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An Introduction to the Principles of Waveguide Transmission

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Part 1.—Fundamental Concepts; Generation of Microwave Energy

U.D.C. 621.396.11.029.64 : 621.372.8

In Part 1 of this article the general principles of transmission in waveguides are described in non-mathematical terms and an outline is given of the means whereby electromagnetic waves are generated. Part 2 will describe how such waves are detected, attenuated, switched and measured in waveguides.

INTRODUCTION

THE concept of the transmission of broadband signals comprising many hundreds of telephone channels or several television channels is now becoming familiar in the world of telecommunications. Broadband point-to-point communication systems can be realised by transmission over either cable or radio, in the first case by employing highly developed coaxial cable techniques and in the second by the use of microwave radio frequencies. Coaxial cables already form a major part of the national trunk network, and many Post Office engineers are intimately acquainted with the associated techniques and equipment. Microwave radio links, on the other hand, are not yet as well known in this country; but their development is proceeding rapidly, and it may not be long before they rival the coaxial cable in importance as a means of transmitting broadband transmission channels.

The techniques of microwave equipment engineering appear at first to differ fundamentally from those employed in lower frequency transmission systems. There is, for example, a notable absence of elaborate wiring; waveguide replaces coaxial cable for carrying the broadband signals to and from the aerials, and precision mechanical engineering becomes as important as electrical design. It is the purpose of this article to describe in non-mathematical language some of the general principles governing transmission by waveguide, and to show the forms that the associated fundamental components such as attenuators, resonant circuits, oscillators and filters may take.

The illustrations and examples will be drawn largely from equipment designed for use with $2\frac{1}{2}$ in. × $1\frac{1}{4}$ in. waveguide operating in the frequency band 3,800-4,200 Mc/s as this is the frequency range and the waveguide size in which the Post Office has, so far, concentrated its own engineering development.

FUNDAMENTAL CONCEPTS

Wave Motion and Modes of Transmission in Waveguides.

Although the concept of transmission of energy in waveguides appears at first sight to be radically different from that in transmission lines, an interesting analogy between the two systems of transmission has been drawn by Barlow[1] and others. A brief description of the analogy will enable the familiar transmission line concepts to be transferred easily to the more recent technique of waveguides.

An ideal transmission line, consisting of two open parallel wires one-quarter of a wavelength long, short-circuited at the far end, appears at the input as an open circuit. If a quarter-wave stub of this kind is placed as a bridge across a transmission line, as shown in Fig. 1, the transmission properties of the line are unaffected. If a large number of stubs are imagined to be placed, side by side, above and below the transmission line, power is transmitted longitudinally as before and transverse standing waves will be produced in the stubs. When the stubs are placed so close together as to be touching, a section of waveguide is formed, as in Fig. 2. A photograph of an actual length of waveguide with connecting flanges is shown in Fig. 3.

Some interesting conclusions result from this picture of the formation of a waveguide. Suppose that a fixed frequency is transmitted in the waveguide of Fig. 2. As the frequency is fixed, the length $\lambda/4$ of the resonant stubs must remain constant. The thickness, t, of each of the original wires of the parallel wire transmission line can be imagined as decreasing until, finally, t is zero and the original transmission wires vanish. There will then be no vehicle for the transmission of energy along the guide; a "cut-off" condition has been reached. The height, b, of the guide in Fig. 2 is then $\lambda/2$, or at cut-off $\lambda_c = 2b$, in which λ_c is the wavelength of the applied energy when the guide ceases to propagate. At cut-off a standing wave is produced across the guide in the dimension 'b' but no propagation of energy takes place along the guide. Energy at frequencies

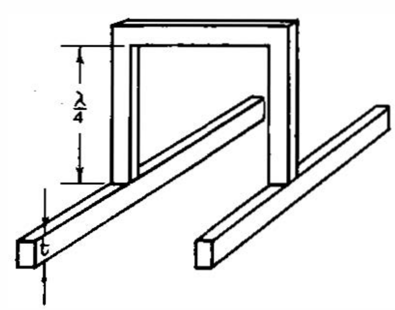

FIG. 1.—QUARTER-WAVE STUB ON TRANSMISSION LINE.

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[1] Barlow, "Microwaves and Waveguides," Constable & Co.

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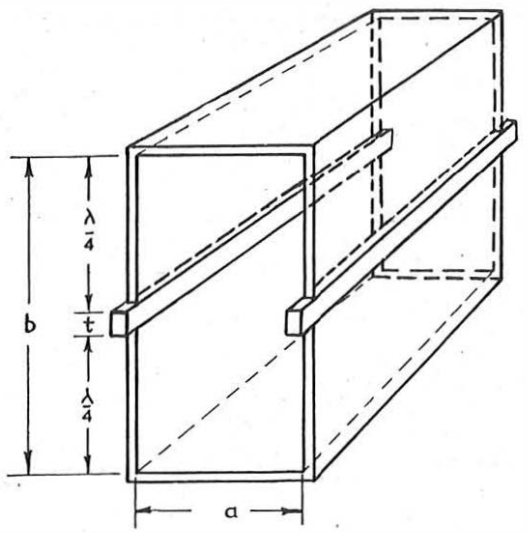


FIG. 2.—INFINITE NUMBER OF QUARTER-WAVE STUBS FORMING A WAVEGUIDE.

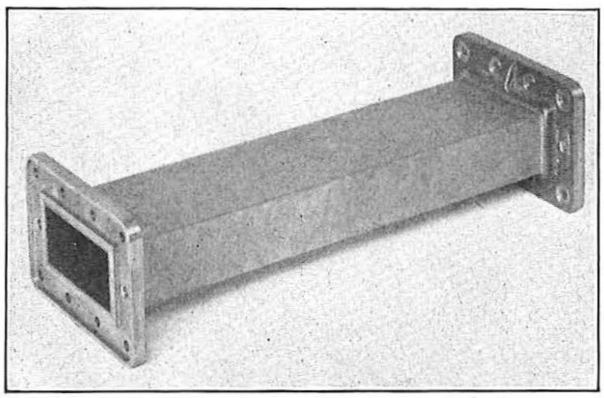


FIG. 3.—A LENGTH OF WAVEGUIDE.

lower than that corresponding to the cut-off wavelength, λ_c, will not propagate along the guide, but at higher frequencies propagation will take place. A waveguide is therefore inherently a high-pass filter.

An understanding of the wave formation in the guide is of importance in practical applications. Electromagnetic theory requires that:—

(a) In a system of electromagnetic waves the electric field is everywhere normal to the magnetic field.

(b) Where an electric field meets a conducting plane of zero resistance it must be normal to the surface.

(c) Where a magnetic field is in proximity to a conducting plane of zero resistance it is tangential to the plane.

In an open-wire transmission line the electric field extends from one conductor to the other and the magnetic field encloses the conductors, as shown in Fig. 4. Both fields are

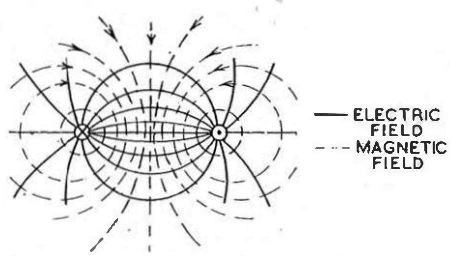


FIG. 4.—FIELD PATTERN ROUND AN OPEN-WIRE TRANSMISSION LINE.

in a plane normal to the axis of the conductors. The instantaneous intensity of the field varies sinusoidally along the line and for a line with no loss, *in vacuo*, the whole field pattern propagates along the line with the velocity of light. The field pattern repeats itself at a wavelength given by:

$$\lambda = \frac{v}{f}$$

where v = velocity of propagation, and
f = frequency.

For such an open-wire transmission line the wavelength is identical to that for propagation at the same frequency in free-space as, for example, in the case of radiations from a transmitting aerial. Inside a waveguide the wavelength is not equal to the free-space wavelength, as will now be shown. Using the simple analogy, already made, of a waveguide as a transmission line with an infinite number of quarter-wave stubs attached, it will be apparent that the currents in the stubs will add other components of electric and magnetic fields to those in the original transmission line, modifying the field patterns considerably as compared with those in Fig. 4. The resultant configurations of the electric and magnetic fields in a waveguide when the energy is being delivered into a matched load are shown in Fig. 5. The

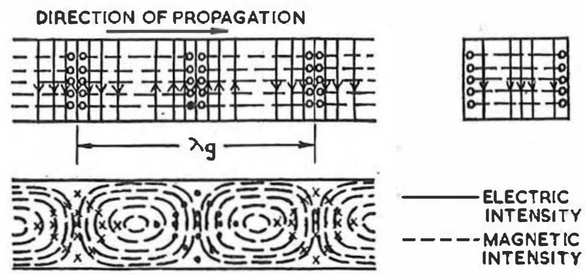


FIG. 5.—FIELD DISTRIBUTION IN RECTANGULAR WAVEGUIDE.

fundamental laws of electromagnetic theory, given above, are, of course, obeyed. The fields are contained entirely within the space enclosed by the conducting walls of the guide and the currents in the guide walls are confined to the skin of the inside surface. Screening is therefore complete at microwave frequencies when the walls have a thickness greater than a few thousandths of an inch. At any instant the current streamlines are as shown in Fig. 6.

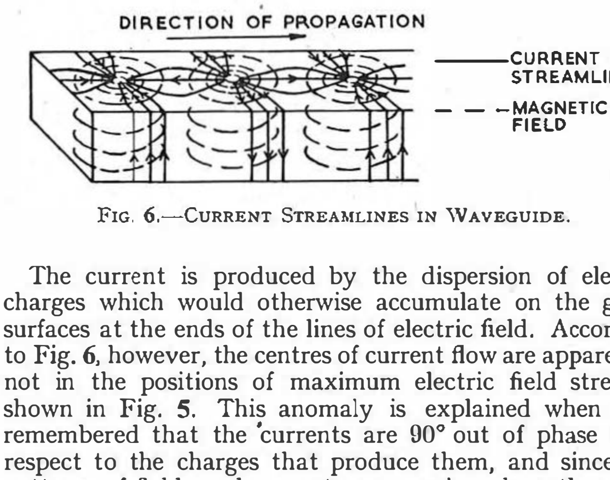


FIG. 6.—CURRENT STREAMLINES IN WAVEGUIDE.

The current is produced by the dispersion of electric charges which would otherwise accumulate on the guide surfaces at the ends of the lines of electric field. According to Fig. 6, however, the centres of current flow are apparently not in the positions of maximum electric field strength shown in Fig. 5. This anomaly is explained when it is remembered that the currents are 90° out of phase with respect to the charges that produce them, and since the patterns of fields and currents are moving along the guide with the velocity of propagation, the centres of current flow appear $\frac{1}{4}$ wavelength along the guide from the positions of the maximum electric field; i.e., at the centre of the ellipses of the lines of magnetic field. The patterns of Figs. 5 and 6 apply only when the energy is being dissipated in a matched termination. The conditions with a mismatched termination will be considered later.

It is found that the relationship between the wavelength in the guide and the wavelength in free space is given by:

$$\lambda_g = \frac{\lambda}{\sqrt{[1 - (\lambda/\lambda_c)^2]}}$$

or,

$$\frac{1}{\lambda_g^2} = \frac{1}{\lambda^2} - \frac{1}{\lambda_c^2}$$

in which, λ_g = wavelength in guide,
λ = free-space wavelength,
λ_c = cut-off wavelength.

The velocity of propagation of the field pattern in the waveguide, or phase velocity, is therefore given by:

$$V_p = \lambda_g f$$

which is always greater than the free-space velocity for the medium filling the waveguide.

It may seem remarkable, at first sight, that in an air-filled waveguide the phase pattern proceeds along the guide with a velocity greater than the velocity of light. The phenomenon is more easily visualised, however, when it is realised that, analytically, the propagation of energy in a waveguide can be regarded as due to two intersecting systems of wavefronts with the axis of the waveguide bisecting the angle of intersection, 2θ, each system moving forward normal to its wavefronts at the speed of light. The velocity at which any point of wavefront intersection advances along the guide axis is obviously $c/\sin\theta$, which is greater than the speed of light. The component of the wavefront velocity along the guide axis is the velocity of propagation of energy, and this is $c\sin\theta$, which is less than the speed of light. The phase velocity is also equal to ω/β, where $\omega = 2\pi f$ and β is the phase angle. The group velocity V_g, where $V_g = d\beta/d\omega$, is the velocity at which energy is propagated along the guide. These two velocities are related to the free-space velocity, c, by: $V_p V_g = c^2$. The free-space velocity, c, is equal to the velocity of light if the space in the waveguide is vacuous; otherwise,

$$c = \frac{\text{velocity of light}}{\sqrt{\mu\epsilon}}$$

where, μ = permeability of medium in the guide, and
ϵ = permittivity of medium in the guide.

So far, only one mode of transmission in rectangular waveguide has been considered. In theory, there is an infinite number of modes of transmission, and propagation can be made not only along rectangular guide but also along circular, elliptical, and guides of various other cross-sections, as well as through coaxial cable and along a rod of dielectric material. This article is confined mainly to transmission in rectangular waveguides, and it is of interest to identify some of the more common modes of transmission, though in practice only one is of major importance. Unlike the field configuration round an open transmission line, there is in waveguide always a component of field, either magnetic or electric, along the axis of propagation. The mode of transmission is designated as an H mode when there is a component of the magnetic field along the guide in the direction of propagation, and as an E mode when the axial component of field is electric. The complete designation of the mode is made by adding two suffixes l, m, to the letter H or E. In rectangular guide the suffix l denotes the number of half-wave patterns of electric (or magnetic) field across one dimension of the cross-section of the waveguide, and the suffix m denotes the number of half-wave patterns across the other dimension. The suffix l usually refers to the shorter dimension. The mode of transmission already described in Fig. **5** is therefore the $H_{0,1}$ mode, i.e., $l = 0$ and $m = 1$, because H denotes that there is a component of magnetic field along the axis of the guide, the suffix 0 denotes that there is no half-wave pattern of field across the narrow dimension, and the suffix 1 denotes a single half-wave pattern of field across the wide dimension of the guide section.

Other common modes of transmission in rectangular waveguide are shown in Figs. **7** and **8**. It should be noted that there can be no $E_{0,m}$ modes in rectangular waveguide. These modes would necessitate the magnetic field being normal to and intersecting the walls of the guide, which contravenes the electromagnetic laws outlined earlier.

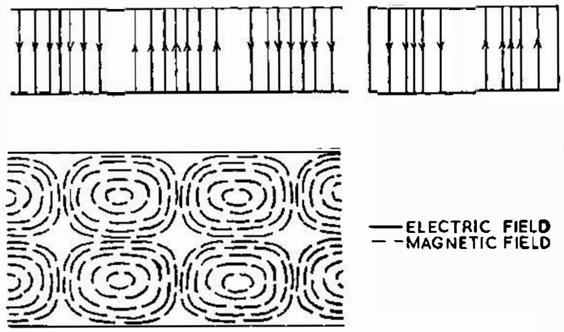


FIG. 7.—$H_{0,2}$ MODE OF TRANSMISSION.

