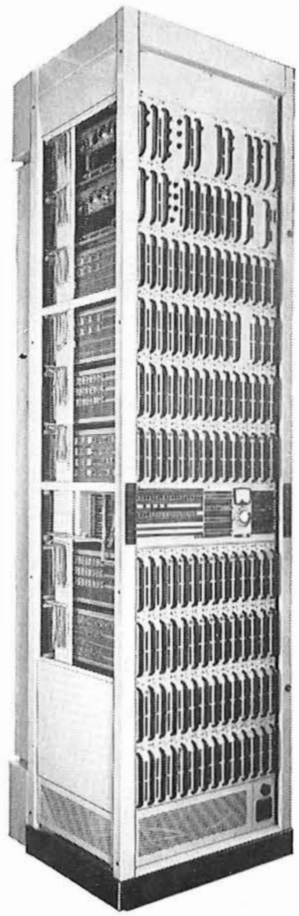
Western Road, Bracknell, Berks.
Tel: Bracknell 941. *Telex:* 84166. *Cables:* Racal Bracknell.



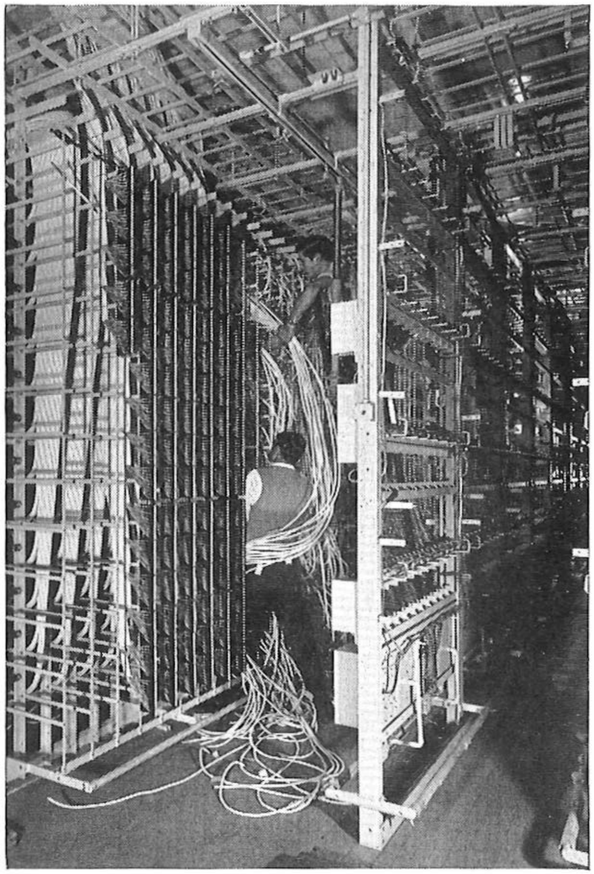




Incoming Register Translator

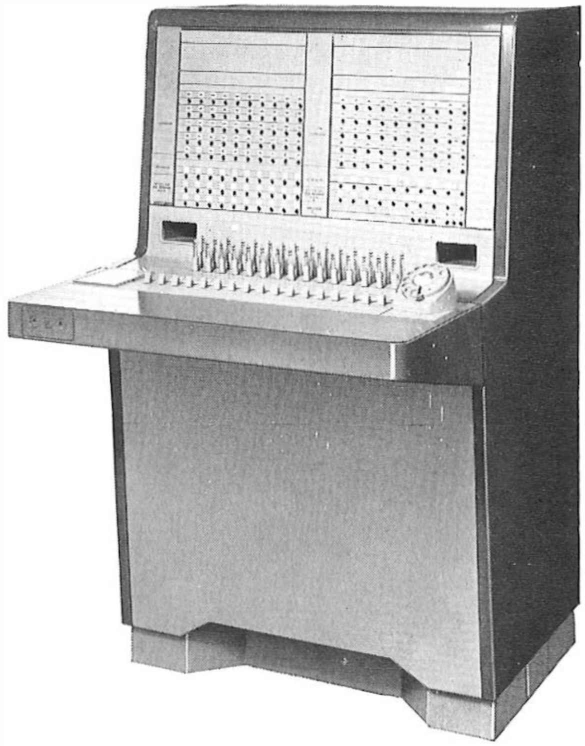
The Trunk Switching Equipment is controlled electronically by the Ferrit Core and Transistor Register Translator developed by E.T.L. for this a similar applications. Housed in units based on an equipment practice the company's design, it occupies approximately one sixth of the flo area of an electromechanical equivalent. In addition it offers potentia much greater reliability and flexibility in use.