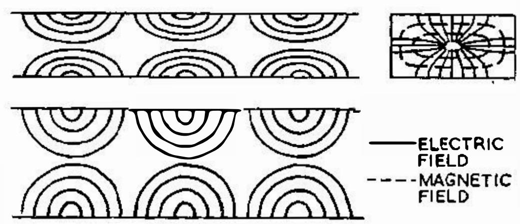


FIG. 8.—$E_{1,1}$ MODE OF TRANSMISSION.

It has previously been remarked that a waveguide behaves as a high-pass filter with a cut-off wavelength related to the dimensions of the waveguide. For a given size of waveguide the cut-off wavelength varies with the mode of transmission. With guide dimensions a and b, as before, the cut-off wavelengths of various modes in rectangular waveguide are given in Table 1:

TABLE 1
Cut-off Wavelengths for Rectangular Waveguide

Mode*	Cut-off Wavelength λ_c
$H_{0,1}$	$2b$
$H_{0,2}$	b
$H_{1,1}$ and $E_{1,1}$	$\frac{2b}{\sqrt{1 + (b/a)^2}}$
$H_{2,1}$ and $E_{2,1}$	$\frac{b}{\sqrt{1 + (b/2a)^2}}$

* In the literature, the $H_{l,m}$ mode is sometimes referred to as the $TE_{l,m}$ mode and the $E_{l,m}$ as the $TM_{l,m}$ mode.

In practice, only one mode of transmission is usually desirable at any one time and it is necessary to find means of suppressing the unwanted modes. Since the waveguide is effectively a high-pass filter with different cut-off wavelengths for various modes, an obvious choice of mode for general transmission purposes is the one with the largest cut-off wavelength (i.e., the lowest cut-off frequency). If the transmission band is restricted to wavelengths between this cut-off wavelength and the next lower cut-off wavelength of other modes, then only the wanted mode can propagate freely. Examination of Table 1 shows that, for rectangular waveguide, the $H_{0,1}$ mode has the largest cut-off wavelength and if the ratio b/a for the guide cross-section is made equal to two, a fairly wide transmission band is available before unwanted modes begin to propagate. In fact the transmitted wavelength can vary between b and $2b$, approximately.

The $H_{0,1}$ mode is usually termed the principal or dominant mode in rectangular waveguide and is the mode of transmission assumed in the literature on waveguide transmission unless otherwise stated.

Waveguide Impedance.

The concept of impedance in waveguide presents difficulties because there are no actual terminals at which current and voltage can be measured. The ratio of the transverse component of electric field strength to the transverse component of magnetic field strength has the dimensions of impedance and is generally used in the definition of impedance. It can be applied to any electromagnetic system. Using this concept, the impedance of free space is found to be 120π ohms (377 ohms) and for guided waves in rectangular guide the impedance becomes:

for H modes $$Z = 377\sqrt{\frac{\mu}{\epsilon} \cdot \frac{\lambda_g}{\lambda}} \text{ ohms.}$$

for E modes $$Z = 377\sqrt{\frac{\mu}{\epsilon} \cdot \frac{\lambda}{\lambda_g}} \text{ ohms.}$$

In these formulæ the permeability μ and permittivity ϵ refer to the dielectric filling the guide. It is clear that the impedance of a waveguide varies with frequency. At the cut-off frequency, the impedance becomes infinite for H modes and zero for E modes. Fortunately, the concept of impedance is easily surmounted in practice by quoting the ratio of the impedance of a component in waveguide to the waveguide impedance. The "impedance" thus quoted is referred to as the "normalised impedance," although, strictly, it is a pure number. Normalisation of impedances, or of admittances, is commonly employed in classical network theory because the quantitative effect of a device is thereby given independently of the circuit impedance. This is of special value in the present application in which the circuit impedance varies with frequency.

Reflection and Standing Waves.

As in a transmission line, the phenomenon of reflection of energy takes place in waveguides at positions in the guide where there is a sudden change of impedance. A reflection of this kind gives rise to standing waves in the guide, and one or two examples of this will be considered. When there is total reflection of energy, say due to a short-circuit, such as can be obtained by fitting a metal sheet to the end of the guide, the incident electric field produces currents in the short-circuit which excite a wave motion in the opposite direction to the incident wave. The incident and reflected waves interact, producing a stationary field pattern in which the positions of maximum intensity of electric field appear in the centre of the ellipses of magnetic field, as shown in Fig. **9**. A complete standing wave is therefore produced and

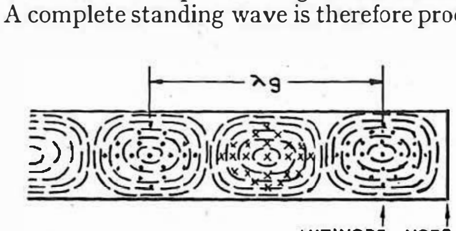


FIG. 9.—FIELD DISTRIBUTION IN SHORT-CIRCUITED WAVEGUIDE.

no power is dissipated in the termination. A similar field pattern could be obtained if the waveguide were open-circuited, except that an antinode in the electric field pattern would appear at the end of the guide instead of a node. In the case of total reflection of this kind, the centres of current flow in the guide walls are coincident with the positions of maximum intensity of electric field. Intermediate values of terminating impedance give rise to lesser intensities of standing waves, and lesser phase shifts in the field pattern. A partial transfer of energy to the load takes place also.

GENERATION AND LAUNCHING OF MICROWAVE ENERGY

The generator at microwave frequencies is usually a reflex klystron or coaxial line oscillator valve for low powers, or a magnetron for high powers. Details of these valves have already been published in this Journal[2] but a brief reference to the klystron is given here as it is commonly used in microwave telecommunication circuits. Fig. **10** shows a typical reflex klystron in which the resonant cavity can be clearly seen with the tuning screws round its periphery. The evacuated glass envelope has two circular metal discs

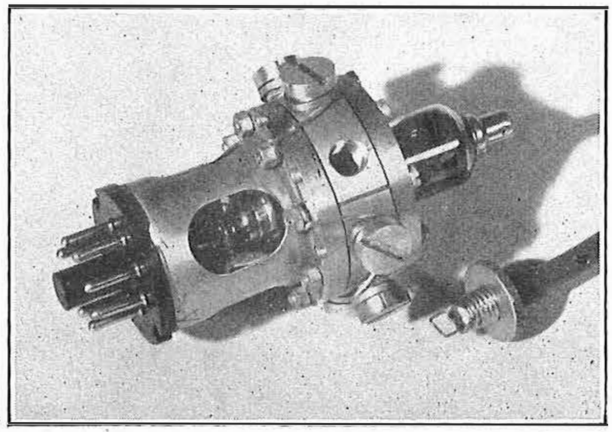


FIG. 10.—REFLEX KLYSTRON OSCILLATOR TYPE VX 5026.

moulded onto it, with glass-to-metal seals. The discs form the upper and lower faces of the resonant cavity and connect inside the glass envelope to two metal discs separated by a small gap. The discs each have an orifice axially through the centre, through which the electron stream is directed from the cathode and grid electrode system in the base of the glass envelope. At the other end of the envelope the connection to the reflector electrode can be seen. The cavity resonator is connected to a potential about 250 V positive with respect to the cathode and the reflector is made about 150 V negative. Resonance in the cavity gives rise to an alternating potential across the gap in the resonator electrodes, which accelerates and decelerates the electron stream passing through the orifices in the cavity. This phenomenon in the electron stream is called "velocity modulation." As the electron stream moves away from the cavity the accelerated electrons overtake the unaccelerated electrons and produce "bunching" of the electron stream. This process takes place, in space, near the reflector plate. The negative potential on the reflector repels the bunched electron stream back through the orifices of the resonator cavity. Here, the electron stream functions as an alternating current whose field induces an alternating field within the resonator. The distance between the reflector plate and cavity, and also the negative potential on the reflector, are such that the bunches of electrons are in the correct phase to maintain the cavity in oscillation. The correct phasing, at any frequency within the tuning range of the oscillator, is obtained by adjusting the potential on the reflector. Energy is extracted from the resonant cavity of the klystron by inserting a loop connected to the end of a coaxial line through one of the tuning-screw holes into the cavity, as shown in Fig. **10**.

Several methods of launching an electromagnetic wave in a waveguide are shown in Fig. **11**. One of two principles is generally employed; either the electric field is stimulated by means of a small antenna placed in the waveguide, or the

[2] *P.O.E.E.J.*, Vol. 43, pp. 148 and 187.

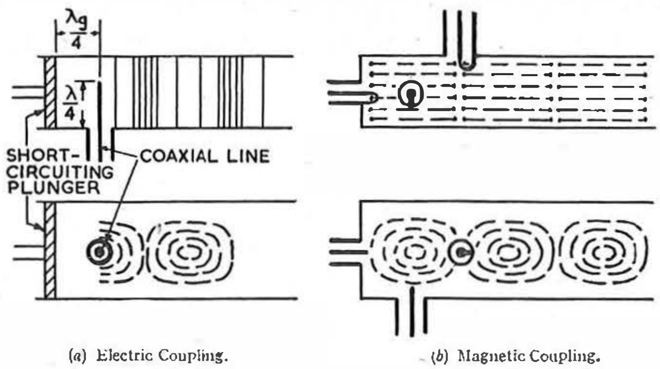


FIG. 11.—METHODS OF LAUNCHING $H_{0,1}$ MODE.

magnetic field is stimulated by means of a loop. In both of these methods the energy is fed to the waveguide by means of a coaxial line from the microwave oscillator. The arrangement shown in Fig. **11**(*a*) is of an antenna placed in line with the electric field. Energy transmitted from the left side of the probe is reflected from the short-circuiting plunger and returns so as to be in phase with the energy being propagated along the guide. An actual launching unit of this type is shown in Fig. **12** which shows a klystron oscillator coupled to a section of waveguide. The racks and knob for adjusting the plunger as the frequency and wavelength are varied are also shown. Fig. **11** (*b*) indicates three alternative positions for a launching loop. In each position the loop intersects the lines of magnetic intensity for the mode being transmitted.

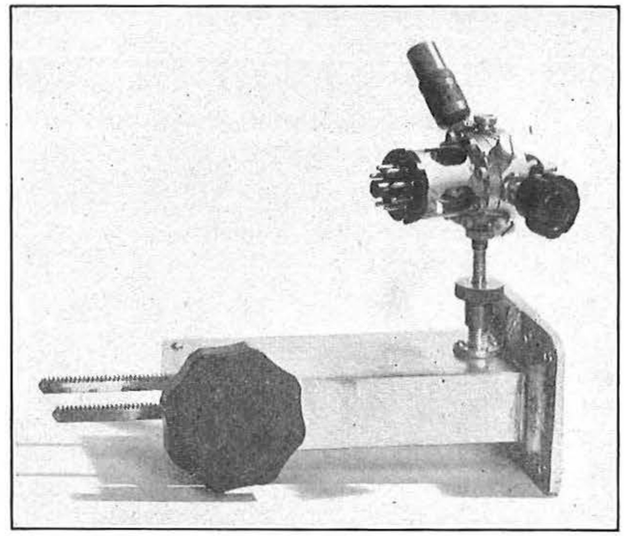


FIG. 12.—LAUNCHING UNIT COMPRISING KLYSTRON OSCILLATOR COUPLED TO SECTION OF WAVEGUIDE.

It is clear that the field configuration of the required mode must be known for the effective placing of the launching loop or probe. A third method of launching the wave is by means of a coupling hole between two sections of waveguide or between the waveguide and the microwave generator itself.

(*To be continued.*)

Book Reviews

"Introduction to Electric Fields." Walter E. Rogers. McGraw-Hill Publishing Co. Ltd., London. 1954. 333 pp. 147 ill. 60s.

This book was written for electrical engineering students at the University of Washington. Its object is to present Maxwell's equations as a logical summary of analytical experience in the use of vector methods of solving problems in electrostatics and magnetostatics. Consequently, the vector analysis approach to electromagnetic problems is emphasised throughout and there is considerable discussion about vectorial thinking processes which are assumed to be new to the student. Since Dr. Rogers has assumed that the reader has had no previous experience of vector analysis (and knows nothing about the solution of partial differential equations) it follows that he is compelled to develop the subject slowly. The very slow pace of the book can be judged by the fact that the first three chapters (which cover 101 pages) discuss only the theory of potential gradients and electrostatic fields from the viewpoint of Coulomb's law. After this, the pace quickens somewhat, and the fourth chapter, which describes electric fields associated with current-carrying conductors, is followed by a chapter describing electrostatic fields from the viewpoint of Gauss's law. Subsequent chapters deal with the theory of images, dielectrics, magnetostatic fields and the equations of Poisson and Laplace. The tenth chapter discusses time-varying electric and magnetic fields and summarises most of the material of the book by expressing Maxwell's equations in vectorial form.

A valuable feature of the book is Dr. Rogers' description of the fluid-flow model he uses to illustrate the direction lines due to point, line and other charge distributions. The water stream used in this model is dyed by crystals of potassium permanganate placed in the flow channel before the demonstration. Of particular interest is the fluid-flow map (shown on page 57) of the direction lines in the electrostatic field of a triode vacuum tube without space charge. In addition to these fluid-flow maps use is made of contour-lighted rubber-sheet models to illustrate the analysis of problems involving two-dimensional potential fields. There can be but little doubt that these visual illustrations of electric fields are much appreciated by students.

Although the mathematical pace of the book is slow, the general discussion is always interesting: the author shows the student that a vector equation is like a pocket map—a map that must be taken out of the pocket and unfolded before it can be of any real use. This vectorial unfolding calls for analytical manœuvres and Dr. Rogers is careful to point out the mathematical pitfalls that await the unwary. There are places where he suggests that the tensor notation may be more convenient than the vector notation for dealing with certain special kinds of electric field problems.

It is made clear in the book that the vector method is of use principally in proving general theorems. In concrete applications to electric field problems there is usually some asymmetry about the co-ordinates that makes it necessary to abandon the vector form at some stage in the work. Then the question of solving boundary-value problems arises and the use of the vector-potential concept in the solution of such problems is discussed briefly in the eleventh and concluding chapter. This book can be warmly recommended not only to students, but to any general reader who wants a comprehensive introduction to the theory of electric fields.

H. J. J.

"The Synchronous Induction Motor." J. Griffin, A.M.I.E.E. Macdonald & Co. (Publishers), Ltd. 136 pp. 55 ill. 18s.

This is a book which probably only the specialist will want to have always at hand, but since the synchronous induction motor is rarely treated fully in electrical engineering textbooks, it will undoubtedly prove useful to students and lecturers interested in electrical machines. There are chapters on starting, synchronising, elementary theory, power factor correction, overload capacity, variable excitation and inversion. The book deals very clearly with the theory, design and construction of these machines which are generally made in the range of 50 to 2,000 h.p. or larger. The interesting history of the 50 years' development of the machine is included in an appendix. The illustrations are useful and the diagrams are well drawn.

A. E. P.

Modern Indoor Lighting

P. E. MARRIOTT, B.Sc.(Eng.), A.M.I.E.E.†

Part 1.—General Principles and Design Factors

U.D.C. 628.972

This article, to be published in two parts, gives a general treatment of the subject of Modern Indoor Lighting and indicates the many factors requiring consideration by lighting engineers. Part 1 is concerned primarily with design factors such as quantity and quality of light, colour, location of fittings and maintenance requirements. Basic design methods and some details of lamps, fittings and control circuits will be included in Part 2.

INTRODUCTION

THIS article deals with a branch of engineering which is an art as well as a science. A lighting installation may be designed in accordance with well established basic principles and yet be dull, depressing or even annoying. Physiological and psychological factors are involved in addition to the normal engineering ones. The test of a good lighting installation is not only, as with most engineering projects, "does it work?", but also "is it noticed?"

It is emphasised that good installation design is not merely a matter of arranging a light over each working position but of making the lighting an integral part of the whole accommodation. With existing accommodation this is often difficult but with new work it can be done provided that there is careful planning of the lighting at an early stage in the planning of the building work and other accommodation services. Very often, however, the positioning of heaters, apparatus, ventilation ducts and pipes is completed before the lighting engineer is given an opportunity to start his design; the result is that lighting fittings must be located in the few spaces left free.

This article outlines the principles of good lighting and shows how they form the basis of modern lighting practice.

DEFINITIONS AND UNITS

In view of recent changes in some of the basic terms, symbols and units commonly used in lighting work it will be useful to summarise them here. The unit of luminous flux (F) is the lumen. Illumination (E) is expressed as the incident flux per unit area in lumens/sq. ft. The obsolete synonymous term for this unit is the foot-candle.

Luminous intensity (I) denotes the concentration of luminous flux in a given direction and may be expressed as flux per unit solid angle. The unit is the candela which is defined from the luminance of a body at the temperature of solidification of platinum. The luminous flux emitted by a source giving one candela intensity in all directions is 4π lumens.

The brightness of a light source in a given direction can be expressed as its intensity per unit area in that direction. The usual units are candelas/sq. in.

The same applies to a surface which is luminous because it reflects incident light. If such a surface is a perfect diffuser, of reflection factor ρ, and receives an illumination of E lumens/sq. ft., the luminous flux emitted will be $E\rho$ lumens/sq. ft. The brightness is then said to be $E\rho$ foot-lamberts. The term luminance (L) is used for the brightness measured by a photometer, and luminosity for the brightness experienced by an observer.

The foregoing are explanations rather than strict definitions. The latter are given in B.S. 233.

LIGHT AND SIGHT

Sight is virtually the only sense with which the lighting engineer is concerned and the success of any lighting installation depends solely on its contribution to efficient and comfortable seeing. But age, condition of eyes, experience with other types of lighting, temperament and even other strictly irrelevant factors affecting personal comfort such as heating and ventilation may affect an individual opinion as to what comprises "comfortable seeing"; there can, in fact, be a wide divergence of opinion regarding any particular installation.

It will be useful, therefore, to consider briefly the visual attributes of a "standard observer," i.e. one with so-called normal vision.[1] For instance, one of the most important visual factors is visual acuity, which is the ability to distinguish detail. A capital C is distinguished from an O by detecting the gap in the C—about 0·05 in. for this print. This gap subtends about 12 minutes at the eye at a distance of 15 in. Persons with normal vision can distinguish the details of a black object on a white background if the detail subtends at least 1 minute at the eye. The reciprocal of this angle gives a numerical value for the visual acuity.

It is the luminosity of a surface which is used in seeing, rather than the incident illumination, and visual acuity depends on the luminance of the task, that of the surround and the natural contrasts of the work.

Experiments have shown that maximum acuity occurs when the task luminance is slightly greater than that of the surround.[2] Under these conditions acuity increases approximately logarithmically with task luminance, whereas when the ratio of surround to task luminance (luminance ratio) is high or low the acuity reaches a comparatively low maximum at a moderate value of task luminance (this is illustrated for low ratios in Fig. 1).[3] The importance of this aspect of lighting is being increasingly acknowledged.

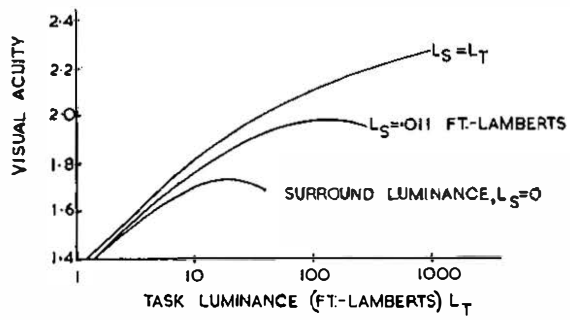


FIG. 1.—VARIATION OF VISUAL ACUITY WITH LUMINANCE RATIO.

As mentioned above the natural contrasts of the task itself affect vision. These should be high. Task contrast is usually given as $(L_2-L_1)/L_2$ where L_1 and L_2 are the contrasting luminances. If the illumination E is uniform and the respective reflection factors of the contrasting surfaces are ρ_1 and ρ_2, then

$$\text{Task Contrast} = \frac{E\rho_2 - E\rho_1}{E\rho_2} = \frac{\rho_2 - \rho_1}{\rho_2}$$

This contrast is often classed as high (above 60 per cent.), medium (30-60 per cent.) and low (under 30 per cent.). Thus for black print on white paper the task contrast would be about

$$\frac{0{\cdot}8 - 0{\cdot}05}{0{\cdot}8} = 94 \text{ per cent.}$$

† Executive Engineer, Power Branch, E.-in-C.'s Office.

This is high and therefore good. (If the paper were placed on a dark desk top with a reflection factor of, say, 0·08 the luminance ratio would be 10, which is bad.)

Fig. 2 shows the relation between task luminance and visual acuity for different values of task contrast.[4]

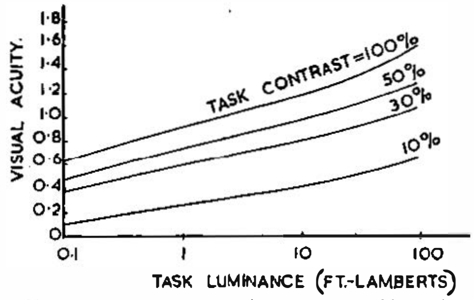


FIG. 2.—VARIATION OF VISUAL ACUITY WITH TASK LUMINANCE.

It should be mentioned that the numerical values obtained for luminance ratio and task contrast do not necessarily give a good idea of the degree of contrast experienced by an observer. For instance, taking the case of a black area on a white background where the luminance of the black is one tenth that of the white, the luminance ratio is 10 and the task contrast is 0·9 irrespective of the actual luminance values. In practice, however, it is found that the observer's impression of contrast increases with the luminance of the visual field (adaptation level).

Visual acuity, depending as it does on illumination, luminance ratio and contrast, is an important yardstick in judging the quality of lighting. It is not the only one, however, since for some tasks speed of perception is important.

Experiments have shown that speed of vision increases with size of detail, contrast and illumination. For a given task, i.e. when size and contrast are constant, speed is approximately logarithmically proportional to illumination,[5] within limits. Thus the illumination of a moving task must be increased to give the same visual efficiency as for a stationary task. Alternatively, any task, such as sorting, involving the viewing of a succession of fixed objects can be done at a higher rate with increased illumination, again within limits.

Finally, it is possible to provide an installation which is efficient in terms of acuity and speed of perception but which causes extreme visual fatigue. A working position lit to high intensity locally without adequate general lighting is a simple example.

These aspects will be discussed more fully in the next section which deals with the many factors involved in designing a good lighting scheme.

DESIGN FACTORS

The factors which must be considered in the design of any installation may be put under the broad headings of quantity and quality. All the factors must be considered in relation to the actual purpose of the lighting. For instance, is it primarily for illumination of some particular task, or is it what may be called amenity lighting, such as for a restaurant, where close attention to detail is not normally required?

Usually some specific task is to be performed and its severity varies from one such as packing, where discernment of detail is not required, to one such as watchmaking where continuous observation of fine detail is needed. Details of the task which decide the intensity of light required and which can usually be ascertained are:—

1. What is the size of the smallest detail to be observed?
2. Is observation continuous or intermittent?
3. How good are the natural contrasts of the task?
4. Is movement involved?

Other factors, which are normally of lesser importance but which need consideration, relate to the need for shadows and highlights and for colour discrimination. The age of the worker also affects his requirements but this is not normally a predeterminable factor.

Quantity of Light.

The experiments referred to previously indicate that increased illumination results in increased acuity and speed of perception, with the result that a given task can be carried out more efficiently and possibly with less strain. Apart from purely visual tests of lighting many field trials of particular types of work have been carried out with production as the criterion of the lighting. These show that, within limits, increased illumination results in increased production even in those tasks where it is not necessary to discern a high degree of detail, for instance foundry work.

Owing, however, to the logarithmic relationship between visual efficiency and illumination a very high illumination would be required for maximum theoretical efficiency. For instance, if an increase in illumination from 1 to 10 lumens/sq. ft. gives a 10 per cent. increase in efficiency it would be necessary to increase the illumination from 10 to 100 lumens/sq. ft. to give a further 10 per cent. increase. In actual fact, with an illumination of 100 lumens/sq. ft. efficiency would probably suffer due to discomfort from glare.

The Illuminating Engineering Society (London) illumination chart[6] takes into account both the size of detail and the natural contrasts of the work and specifies levels of illumination which will give high (but not maximum) visual efficiency. The size of detail is in six categories ranging from "minute" to "large" and the contrast in three categories, "high," "medium" and "low." For instance, this print has high contrast (above 60 per cent.), pencil lines on drawing paper have medium contrast (30-60 per cent.) and pencil lines on drawing paper covered by tracing paper have poor contrast (under 30 per cent.). Characters with indistinct edges make vision more arduous.

Thus this print, with ordinary detail and high contrast needs, according to the I.E.S., 2½ to 5 lumens/sq. ft. for reading it comfortably. On the other hand 30 lumens/sq. ft. are required for setting small type by hand, where the detail is small and the contrast only moderate.

Where movement of the task is involved or where close attention to detail is required for long periods, an increase in illumination of from 50 to 100 per cent. on the values given in the chart is recommended.

Quality of Light.

An indiscriminate increase in illumination will not necessarily give more satisfactory lighting. An installation must be carefully designed to give adequate quality as well as quantity.

The chief cause of visual discomfort is glare; this has been defined as "the disturbance when portions of the field of view have a brightness greatly in excess of that of the average for the field of view"[7] or more concisely "light out of place." This may be direct glare from the light source or reflected glare from objects having a high reflection factor.

All formulæ for calculating the maximum comfortable luminance of a potential glare source are of necessity empirical and involve a "glare factor" or "index of comfort." Hence no formula is universally accepted or applicable. One of the best known is[8]

$$L_G = \frac{K\ L_A{}^{0.3}}{\omega^{0.25}}$$

where L_G = maximum comfortable luminance of potential glare source,

L_A = luminance to which the observer was adapted immediately prior to encountering the glare source,

ω = solid angle subtended by glare source, and

K = index of comfort which is taken as 75 for a "normal" observer.

Although this formula takes into account the chief factors affecting glare (L_A and ω) there are others such as the severity of the task, the position of the glare source and the variation of luminance with time.

Normally a worker does not look at a task continuously but from time to time looks away from the work. Thus the luminance of the task and its immediate surrounds is not the only factor to be considered, since a glare source may exist which is only within the field of view when the worker looks *away* from his task. In fact, the general luminance distribution over the whole field of view is important and this aspect will be discussed in Part 2 under the "brightness" method of design.

Colour and Harmony.

Light energy is perceived over a range of colours ranging from violet (4,000 Å wavelength) to red (7,000 Å). "White light" consists of a combination of the various colours. The normal standard of white light is daylight although the colour of this varies considerably at different times of the day. Tasks which require accurate judgment of colours are usually carried out by daylight from a north-facing window, sunlight being excluded.

"White" light from artificial illuminants is subject to even greater variation. The light from a tungsten filament lamp is rich in red and deficient in blue as compared with daylight; a small variation in colour can be obtained by varying the filament temperature (and therefore the life and efficiency) but, apart from the use of colour filters which are very inefficient, little more can be done to change its colour. With fluorescent lamps, however, variation of colour can be obtained by using different fluorescent powders.

There are two aspects of colour, the appearance of the light source and the appearance of coloured objects illuminated by the source. The latter, called colour rendering, is important where colour discrimination is necessary. For instance, a red postage stamp appears to be very dark under a light source deficient in red. Also the colour of the background considerably affects the apparent colour of the viewed object.

We are used to the light from filament lamps which is rich in red and find that decorations, food and people appear "warmer" and generally more acceptable under it than under the "colder" light from fluorescent lamps giving a larger proportion of blue. But the latter lamps give a more stimulating light which blends far better with daylight. When fluorescent lighting is used consideration must be given to the colour rendering of work, furniture and decorations by both daylight and artificial light. A colour scheme which is very pleasant during daylight hours can be drab or discordant under fluorescent lighting.

It is an essential part of a lighting engineer's work to ensure that the type, colour and position of the lighting will harmonise with the architectural features and decorations and also be suitable for the use to which the premises will be put. Lighting which gives a "milk-bar" atmosphere in a conference room is clearly inappropriate.

Installation of modern lighting to harmonise with the architectural features of older buildings is a fairly common problem. Although general rules are applicable to this aspect of lighting, each of these cases must be treated on its merits.

Position and Type of Fittings.

The type of fitting will depend largely on the type of lighting used. The types of lighting may be summarised briefly as follows:—[9]

Type	Flux Distribution		Typical Fittings
	% up	% down	
Direct	0–10	90–100	Fittings with opaque reflectors; "built in" fittings; laylights.
Semi-direct	10–40	60–90	Enclosed fittings; batten-type fluorescent fittings; fittings with translucent reflectors.
General diffusing	40–60	40–60	Enclosed diffusing fittings.
Semi-indirect	60–90	10–40	Translucent bowls.
Indirect	90–100	0–10	Opaque bowls; "built in" fittings.

Direct lighting is efficient but with suspended fittings the small proportion of upward light may result in severe contrast between the luminance of the task and that of the upper field of vision, especially the ceiling. Excessive contrast can also be experienced where fittings are built into a ceiling which receives no direct illumination. With laylights and illuminated ceilings of the "Louverall" type the danger of excessive contrast is less great. Care must be taken, however, that the luminance of the source is not so high as to cause direct glare.

Indirect lighting is comparatively inefficient but may be of high quality. In general it is unsuitable for working on detailed tasks unless supplemented by local lighting; otherwise the task luminance will be much lower than the ceiling luminance and a feeling of gloom will result. Furthermore, large areas of uniform luminance will give a "flat" appearance.

Semi-direct and general diffusing lighting is very suitable for most purposes, combining reasonable efficiency with good quality and acceptable appearance. Special consideration is necessary in the positioning of the fittings so as to avoid glare and unnecessary shadow.

Economy.