MERCURY the large



Cabling in progress

Mercury exchange utilises nearly 1,000 racks which provide accommodation for 11,000 relay sets and more than 10,500 selectors together with ancillary equipment and covers a floor area of nearly one acre. Over 15,000 incoming trunks and outgoing junctions are terminated at the Main Distribution Frames. From here calls go out to the exchanges in the London Director Network. Also part of this mammoth enterprise is a local tandem exchange which replaces one installed by the company well over twenty years ago.



Floor Pattern Lamp Signalling PMBX

The first of its type to go into service, this compact switchboard now being installed in the Howland Street building incorporates many new features among which are automatic ringing and automatic holding of exchange calls, 'jack-in' relay sets and individually removable jacks. This design will form the basis of the new standard B.P.O. PMBX.

ange order of its type ever awarded by the B.P.O. to a single manufacturer

A further E.T.L. contribution to Britain's S.T.D. network is the current installation of Mercury Trunk Exchange in the Tower Building, Howland Street, London. Developed in conjunction with the B.P.O. and scheduled for completion later this year, this project will form a master switching centre for the increasing volume of trunk telephone traffic entering London via the massive micro-wave tower. The largest exchange installation of its kind in the world, this undertaking represents further evidence of E.T.L.'s leading position in the field of telecommunications.

Plessey Telecommunications Group

ERICSSON TELEPHONES LIMITED · ETELCO LIMITED

Head Office & Main Works: Beeston · Nottingham · Tel: Nottm. 254831 · Telex 37666
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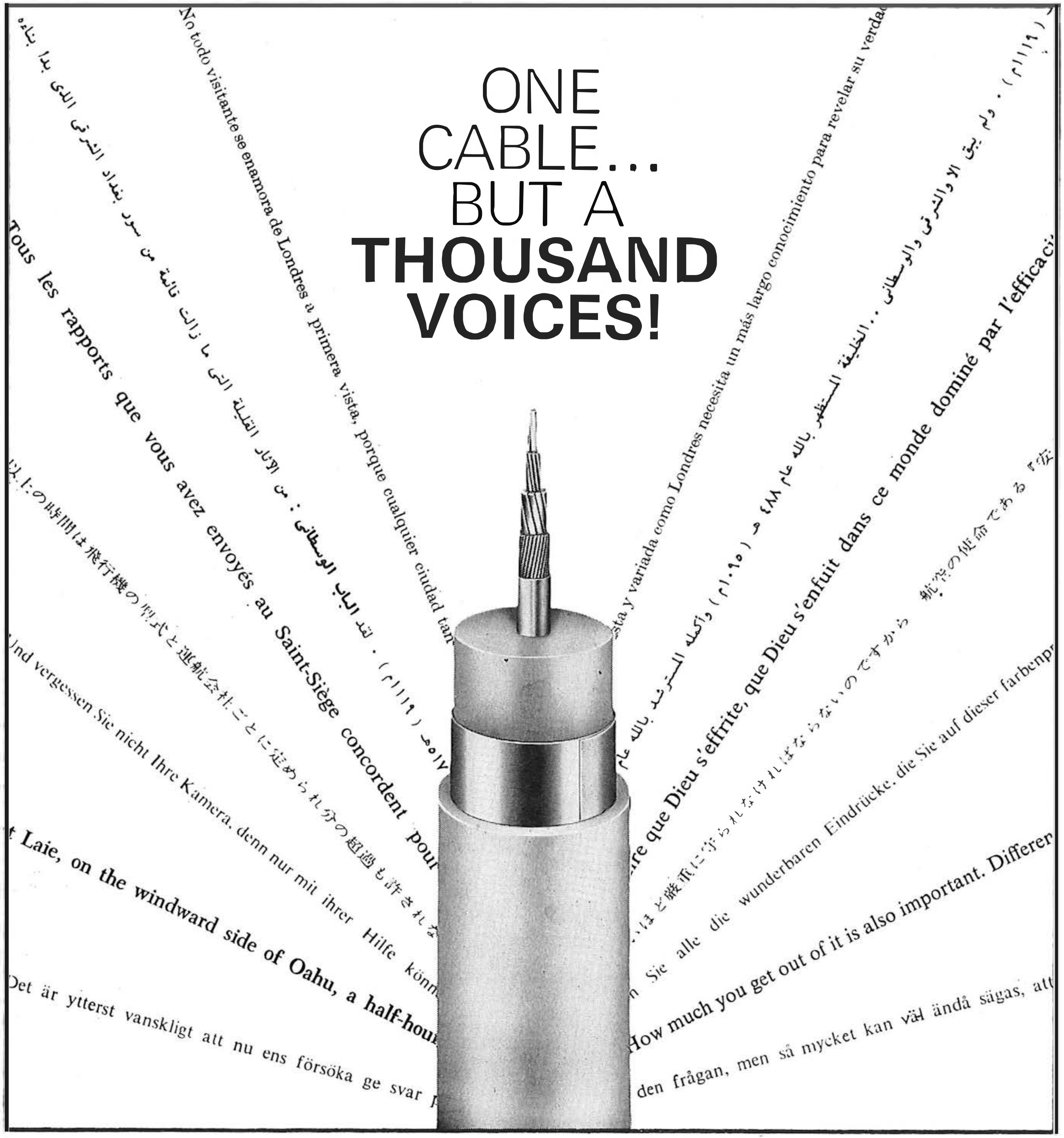
PTE 125