The cost of an installation is not necessarily an indication of its quality. Having set the standards of quantity and quality there are several ways in which economy can often be effected. In all cases the most efficient use should be made of the light provided by using decorations and furniture with reasonably high reflection factors, say 0·5 for walls and 0·8 for ceilings. This is not always within the control of the lighting engineer. Also a certain amount of localising of light is often possible where high illumination is required in only a few parts of a room. For instance, in a bank or post office the high illumination is required only on the counter and writing positions and the illumination in the concourse can be as low as one-third of that on the working positions without unpleasant contrasts resulting. In other cases, such as a clerical or typing office, this principle might apply equally well but the frequency with which the furniture and desk layout changes usually makes it more economical to use uniform general lighting.

When a scheme has been decided upon, with these factors in mind, the annual cost of an installation may be divided into three parts, i.e. (i) providing the fittings, installing and wiring, (ii) maintenance, and (iii) supplying with electricity.

Providing, installing and wiring.—The cost of providing, installing and wiring the fittings can be minimised by the use of high-power lamps or groups of lamps. As high-power lamps are more efficient than low power, either approach will reduce the number of supply and mounting points required. The extent to which this can be done will depend on the permissible mounting height. Too few fittings, too low a mounting height or too high an intensity will result in bad distribution of the light over the working plane, glare or both. Where large numbers of fittings are required for standard types of accommodation, standardisation of fittings into a few types and designs is an obvious economy.

Maintenance.—Maintenance of an installation is an important consideration as its cost may equal the annual charge proper to provision and installation. It may be divided into two categories, namely engineering maintenance including lamp replacements, and cleaning. For all maintenance work accessibility of the fittings is of prime importance. Where the mounting heights are large, lowering gear may be justified providing that it can be made inconspicuous. Very little engineering maintenance is usually required apart from lamp replacements and renewal of supply flexes. Changing a fluorescent lamp involves going to both ends of most commercial fittings to release the lamp from the lampholders. To avoid this a lampholder assembly has been designed for P.O. use in which the lampholders are carried at each end of the fitting on a spring loaded sliding plate which gives the necessary end pressure to hold the lamp in position. Thus the lamp can be removed by one hand from one end of the fitting, the usual rotary motion to release the bayonet caps from the lampholders not being needed.

Ease of access to the reflecting and light transmitting parts of a fitting ensures that washing and dusting may be carried out efficiently. Unfortunately the steps taken to ensure that the light sources are not glare sources, such as using diffusing enclosures and louvres, mean that cleaning and lamp replacements are made more difficult. Louvres and diffusers should be easily removable without the use of tools and, if possible, hinged to the fitting.

Accumulation of dirt on fittings results in both reduction of the illumination and waste of light. The over-riding necessity is that the cleaning interval shall be such that the illumination never falls below an adequate value. Subject to this the most economic cleaning interval is such that the cost of cleaning equals the cost of the light wasted by depreciation over that interval. Hence the most economic cleaning interval is $\sqrt{2M/CD}$, where C = average cost of electricity per month (including a proportion of fixed charges) and of lamp replacements, M = cost of one cleaning and D = monthly rate of depreciation. For an average filament installation the most economic interval is of the order of 3 months. The higher cost of cleaning makes the interval longer for a fluorescent lighting installation.

Supply.—For a given installation the cost of electricity and wiring may be reduced by using higher efficiency lamps, and, where suitable on considerations other than that of economy, discharge lamps are an obvious choice, having efficiencies of two to three times those of filament lamps. Capital and maintenance charges are, however, higher for discharge lamps so that for a given installation the comparative economies of the two types of lighting depend on the hours of use.

Thus minimum hours of use per year (H) for discharge lighting to be economic is given by,

$$H = \frac{1{,}000\,[(C - c) + (M - m)]\,Ee}{p\,(E - e)}$$

	Filament	Discharge
where, lamp efficiency	= e lumens/watt	E lumens/watt
Yearly cost of maintenance, cleaning and lamp replacements	= m pence/lumen	M pence/lumen
Cost of electricity	= p pence/kWh	p pence/kWh
Fixed annual charges	= c pence/lumen	C pence/lumen

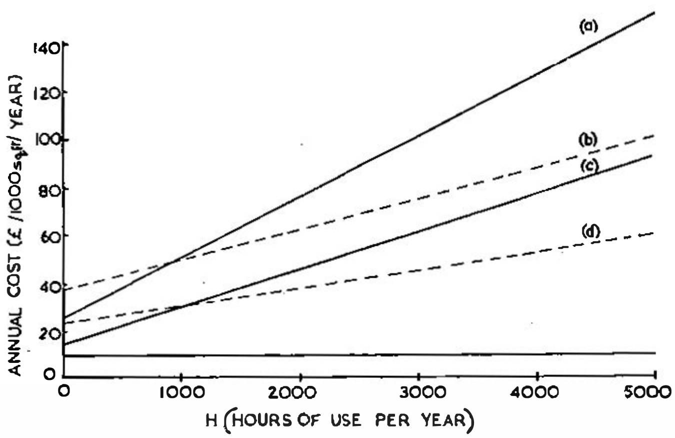
Comparing normal filament and fluorescent installations and taking E as $2{\cdot}5e$, M as $2m$ and C as $1{\cdot}5c$

$$\text{then, } H = \frac{5{,}000e\,(c + 2m)}{6p}$$

For normal indoor installations, such as offices, H is about 1,000 hours/year.

It is emphasised that the above formulæ only apply for comparison between filament and fluorescent installations to give the same illumination. The actual economy effected by using fluorescent lighting is often less than it would appear at first sight. For a given minimum illumination the average illumination must be greater by fluorescent lighting to allow for the higher lamp output depreciation; it is found in practice that higher illumination than the visual task demands is sometimes needed with present-day fluorescent lamps to avoid any general appearance of gloominess; as the spectral distribution of the light output of fluorescent lamps is normally nearer that of daylight there is greater tendency for the lamps to be switched on to supplement daylight and the hours of use may increase when fluorescent lighting is installed; finally, the number of cases where filament lighting can be replaced by fluorescent to give increased illumination without the need for replacing existing distribution wiring is reduced by the I.E.E. rule in the "Wiring Regulations" which calls for the current carrying capacity of wiring supplying discharge lamps to be de-rated by 20 per cent.

Fig. 3 shows comparative annual costs per 1,000 sq. ft. of illuminated area for filament and fluorescent lighting.



(a) Filament (15 lumens/sq. ft., average).
(b) Fluorescent (15 lumens/sq. ft., average).
(c) Filament (9 lumens/sq. ft., average).
(d) Fluorescent (9 lumens/sq. ft., average).

FIG. 3.—COMPARATIVE COSTS OF FILAMENT AND FLUORESCENT LIGHTING.

Although most fluorescent lamps, except those in public service vehicles and aircraft, are operated on a 50 c/s supply, recent investigations[10] show that there are considerable advantages to be obtained from operation on a higher frequency supply, preferably about 3,000 c/s. The chief advantages are longer lamp life and higher efficiency, smaller control gear with lower losses, no flicker or stroboscopic effect and sinusoidal wave form. It has been claimed that the use of lamps on a higher frequency supply, with a motor generator to convert the frequency, results in financial saving as compared with a similar installation supplied at 50 c/s. The comparison ignores maintenance charges, however, and bases its running costs on 2,500 hours use per year.

A point of international interest at present is whether medium and large filament lamps with lives in excess of the usual 1,000 hours should be added to the present standard range. For P.O. purposes, with an average electricity cost of 2d. per kWh, an average cost of replacing a lamp of 20 pence and assuming that lamp life is inversely proportional to the seventh power of efficiency, the optimum life of a 150W lamp is about 1,600 hours. This indicates that the present nominal life of 1,000 hours is rather low. In certain cases, however, where lamp replacement is difficult long-life (say, 2,500 hours) lamps would be more economic.

Small sizes of lamps with extra filament supports are already in use for rough-service purposes where the saving due to the reduced rate of replacement outweighs the extra cost of electricity due to reduced efficiency.

Safety.

No special precautions are necessary from an electrical point of view except with cold cathode lighting which uses high voltages. Modern cold cathode fittings employ an interlock which precludes access to the fitting wiring while any part is still live.

With fluorescent lamps, the cyclic variation in light output is much more marked than with filament lamps and this may be dangerous where there is rotating machinery. In such cases a twin lamp fitting can be used with a capacitor in series with one lamp to give a phase difference in the light output of the two tubes (usually about 120°). Although the discharge is extinguished every half cycle the after-glow of modern fluorescent powders ensures that the light output drops to only one-third of the maximum. Thus with 120° phase difference the minimum light output is about 70 per cent. of the maximum on a 50 c/s supply. This compares with about 85 per cent. for a 200W filament lamp. The stroboscopic effect of fluorescent lighting is often reduced still further by supplementing it with filament local lighting.

Other Factors.

Although increased illumination gives increased visual acuity, this is only true within limits, and there are some tasks, such as watchmaking, which demand so high an acuity that very high illumination is not the answer. In such cases the task is magnified by a lens so that the severity of the visual demands made on the worker is reduced.

In other cases visual comfort can be increased by reducing the task/surround luminance ratio—in offices, for instance, by using desk tops having a higher reflection factor. The position or inclination of the task can sometimes be altered so that specular reflections or shadows are not troublesome to the operator. Conversely, specular reflections from the markings on a steel rule are desirable to enable it to be read more easily.

These and other similar considerations can be regarded quite fairly as within the lighting engineer's purview.

References.

[1] C.I.E. Proceedings, 1931.
[2] Medical Research Council Special Report No. 173.
[3] I.E.S. Lighting Handbook, Chapter 2.
[4] ibid.
[5] ibid.
[6] I.E.S. (London) Code for the Lighting of Building Interiors, 1949, p. 15.
[7] ibid., para. 24.
[8] I.E.S. Committee on Quality and Quantity of Interior Illumination, Report No. 1.
[9] Stevens, W. R. "Principles of Lighting," Appendix 2.
[10] Spencer, D. E. "Frequency and Fluorescent Lamps," *Elec. Eng.* (N.Y.), December 1953.

(*To be continued.*)

Book Reviews

"Data and Circuits of Television Receiver Valves." J. Jager. Philips Technical Library, Electronic Valves, Book IIIC, distributed in U.K. by Cleaver Hume Press Ltd. 216 pp. about 225 illustrations. 21s.

Although early television receivers were made using receiving-type valves in existence at the time, such valves did not entirely meet the special requirements of the new television techniques, and later the large-scale production of television receivers led to extensive demands for more suitable types.

This volume, a further addition to the Philips series on electronic valves and their applications, gives details of a range of valves specially produced to meet the new demand. About two-thirds of the book is devoted to describing in detail the characteristics of each valve in the range. The information is more comprehensive than is usually found in valve data sheets and is, of course, specifically directed towards the television application. Details of two cathode-ray tubes are included.

The remaining third of the book describes circuits in which the valves may be used, with particular reference to inter-carrier sound and flywheel synchronisation circuits. Inter-carrier sound reception is a system, used extensively in the United States, in which the same I.F. stages are used for both sound and vision. At the detector a beat is produced between the sound and vision carriers which carries the sound as frequency modulation and the vision as amplitude modulation. In the sound section of the receiver the vision amplitude modulation is removed by limiting and the sound is obtained by means of a discriminator. This system cannot be used with British television in which the sound is transmitted as amplitude modulation as well as the vision. For this reason the receiver circuit described is not suitable for use in this country. Flywheel synchronisation has been fully described in another volume from the Philips Technical Library which was reviewed recently.

Although confined to the products of one manufacturer the book will be of great value to the television receiver designer as well as to the amateur constructor.

T. K.

I.P.O.E.E. Library No. 2198.

"Electrical Earthing and Accident Prevention." Edited by M. G. Say, Ph.D., M.Sc., M.I.E.E. George Newnes, Ltd. 248 pp. 123 ill. 25s.

This attractively produced book provides a good introduction to a subject of interest and concern to all electrical engineers, as well as to all connected with safety measures in the home or industry. The book is the work of 19 contributors, each a specialist on his branch of the subject, and outlines the accepted practice and recent development in each field.

In an introductory section, contributed by H.M. Senior Electrical Inspector of Factories, on "Accidents and their Prevention," an analysis is given of recent fatalities caused by the use of electricity, and remedial measures applicable in home and industry. Sections then follow on the earthing regulations; power-system earthing; the earthing of domestic and industrial installations including ship, electric traction, mining and aircraft installations; the earthing of telecommunication systems; consumer plant earthing including portable appliances and machine tools; and finally, earthing measurements and maintenance, and lightning protection.

The book is designed for the non-specialist who, while wishing to increase his knowledge of the subject, has little time to delve into a mass of detailed technical literature. It serves this purpose admirably and most engineers will find something of interest and value in its pages.

L. F. S.

The New Standard Subscriber's Line Circuit Equipment

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U.D.C. 621.395.341.21

With the development of the Type 3 uniselector of reduced width it became possible to mount 300 uniselectors on a 10ft. 6½in. rack. At the same time it was decided to introduce a two-home-position feature into the uniselector circuit to give improved service to subscribers under certain conditions. The introduction of equipment giving these new facilities has necessitated major re-design work as explained in this article, which opens with an account of the revised trunking arrangements required for two-home-position working. The rack design and cabling arrangements are then described in some detail and, in conclusion, the main constructional features of the Type 3 uniselector are referred to.

Introduction

FOLLOWING the development of the Type 2 uniselector for general use, a uniselector of lighter construction (known as the Type 3) has been produced for subscribers' calling equipments. It is narrower than the old Type 1 to the extent that it is possible to mount 25 switches instead of 20 on one shelf of a standard 4ft. 6in. rack. To make the best use of this narrower uniselector it has been necessary to re-design the rack for subscribers' calling equipments and opportunity has been taken to incorporate the two-home-position facility into the circuits.

This article describes the two-home-position circuits and their trunking arrangements, the "preference" and shared-service facilities, the new rack with grading facilities and the Type 3 uniselector which was only briefly mentioned in a previous article[1] on the Type 2 uniselector.

Trunking and Grading Considerations

Two-Home-Position Facility.

With the present method of trunking the outlets from a subscriber's uniselector to 1st selectors, the grading forming the interconnection implies that all choices are tested in a definite order, this order being the same on every call attempt. It has always been appreciated, therefore, that, if the selector representing the first choice to a particular subscriber is faulty, the calls originated by this subscriber could repeatedly seize the faulty choice. This condition could arise during periods of light traffic when most of the exchange equipment is not in use. During normal and busy periods, the condition is not so serious, as, due to the intervention of other calls, the second attempt may seize a different selector.

It will be appreciated, therefore, that, if a subscriber's uniselector has a faulty first-choice outlet, this could have the effect of isolating that subscriber from the exchange during periods of light traffic.

With the continued growth and use of the 999 Emergency Service and the increased incidence of these calls during periods of light traffic, the above disadvantage assumes greater significance, thus increasing the need for an alternative first-choice selection on a repeat attempt.

Many schemes for providing an alternative choice have been investigated, including different methods of "search" and "interconnection," which for technical or economic reasons were not introduced. Of these schemes the simplest was found to be that which used a uniselector bank with two home positions, as illustrated in Fig. 1. This scheme enables a subscriber to be given a different first-choice outlet on a repeat call during periods of light traffic and also produces a more even distribution of traffic over the outlets. Although at that time it was not considered practicable to introduce this arrangement, the later development of the new Subscriber's Line Circuit Rack provided an opportunity to bring the scheme into use with little additional expense.

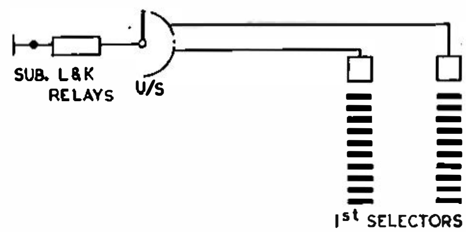

FIG. 1.—SIMPLE TRUNKING DIAGRAM ILLUSTRATING USE OF TWO-HOME-POSITION SUBSCRIBER'S UNISELECTOR.

In view of the importance of the telephone service in emergencies, this has now been adopted as the standard method of trunking subscribers to 1st selectors. Circuits have been produced which, in addition to all the usual facilities given by a single-home-position uniselector, provide for connection to the first free outlet in the group or groups, with continuous search over both groups if all outlets are engaged. On the release of the call the wipers are driven to the next home-position.

These circuit facilities have been made possible by the use of "split" homing arcs in the bank assembly arranged in the circuit, as shown in Fig. 2.

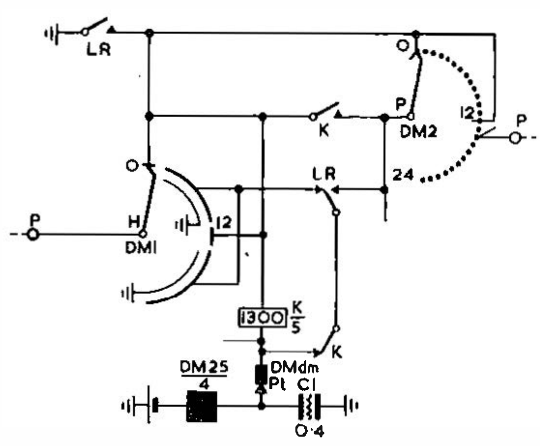

FIG. 2.—PART OF CIRCUIT OF TWO-HOME-POSITION SUBSCRIBER'S UNISELECTOR.

The operation of the circuit follows the same sequence as the usual single-home-position circuit, but it should be noted that contacts 0 and 12, which form the two home-positions on the homing arc, are strapped so that, on an incoming call from the final selector to the subscriber, an operating circuit for K relay is available from either home-position. Also, on the P arc, the same contacts 0 and 12 are strapped to provide an initial operating circuit for the drive magnet from either home-position when the subscriber originates a call. It also follows that the 0 and 12 contacts on the — and + arcs must be disconnected and not multipled.

Positioning of the Second Home-Position.

The selection of position 12 for the second home-position

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[1] *P.O.E.E.J.*, Vol. 42, p. 17.

was determined by calculation and artificial traffic tests which sought to ascertain whether a small group followed by a large group, or two equal groups, produced the more efficient traffic-carrying combination. It was found that, ideally, two equal and efficiently-graded portions produced the best traffic-carrying combination and that, at any instant, an equal number of uniselectors would be standing on each home-position. In practice, therefore, as the nearest equal division is 11 + 12, approximately equal amounts of originating traffic would be offered to each group of outlets.

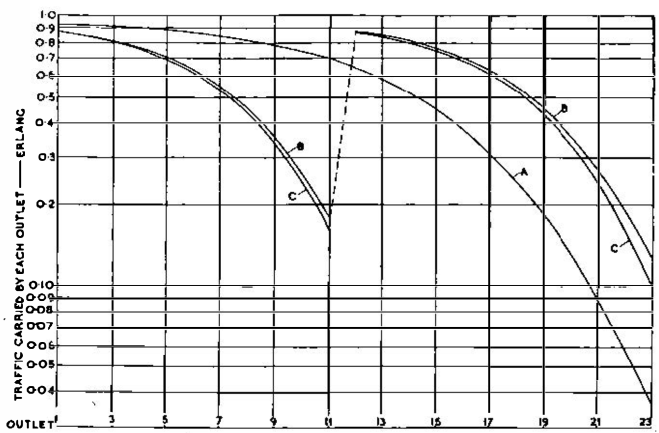
The result of this nearly equal division is most important from a maintenance point of view in the following three ways:—

(*a*) As the traffic is more evenly distributed over the switches in the 1st selector rank, these switches sustain more even wear, thus reducing the fault liability of the first-choice selectors.

(*b*) The uniselector will require to make fewer steps to find a free outlet and fewer steps on completion of a call to return to a home-position, so reducing contact wear.

(*c*) Due to (*b*) a reduced demand will be made on the exchange battery.

The distribution of traffic over the outlets of a uniselector under three different methods of search is shown in Fig. **3**.



A—Full-Availability Group: Single Home Position.
B—Full-Availability Group: Two Home Positions.
C—Two Independent Groups.

FIG. 3.—TRAFFIC CARRIED BY EACH OUTLET OF A UNISELECTOR FOR THREE METHODS OF SEARCH.

Curve A shows the traffic carried by each outlet in a 23 full-availability group when 13·0 Erlangs are offered, a complete search being made over all outlets before a call is presumed lost. From this it may be seen that the traffic occupancy of the 1st and 23rd choices is 92·8 per cent. and 3·7 per cent. respectively. Curve B, derived from results obtained on the Electronic Traffic Analyser,[2] indicates the distribution of the same amount of traffic (13·0 Erlangs) offered equally, i.e., 6·5 Erlangs, to each portion of a two-home-position uniselector of 11 + 12 availability; a complete search being made over all outlets before a call is presumed lost (i.e., a total of 23 outlets). The traffic occupancy of the 1st and 11th choices is 86·8 per cent. and 18·4 per cent., and of the 12th and 23rd choices it is 87·3 per cent. and 12·7 per cent. respectively.

Curve C shows, for comparison, the distribution of traffic over two independent full-availability groups of 11 and 12 outlets respectively. Any call originated in either of these groups tests, once only, the outlets in that group before it is lost, i.e., all calls originally offered to the 11-availability group must be carried by or lost in that group.

[2] *P.O.E.E.J.*, Vol. 42, p. 181.

Grading of Outlets.

The uniselector bank has 25 contacts, two of which, 0 and 12, are used as the home-positions; the uniselector, therefore, has a total of 23 outlets made up of 11-availability and 12-availability portions. When the total number of 1st selectors required is less than the availability of the uniselector the number of trunks is divided equally between the two portions of the bank; an odd trunk will be allocated to the 12-availability portion of the bank.

When the total number of 1st selectors required exceeds the availability of the uniselector (i.e., over 23) gradings must be provided. Many arrangements are possible, but the highest traffic-carrying formation is produced when:—

(*a*) Equal numbers of trunks are available in each portion of the grading.

(*b*) The formation of the grading on each portion is based on the availability of each portion separately.

(*c*) The formation gives the smoothest progression from individuals to pairs, etc., as at present.

Fig. **4** is an example of the "formation" of an efficient grading, assuming four groups of uniselectors which require 39 trunks.

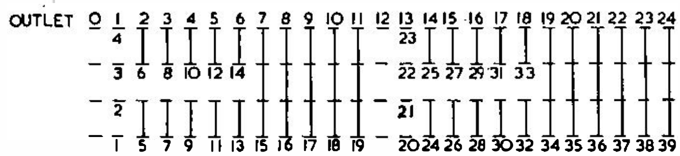


FIG. 4.—GRADING WITH AVAILABILITY 11 + 12; 4 GROUPS; 39 TRUNKS.

Allocation of Selectors.

The general principles of the present practice are to:—

(*a*) Maintain equal traffic loading of selector shelves.

(*b*) Give the widest accessibility from each group of the grading.

(*c*) Ensure that consecutive choices are not associated with selectors on any one shelf.

To maintain these principles, selectors, from gradings of uniselectors with two home-positions, should be allocated commencing with the first choice of the lowest grading-group of the first portion of the grading and working upwards to the top group, then allotting selectors to the first choice of the second portion of the grading in an upward direction, followed by the second choice of the first half in a downward direction and the second choice of the second portion in a downward direction and so on throughout the grading.

In order to meet the requirements of (*c*) above, it is necessary to regard contacts 1 and 13 of any one group as consecutive choices, since only these contacts will be used during periods of light traffic. Therefore, the selectors allocated to outlets 1 and 13 should be on different shelves.

The allocation of selectors to the grading in Fig. **4** could be as shown in Fig. **5**.

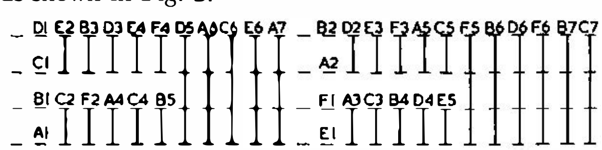


FIG. 5.—ALLOCATION OF SELECTORS ON SHELVES A TO F TO A TWO-HOME-POSITION UNISELECTOR GRADING.

Traffic Capacity.

It will be appreciated that the 24-availability table at present used for the single home-position gradings could not be applied to the new gradings.

To determine, however, whether the 23-availability tables could be applied in practice, tests were made with the

Electronic Traffic Analyser and the traffic capacity for the standard grade of service was obtained. The results showed the capacity of the new gradings to be slightly greater than that of a normal 23-availability grading of the same number of trunks as given by the pure chance 23-availability table, which has been shown to be rather generous in provision when applied to single-home-position switches.

It was decided, therefore, that a grade of service not worse than the "Standard" could be obtained by the use of the existing 23-availability traffic capacity tables for assessing the number of trunks required on a two-home-position uniselector grading.

Limitations of Gradings.

The maximum size of a two-home-position uniselector grading will be limited by the present "cross-talk" and maintenance factors which require that not more than 2,000 subscribers' uniselectors should be in one common grading and that the number of 1st selectors served from a grading should not exceed 240, when used with 2,000-type equipment on standard 10ft. 6½in. racks.

This latter factor governs the total traffic which may be offered to a fully loaded grading, and represents, for a two-home-position subscriber's uniselector grading, a traffic capacity of 154·4 Erlangs.

The minimum number of grading groups which will be required is normally given by the formula

$$g = \frac{2N}{A}$$

where, g = minimum number of groups,
N = number of 1st selectors, and
A = availability (23).

In small gradings of 2, 4 and 6 groups, however, the maximum permissible numbers of 1st selectors are 37, 58 and 74 respectively.

As an example, assume an exchange of 600 lines and an anticipated originating traffic of 42·0 Erlangs, to be equipped with subscribers' uniselectors with two home-positions per bank, 25 uniselectors per shelf and 12 shelves per rack, trunked to 200-outlet, 2,000-type 1st selectors. Then,

No. of 1st selectors required = 69 {Pure chance, 23-availability, "Standard" grade of service, traffic capacity table.

No. of uniselector shelves $= \frac{600}{25} = 24$

Minimum number of grading groups

$$= \frac{2N}{A} = \frac{2 \times 69}{23} = 6.$$

Therefore with 24 shelves each "grading group" will be 24/6 = 4 shelves of uniselectors.

With 4 shelves per group there will be 3 grading groups per rack.

The arrangement of the two portions of the grading to accommodate 69 1st selectors will be:—

3 Individual choices + 3 Pairs + 2 Threes + 3 Commons in the 11-availability portion, followed by 3 Individuals + 3 Pairs + 2 Threes + 4 Commons in the 12-availability portion, as shown in Fig. **6**.

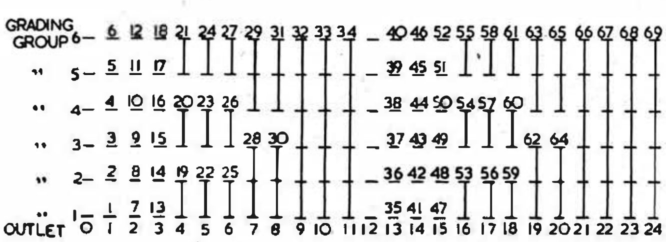


Fig. 6.—Grading with Availability 11 + 12; 6 Groups; 69 Trunks.

Traffic Meters.

After tests on the Electronic Traffic Analyser, it was decided that, for the purpose of estimating the traffic carried by the last choice outlets in each half of the grading at grades of service of 0·005 or better, a grading on the two-home-position uniselector could be regarded as two independent gradings, each being offered half the total traffic. Accordingly, late choice critical figures were determined on this basis to be a pointer to conditions of congestion.

The late-choice traffic meter is connected to the last outlet in the second half grading, and the critical capacity of this contact has been calculated assuming that half the total traffic at a grade of service of 0·005 was offered from the second home-position.

It should be realised that the method of estimating the traffic carried by any grading is inherently inaccurate when the same critical figures are used for gradings with varying numbers of groups.

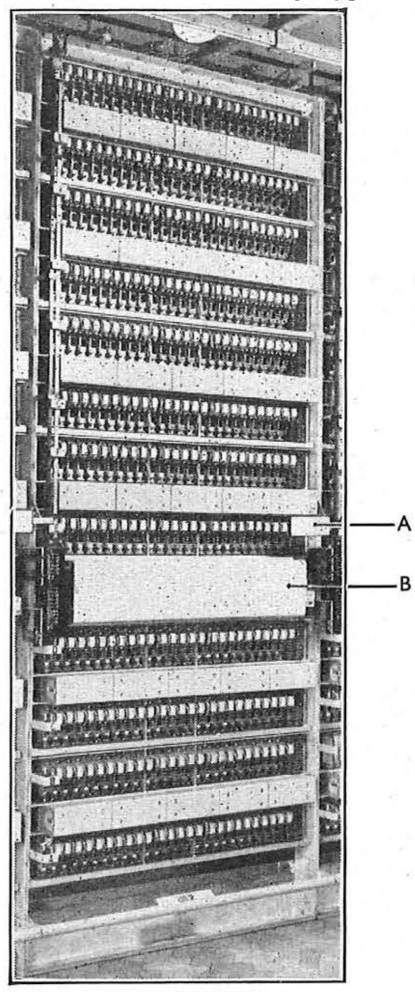
It is, therefore, expected that the application of the same principle to two-home-position uniselector gradings will yield results comparable to those already obtained in practice on normal gradings, with continuous search.

The actual traffic carried by the uniselector grading is measured, as at present, by use of the Automatic Traffic Recorder to count the traffic carried by the 1st selectors connected to the grading.

Rack Design and Cabling Arrangements

The Subscriber's Line Equipment Rack.

New Standard Line Equipment Racks have now been developed, based on the normal exchange-type rack frame-



A—Grading Chart.
B—Grading Shelf.

Fig. 7.—Subscriber's Line Equipment Rack of Capacity 300 Lines.

work of 4 ft. 6 in. width and 10 ft. 6½ in. or 8 ft. 6½ in. height. The 10ft. 6½in. rack carries, as shown in Fig. 7, 12 shelves of 25 uniselectors with their attendant relays together with a shelf of grading connection strips; on the 8ft. 6½in. rack, eight uniselector shelves and the grading shelf are accommodated.