The first submarine cable, laid between England and France in 1891, provided one or two speech circuits. The Atlantic telephone cable system of 1956 provided thirty-six circuits.
Submarine Cables Ltd. can now supply a submarine telephone cable system with transistorised submerged repeaters capable of handling up to 640 simultaneous conversations. Five systems of this type equipped for 480 circuits and with AEI terminal equipment, also fully transistorised, are on order for installation in the North Sea, Baltic and English Channel in 1966-7. Such systems are suitable for ocean, coastal and inter-island routes—wherever, in fact, trade demands reliable communications.

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Pirelli General are in a position to advise on complete Telecommunications schemes and are organised to manufacture and install cables for distribution and trunk services; also carrier and all types of coaxial cables.

Pirelli General also manufacture cables to meet special requirements of Public Utilities or of industry.

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Now...transistorised terminal equipment

FOR A 480 TELEPHONE CHANNEL BOURNEMOUTH-JERSEY CABLE LINK

AEI is to supply fully transistorised terminal equipment for the Bournemouth-Jersey Submarine cable telephone system. This follows AEI's substantial contribution to the Commonwealth Submarine Telephone Cable System and the North Sea transistorised systems. The cable and transistorised repeaters will be supplied by Submarine Cables Ltd., the principal contractors.

Where reliability matters – AEI equipment is used.