The facilities given by these racks are:—

(*a*) Capacity for 300 line circuits on the 10ft. 6½in. rack or 200 on the 8ft. 6½in. rack.

(*b*) Grading of the 23 outlets of each shelf over a maximum of 80 trunks to the I.D.F.

(*c*) Conversion of each shelf from "preference" to normal working by a simple strapping operation on two tags. (The "preference" scheme is explained later.)

(*d*) Two-key control of the preference disconnect scheme.

(*e*) Conversion of pairs of line circuits from exclusive to shared service by a simple wiring connection.

(*f*) Connection strip termination of all incoming and outgoing cables.

Several novel details of construction have been incorporated in this rack and the design is such that, while many maintenance advantages are available, more speedy production methods may be used.

Shelf Unit.

The uniselectors are mounted on a unit framework of light-gauge steel sections, each unit carrying two shelves of 25 uniselectors spaced above and below a row of five relay plates. Connection strips at the right-hand side provide for connection of incoming lines from the I.D.F.

Fig. 8 illustrates the construction of the framework. The upper and lower angles are fixed in the opposite sense so saving rack space by permitting a measure of overlapping. The fact that the frameworks overlap does not prevent removal of individual shelf units should this be necessary. The rigidity of the unit frame, which has to carry a load of some 180 lb. without sagging, is increased by the crossbraces and by the brackets which support the relay plates and also serve as cover guides.

Each relay plate contains the LR and K relays for 10 circuits, corresponding to the five uniselectors above and the five immediately below the relay plate. On the rear of the plate is fitted the auxiliary tag strip which carries the normal battery and earth, and the "preference" battery connections for the relay plate.

The uniselectors are mounted in groups of five on pairs of L-section rubber anti-vibration mountings, one of which is shown in Fig. 9. The rubber is of a special quality and is

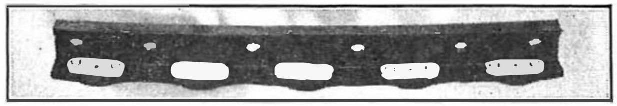


Fig. 9.—Rubber Anti-Vibration Mounting.

internally reinforced with rubber-impregnated fabric; to minimise mechanical coupling between adjacent mounting points, the material is so cut that the threads run diagonally and thus do not link any two uniselectors. This form of mounting prevents any tendency for a running uniselector to produce microphonic noises in the speaking circuit of a neighbouring unit.

As shown by Fig. 10, the rubber mountings are affixed to pins on the horizontal bars of the steel framework by

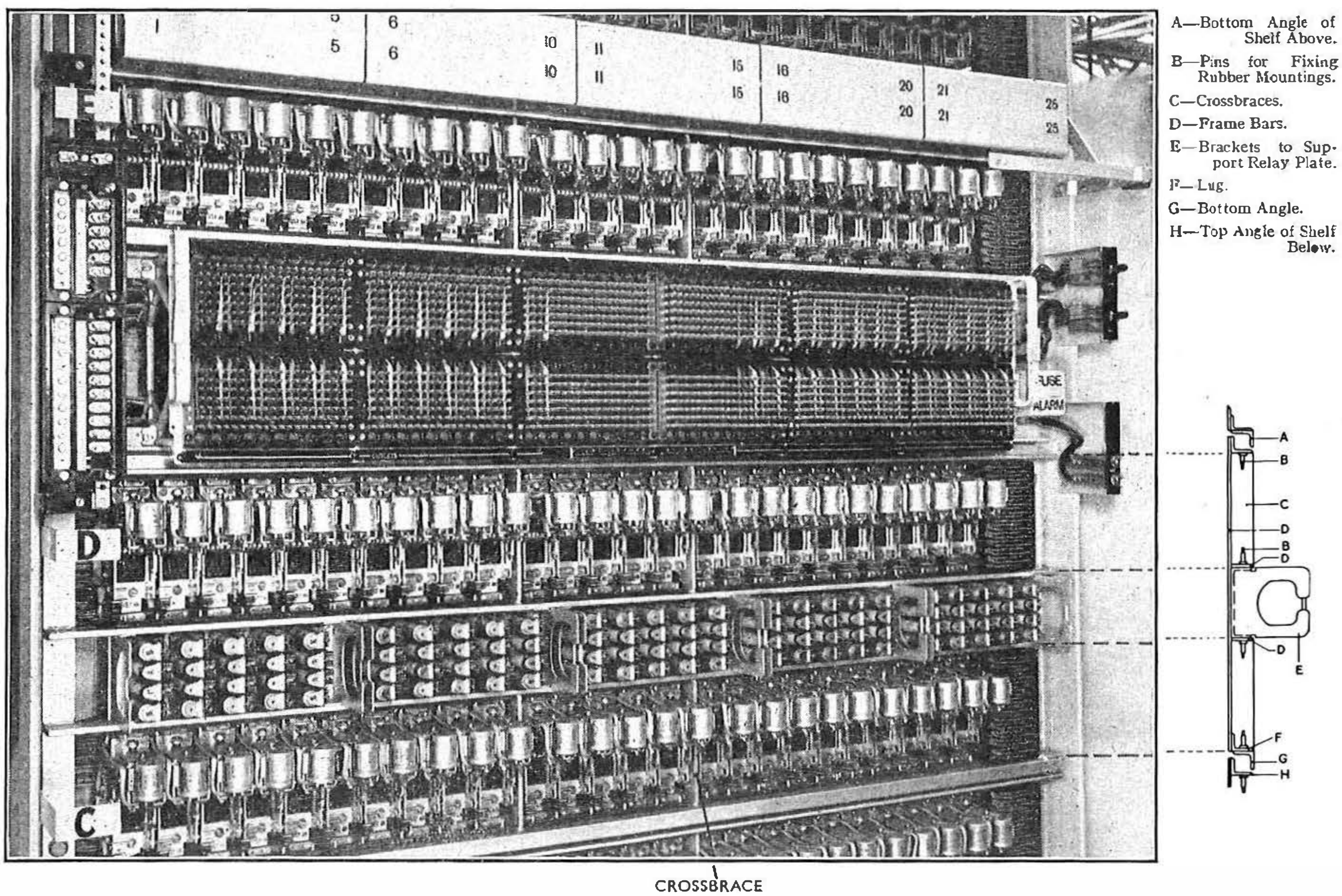


Fig. 8.—Twin-Shelf Unit and Grading Frame with Covers Removed and, at Right-Hand Side, the Frame Construction Showing Overlapping.

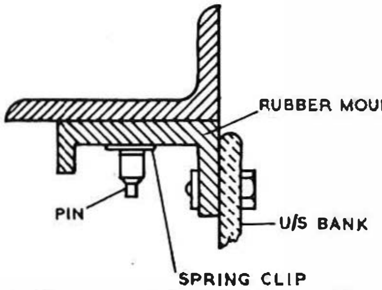


FIG. 10.—CROSS-SECTION OF ANTI-VIBRATION MOUNTING FIXED TO TOP ANGLE.

press-on spring clips, while the uniselector banks are screwed to steel plates riveted to the rear flange of the mounting; a projecting fin moulded along the front edge serves as a support for a jig on which the mechanism may be mounted for adjustment and running tests as described later.

This new type of mounting is an improvement on the U-shaped metal springs previously used, since these, being fitted behind a horizontal framework member, obstructed access to the mechanism fixing screws; it is also quicker to assemble, and thus gives economy in manufacture.

Wiring.

To simplify the wiring forms, a stage-by-stage layout has been developed in which, as shown in Fig. 11, the cables, A, carrying the incoming lines from the I.D.F. to the rack are terminated on the connection strips at the right-hand end of each shelf. (These connection strips appear at the left of Fig. 11, since this shows the rear view.) From here a wiring form, B, leads to the relay-tags on which all the wires are appropriately terminated. Small forms, C, individual to each circuit are led from the relays to each uniselector and are enclosed in a plastic tube to give mechanical protection. (These are seen again in Fig. 15 at C, which shows these forms to have sufficient free length to permit the mechanisms and brush feeds to be readily withdrawn for maintenance adjustment.)

With the exception of the bank multiple, all those connections to the uniselector, which are not required for circuit reasons to be connected to relay coils or springs, are terminated on spare relay tags. This enables all wires to the uniselector to be collected easily into these small forms, C.

The bank multiples, D, via their multiple tails, E, are terminated on the grading connection strips to which are also connected rack-to-rack ties, G, and the I.D.F. cables, F, carrying the outlet connections.

As much as possible of the relay wiring is carried out by strapping and commoning local to the plate. All shelf unit wiring except the bank multiple tails and connection of the switch tails can be carried out on the bench, thus facilitating inspection.

With this wiring layout all switchboard cables are terminated on connection strips, thus simplifying installation of the rack. Fig. 11 also illustrates the present standard "square" dressing for uniselector multiples; this gives both a neat appearance and excellent access to the bank-contact tags, thus avoiding liability to wire breakages caused by disturbance of the wiring.

The Preference Facility.

It has long been desirable to have some means of discriminating readily, under emergency conditions such as serious overloading, or breakdown of power supplies, between the subscribers who should be given preferential service and those whose calling facilities might be temporarily suspended to ease the emergency. In the former category, of course, are the medical, ambulance, police services, etc. Arrangements of this kind were made during the war by temporarily connecting battery cut-off keys into the subscribers' calling relay battery feeds via connection strips, and involved considerable alteration to the standard rack wiring.

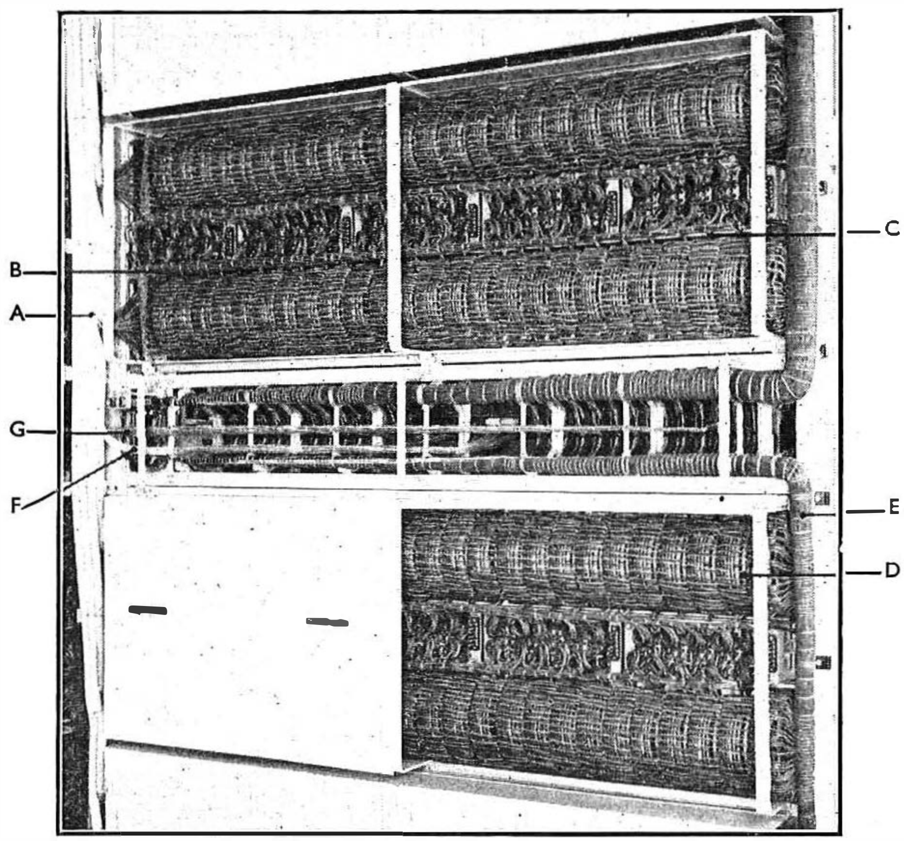


FIG. 11.—WIRING FORMS ON BACK OF SHELF UNIT.

It has now been decided that this facility should be made standard and, on the new racks, two disconnect keys are fitted, having six contacts each, thus providing one contact for each shelf battery-feed to the LR relays. On shelves intended for uniselectors for preference subscribers, the break contact is short-circuited by the strap between tags B and D on a tag block at the end of each relay plate. The circuit for this facility is illustrated in Fig. 12. Key stops are provided on the keys to prevent accidental operation under normal conditions.

Shared Service.

The earlier forms of shared-service circuits and the facilities required have been described previously[3] but the circuit incorporated in the equipment now described overcomes some of the drawbacks mentioned in the earlier article. In particular, by arranging that the Y subscriber's uniselector circuit is connected to line via the home-position of the X subscriber's uniselector, the seizure of 1st selectors by both the X uniselector and the Y uniselector under the condition of simultaneous calling by both subscribers is

[3] *P.O.E.E.J.*, Vol. 41, p. 139.

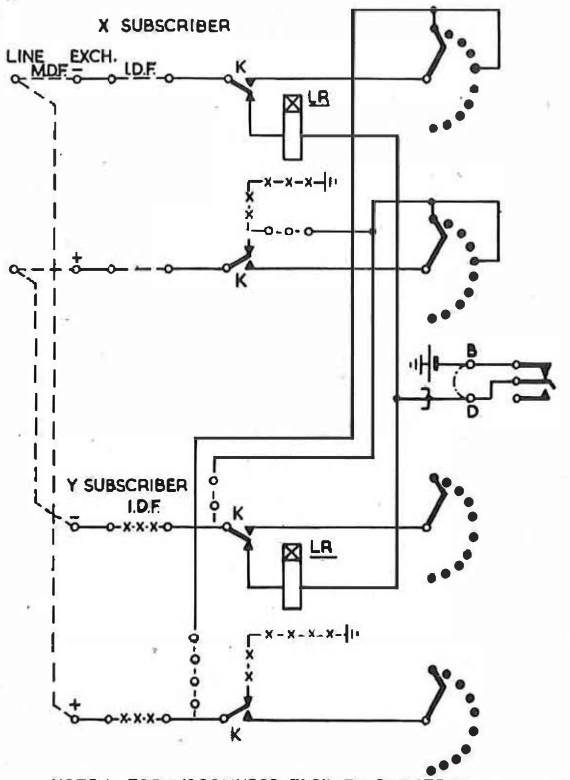


Fig. 12.—Outline of Shared Service and Disconnect Key Connections.

prevented. Thus the lock-up between selectors which was possible with the earlier circuits is prevented.

Provision is made in the shelf wiring for converting pairs of adjacent circuits from exclusive line working to shared-service working by a very simple alteration in connections. This is shown in Fig. **12**. The alternative connections are provided in the wiring forms, the wires not in use being disconnected and tied back. When connected for shared-service the even circuits on a shelf will become X subscribers and the odd circuits Y subscribers, but circuit No. 1 on the shelf will always be used for an exclusive line. The six right-hand circuits on the upper shelf (shown later in Fig. **15**) are connected for shared-service.

Grading Shelf.

This consists of a shelf of connection strips providing a horizontal row of tags for the outlets of each shelf of 25 uniselectors (see Fig. **8**). In addition, rows of tags are provided above and below the shelf-outlet tags for termination of the cables to adjacent racks. In the centre of the shelf, a block of tags is provided for up to 80 trunks outgoing to the I.D.F. for cross-connection to the selectors. Grading is carried out by vertical wires; and jumpers connect the bank outlet tags to the outgoing trunk tags. Cast aluminium brackets support the connection strips and are provided with spaces at top and bottom to form a jumper field.

The designations of the selectors connected to the grading are recorded on a chart mounted on the right-hand upright of the rack.

Covers.

Covers, as illustrated in Fig. **13**, have been provided for the wiring side of the rack to protect the multiple from damage and dust. These covers are in three parts, consisting

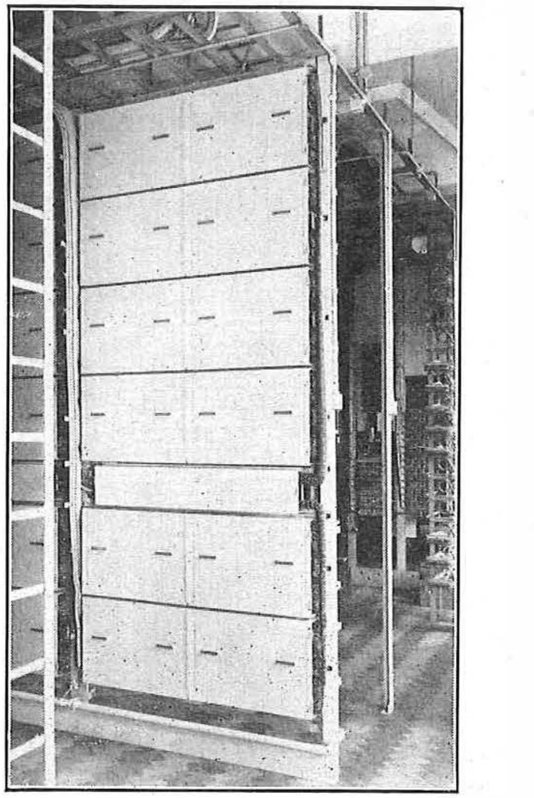


Fig. 13.—Rear of Rack with Covers in Position.

of a sheet steel barrier plate above each two-shelf unit and two removable back cover plates of sheet steel which are fitted with interlocking handle grips enabling them to be stacked one upon the other. This "stacking" feature will prevent wiring gangways from being congested with covers displaced to obtain access to the wiring for maintenance attention.

It has also been proved that these covers protect the wiring from extensive damage due to adjacent incendiary activity such as occurred during the war-time air raids.

On racks which are wired throughout with the new P.V.C. insulated wiring, the bank covers are omitted since this type of wiring does not collect dust as does the waxed wiring. It is also inherently flame-proof. Steel tube guards are provided, however, for mechanical protection of the lower banks.

Simple sheet steel covers, incorporating the stacking feature in a modified form, are also fitted to both the front and rear of the grading frame.

On the front of the rack the relay plates are provided with covers which clip on to the support-brackets (Fig. **8**) and over the frame-bars as indicated in Fig. **15** at B.

Type 3 Uniselector

The general construction of this uniselector was briefly described in the article referred to earlier, but further developments have since taken place, as described below. These are illustrated in Fig. **14**.

A tubular spark-quench capacitor, A, has been developed retaining the inherent resistance element in its construction in place of the normal series resistor. This capacitor is mounted in clips, B, on the front of the mechanism, and thus it may readily be removed for access to the uniselector knife edge (Fig. **15** (E) illustrates this). An advantage of this construction is that the capacitor is close to the interrupter contacts which renders it more effective in spark-quenching.

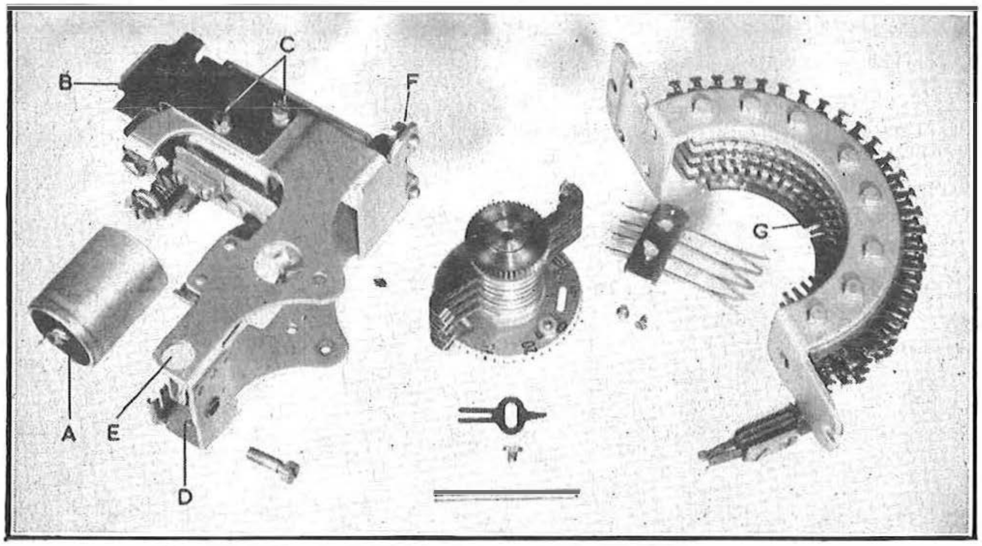


FIG. 14.—EXPLODED VIEW OF TYPE 3 UNISELECTOR AND BANK.

The Type 3 uniselector has been designed with the aim of mounting on 1⅜-in. centres and, to this end, the fixing screws, C, for the coil box and capacitor clips, have been arranged in alternate positions on the two sides; thus, since they do not abut, more clearance is given between the uniselectors on a shelf.

Similarly, although the label fixing screw, D, is within the 1⅜-in. overall dimension, clearance, E, has been provided in the mechanism frame to accept the head of the screw on an adjacent mechanism, should the latter be twisted on its mounting.

Therefore, while the clearance between mechanism frames has been reduced compared with the previous design, freedom from mechanical contact between adjacent uniselectors is obtained under all normal running conditions.

To improve maintenance access to the mechanism an outrigger mounting jig has been produced on which the mechanism can be fixed sufficiently clear of adjacent mechanisms to give facility of adjustment. The outrigger is shown in use in Fig. 15 at A.

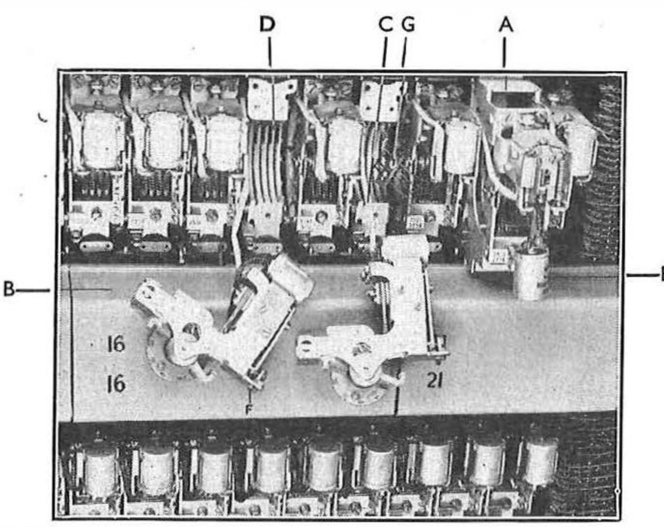


FIG. 15.—MECHANISMS REMOVED FROM BANKS FOR MAINTENANCE, SHOWING SLEEVED INDIVIDUAL WIRING FORMS AND MECHANISM ON R.H.S. MOUNTED IN OUTRIGGER.

Since the removal of the mechanism from the bank is now encouraged during maintenance adjustment, it is desirable to retain the fixing screws with the switch, particularly as there is not space enough between the switch on the lower shelf and the relays to permit the screws to be inserted readily by hand. A small retaining clip has therefore been made which keeps the upper bank-screws in their holes in the uniselector frame. It is now a simple matter to insert these screws by screwdriver and the lower screw may easily be placed in position by hand.

When re-inserting the mechanism into the bank it is necessary to hold the tips of the divided blade brush-feeds together to enable them to enter the collector-ring grooves. This is accomplished by fitting over the blades a moulded locating-comb. The brush-feeds themselves may be taken out by removing two screws.

Two-Home-Position Bank.

This is illustrated in Fig. 14 at G, and is similar to the single-home-position bank with the exception that the double homing-arc is divided into two portions separated by the additional home contact at position 12. This arc is formed of pairs of nickel-silver laminæ separated by a synthetic resin sheet insulating sector. This sector is larger than the contact sector so providing a dividing edge proud of the contact edges which prevents any conductive dust or metal particles from bridging them. The home contacts are built up to the same overall thickness to ensure reliable contact with a bridging wiper.

Wiper Lubrication.

Recent tests have indicated that while heavy oiling of wiper and bank-contact faces causes any deposited dust to form a grinding paste, thus wearing the wipers and bank-contacts, entire absence of lubrication will also cause heavy wear. Consequently, it is now the practice for uniselector wiper tips to be very lightly lubricated on installation and after overhaul but not more frequently.

CONCLUSION

The development of the Type 3 uniselector with 1⅜-in. mounting centres has paved the way for a new standard rack with capacity for 50 per cent. more circuits than the previous standard rack. It is now possible to mount 300 line circuits on the 10ft. 6½in. rack and 200 circuits on the 8ft. 6½in. rack together with facilities for grading the uniselector outlets.

When this is considered along with the facilities for greater service reliability provided by the two-home-position uniselector and the improved shared-service and preference facilities, it will be realised that this equipment marks a distinct advance in exchange design.

The work in connection with this design has been in progress ever since the war, and the engineers who have been engaged upon it both in the manufacturers' organisation and in the Telephone Branch of the Engineering Department may well feel proud of the racks now installed for the first time at Ashfield exchange, Birmingham.

The authors are indebted to many of their colleagues for assistance in the preparation of this article, and to the General Electric Co. for the photographs used in the illustrations.

Automatic Teleprinter Working

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U.D.C. 621.394.33

This article reviews the automatic machines used on teleprinter circuits for point-to-point working, switched systems and the simpler tape relay networks. Some details of recent developments are included, and the trend of future development is referred to.

Introduction.

THE fundamental principles of automatic telegraph transmission, i.e. transmission from a perforated paper tape, have remained unchanged during the transfer of telegraph working from morse to teleprinter. The basic machines required are still the perforator, automatic transmitter, reperforator and printer; the difference being that they are designed for operation on the 5-unit start-stop code instead of the morse code. The method of operation is to prepare a paper tape by means of a keyboard perforator, the perforations on the tape corresponding to the code signals of the message to be transmitted, and to feed this tape into an automatic transmitter which "reads" the tape and translates the perforations into electrical signals for transmission over a telegraph circuit. At the receiving end these signals either operate the receiving mechanism of a printer to produce a printed message, or the perforating mechanism of a reperforator to give a perforated paper tape similar to that prepared on the original perforator.

The objects of automatic operation are,

(*a*) to enable circuits to be operated at the maximum speed of which they are capable, and

(*b*) to avoid manual re-transmission at relaying points, and thus economise both in time and operating staff.

At present the standard transmission speed adopted in the British Post Office, in conformity with international agreement, is 50 bauds, or 66·7 words per minute (the average word being considered to consist of five letters and one space). Although it is possible that machine speeds might be increased by careful re-design, and, in fact, machines capable of operating at 75 bauds (100 words per minute) are already in production in the United States and are being developed in this country, a further limitation is imposed by the band width of 120 c/s adopted for the multi-channel voice-frequency system which forms the trunk telegraph network of this country. Experience has shown that any attempt to operate over this network at signalling speeds much in excess of 50 bauds results in increased distortion and either necessitates more frequent maintenance attention or limits the number of channels which may be connected in tandem. It is therefore unlikely that any change will be made in the near future in the speed of operation over lines.

Another requirement, however, arises in the system of operation known as "tape relay." In this system the incoming messages at a tape relay centre are received on reperforators (or printing reperforators) and retransmitted over the next stage by means of automatic transmitters. In the simplest form of tape relay centre the tapes are taken from the incoming position to the outgoing position by hand or by means of some conveyor system such as pneumatic tubes, but other methods are envisaged in which the message is transmitted across the office from an automatic transmitter associated with the incoming reperforator to a reperforator associated with the outgoing automatic transmitter. For this cross-office traffic the limitations on speed imposed by the line conditions do not apply, and economies in switching equipment and machines can be effected by arranging for the cross-office transmission to take place at high speed.

The machines used for automatic teleprinter operation in the British Post Office are described in the following paragraphs, together with some indication of current developments.

Keyboard Perforators.

Keyboard perforators are used for the initial preparation of a paper tape perforated to correspond with the signals comprising a telegraph message.

The majority of keyboard perforators in use in the British Post Office are Perforators No. 44. These were developed from the Murray perforator used on the Murray Multiplex system. The principle of operation is shown in Fig. 1.

The depression of a key positions five combination bars which have saw-tooth projections on their upper edges engaging with the lower edge of the keybar. The combination bars can move either to the right or to the left, and the saw teeth are cut so that the movement corre-

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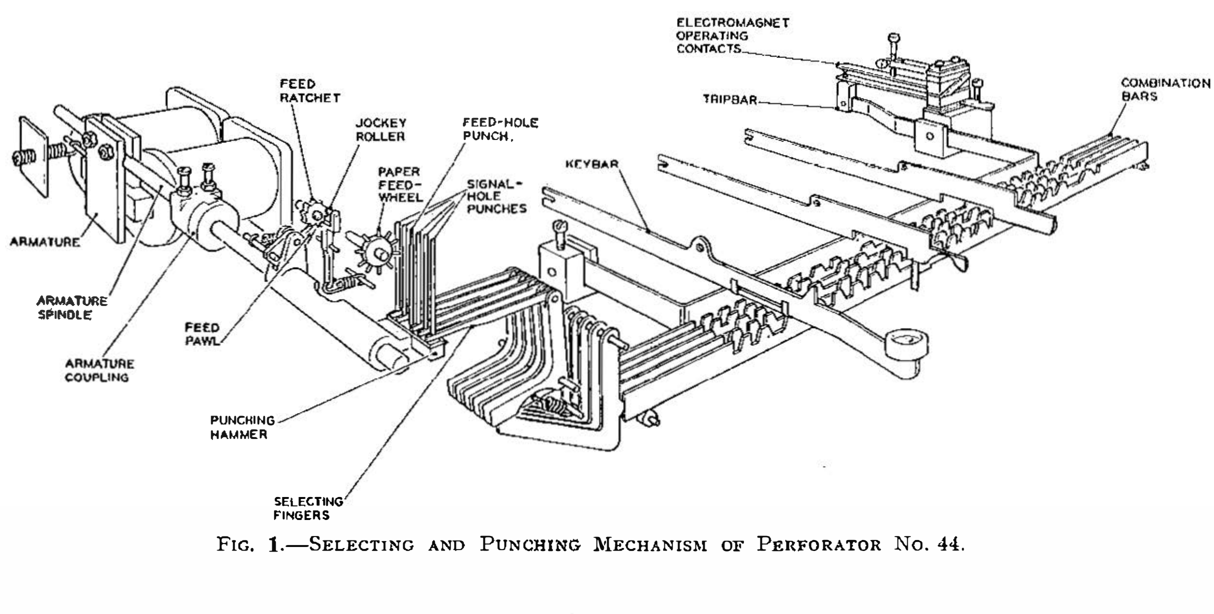


FIG. 1.—SELECTING AND PUNCHING MECHANISM OF PERFORATOR No. 44.

sponds to the 5-unit code of the required character. The movement of the combination bars is transferred through a system of levers to the selecting fingers, and those corresponding to spacing elements of the code are withdrawn from under the punches. When the keybar approaches the lower limit of its travel it engages with a trip bar and operates a pair of contacts which close a circuit for the punching electromagnet. This raises the punching hammer, and those punches from under which the selecting fingers have not been withdrawn are forced through the paper tape to form perforations corresponding to the "marking" elements of the code. The feed-hole punch is slightly longer than the code-hole punches, and has no associated selecting lever, so that it is raised, and a feed-hole is perforated, on every operation of the electromagnet. When the key is released the electromagnet is de-energised, and during its restoration the paper tape is fed forward ready for the next punching operation.