- Fully transistorised
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- Frequency spectrum 300-4800 Kc/s
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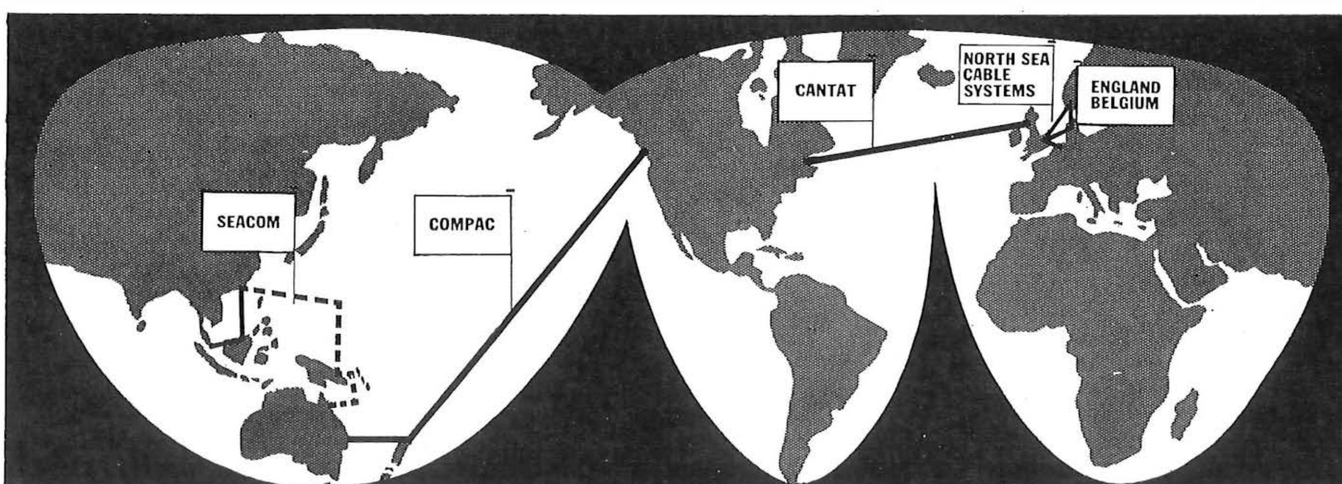
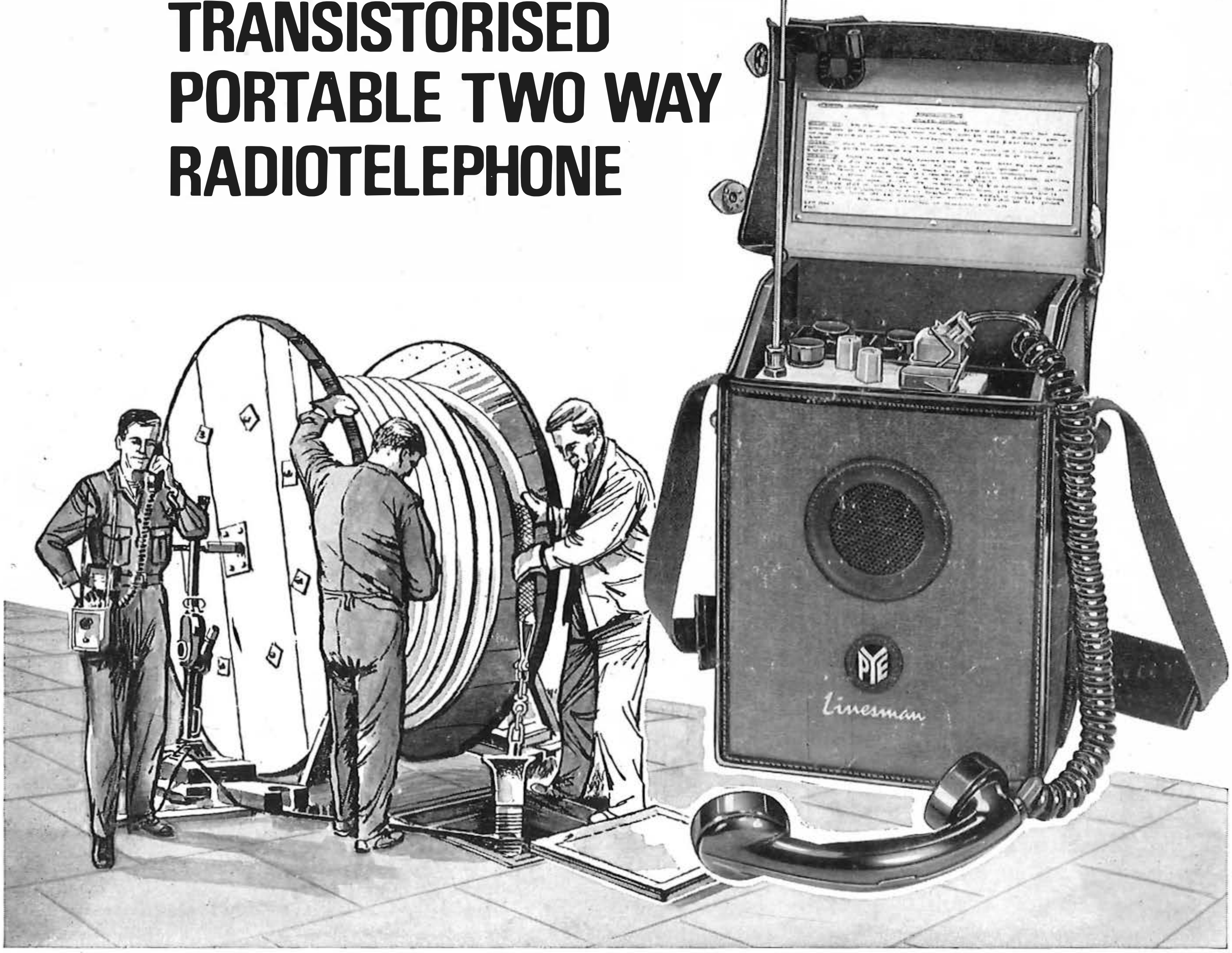


TA1450

THE PYE Linesman

FULLY TRANSISTORISED PORTABLE TWO WAY RADIOTELEPHONE



Based on the now famous Pye Bantam solid-state Walkie/Talkie, the Pye Linesman with many additional features, makes it suitable for use in all types of weather, the Pye Linesman is proving invaluable in cable laying, road construction, building sites etc.

Important features are that it is free-standing, incorporates large capacity batteries, is weatherproof and has a voltage indicator to show the state of the battery.

The 'Linesman' is designed never to let you down in the field. It is available for AM and FM in frequency bands from 25–174 Mc/s. It is used by the British Post Office.

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