This perforator has been found to be somewhat noisy in operation. This was probably not considered of great importance when the machine was originally developed, but the present tendency is to reduce noise in instrument rooms as far as possible, thereby lessening the nerve strain on the operating staff. In addition, the machine is slow in operation. The maximum speed is about 80 words per minute, a speed which can be exceeded for short periods by a good operator, and as the keyboard is not "locked" during each operation, a second key can be depressed before the operations initiated by the first key have been completed, with consequent incorrect perforating of the paper tape.

A new perforator, known as the Perforator No. 45 (Creed Model 7P/N3), has recently been introduced and is shown in Fig. **2**. This is a motor-driven machine which uses the

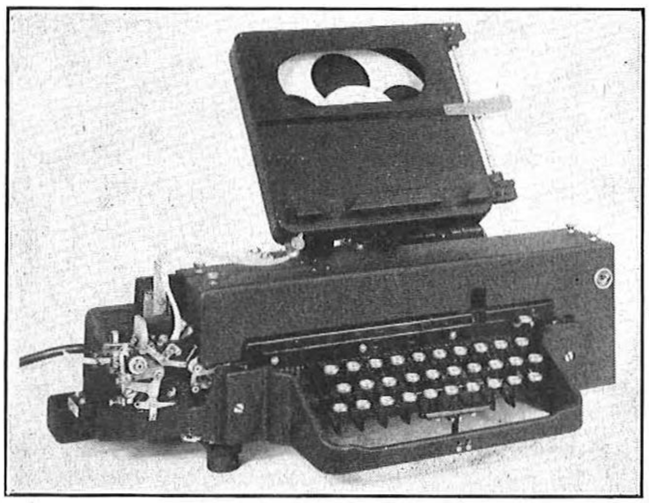


FIG. 2.—PERFORATOR No. 45.

energy stored in the rotating motor to operate the punching mechanism. The keyboard is similar to that used on the Teleprinter No. 11[1], and locking arrangements are provided although, as the maximum speed is about 130 words per minute, there is little risk of an operator "racing" the keyboard.

Fig. **3** shows the perforating mechanism of the Perforator No. 45. The combination bars have saw-tooth projections, and are operated from the keybars in the same way as in the Perforator No. 44; they cause the selector bars corresponding to "spacing" elements of the code to be withdrawn from beneath the corresponding punches. At the same time a trip bar is operated which releases the punching cam to perform half a revolution; this causes the punch block to rotate about its pivot and the punches corresponding to the

[1] "The Teleprinter No. 11." *P.O.E.E.J.*, Vol. 46, p. 53.

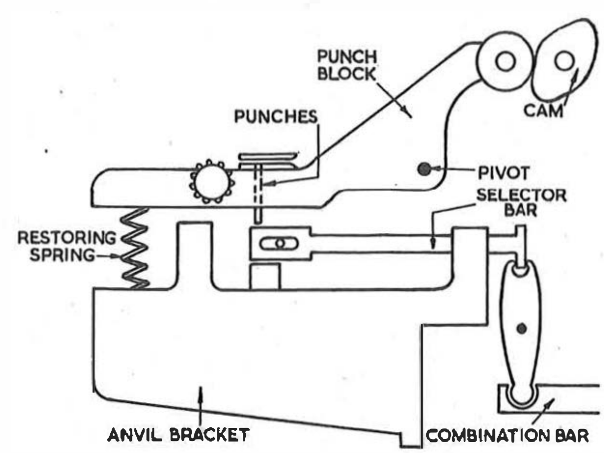


FIG. 3.—PERFORATING MECHANISM OF PERFORATOR No. 45.

marking elements of the code engage with their selector bars and are forced through the paper tape. A further cam (not shown) restores the punch block to its normal position when perforating has been completed; the feeding forward of the paper tape takes place during this restoration period.

Automatic Transmitters.

The standard automatic transmitter used by the Post Office is the Transmitter Automatic No. 2A (Creed Model 6S/4), shown in Fig. **4**. When in use the mechanism

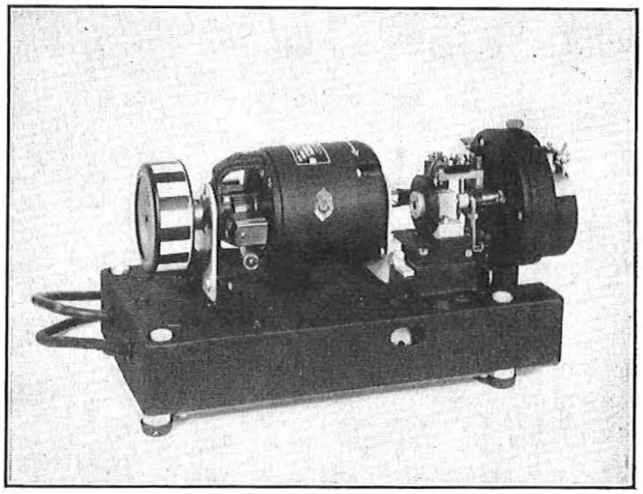


FIG. 4.—TRANSMITTER, AUTOMATIC, No. 2A.

is protected by a sheet steel cover. A number of earlier models may remain in use for some time, but it is not proposed to describe them separately as in principle they are the same as the 2A.

The machine is driven by an electric motor, the speed of which is controlled within close limits by a centrifugal governor. The governor cover is painted with 12 white and 12 black segments, to enable the speed to be checked stroboscopically. The motor drives the transmitting head through a ratchet and pawl clutch of the type commonly employed on teleprinters, and in the rest position the clutch is held out of engagement by means of a control lever which can be operated by hand or by the tightening of the paper tape being fed into the transmitting head.

The mechanism of the transmitting head is shown in Fig. **5**. The perforated paper tape passes between the pecker guide plate and the tape retaining plate, and when the clutch is released the tape is fed forward continuously by the tape feed wheel. At the same time the transmitting cam rotates and allows each pecker lever in turn to rise provided that this is permitted by a hole in the paper tape. If the

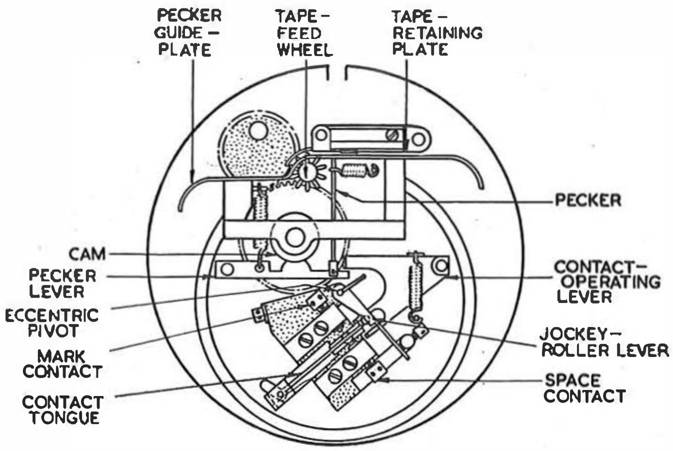


FIG. 5.—TRANSMITTING HEAD OF TRANSMITTER, AUTOMATIC, NO. 2A.

pecker lever rises, the movement is transferred via the contact operating lever to the contact tongue and moves it to the marking contact. If, however, there is no hole in the paper tape the contact tongue remains on the spacing contact.

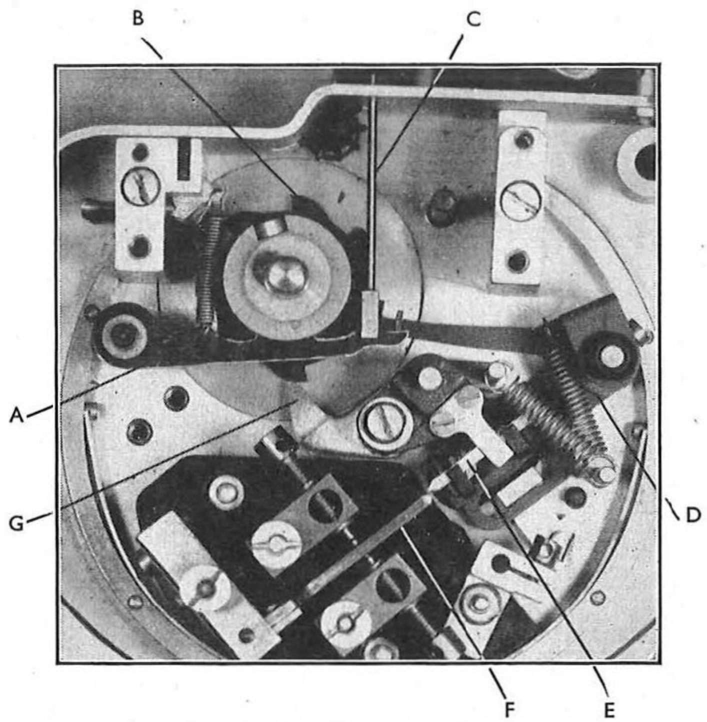
It will be appreciated that the operation of the contact tongue depends on the interaction of the pecker lever springs, the contact operating lever spring, and the jockey roller spring, and it has consequently always proved difficult to adjust the machine to give accurately timed signals. It had been realised for some time that an improved performance could be obtained if the striker principle employed on Teleprinters Nos. 7 and 11, whereby the moment of transit of the contact tongue is controlled from an accurately cut cam, could be applied to the automatic transmitter, and a model embodying this principle was developed at the Post Office Research Station in 1949. This, however, involved a complete redesign of the machine, and when, in 1951, a suggestion was received from the New Zealand Posts and Telegraphs Department, showing a method of applying the striker principle to the existing machine, this was considered a more promising line of development. Using the New Zealand model as a basis, some further work was carried out in the Telegraph Branch Development Laboratory and successful field trials were carried out on 12 models manufactured by Creed & Co., Ltd., in which were incorporated certain minor modifications to facilitate mass production. These models have given a very good performance, distortion generally being of the order of 2 per cent., and wear after several thousand hours being negligible. In future, this will be the standard head supplied on this type of automatic transmitter, and the model will be known as the Transmitter Automatic No. 2D (Creed No. 6S/5).

The striker head, with some parts removed for greater clarity, is shown in Fig. 6. The pecker levers, controlled as before by the transmitting cam and the paper tape, position the contact operating lever which carries the striker dart. The moment of operation of the striker dart is controlled from the timing cam via the striker timing lever.

A further change which has been incorporated in the Automatic Transmitter No. 2D is step-by-step feed of the paper tape. The tape is fed forward during the transmission of the stop signal and is stationary during the transmission of the code elements, thus providing greater tolerance of any inaccuracies in the spacing of the perforations in the tape.

Ganged Transmitters.

When large numbers of automatic transmitters are installed at one station, it is desirable from the points of view of both operating and accommodation to mount them



A—Pecker Lever; B—Timing Cam; C—Pecker; D—Contact Operating Lever; E—Striker Dart; F—Transmitting Tongue; G—Striker Timing Lever.

FIG. 6.—STRIKER HEAD OF TRANSMITTER, AUTOMATIC, NO. 2D, WITH SOME PARTS REMOVED FOR CLARITY.

as close together as possible. The Automatic Transmitter No. 2A does not readily lend itself to this requirement since, as the tape is fed from right to left across the front of the machine, a space must be left between machines for the tape to enter and leave. The Teletype Corporation had developed a triple-headed machine in the United States of America, and this machine is now manufactured under licence in Great Britain by Creed & Co. One version of the machine is shown in Fig. 7. In this machine one motor is

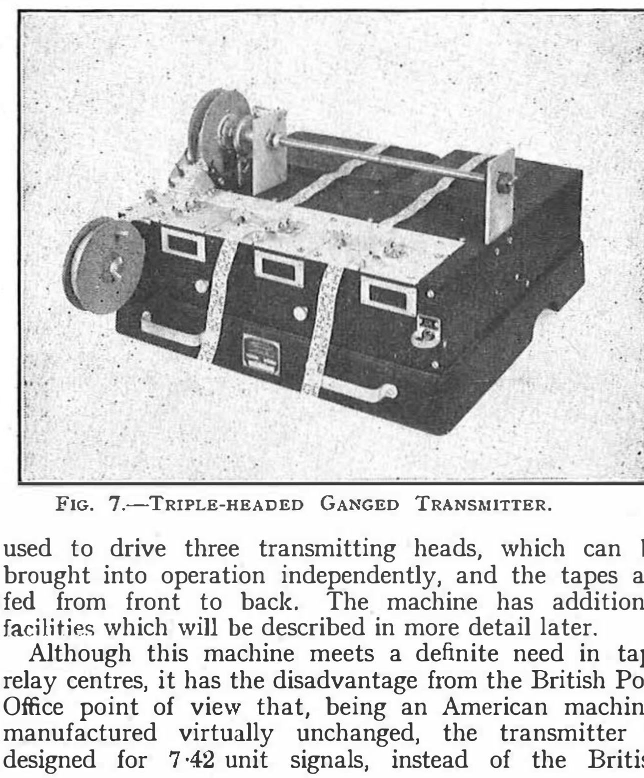


FIG. 7.—TRIPLE-HEADED GANGED TRANSMITTER.

used to drive three transmitting heads, which can be brought into operation independently, and the tapes are fed from front to back. The machine has additional facilities which will be described in more detail later.

Although this machine meets a definite need in tape relay centres, it has the disadvantage from the British Post Office point of view that, being an American machine, manufactured virtually unchanged, the transmitter is designed for 7·42 unit signals, instead of the British standard of 7·5 unit; this introduces some difficulties when using British testing equipment for measuring transmitter distortion. This point would undoubtedly have been brought into line with British practice had time permitted, but there was an urgent demand for machines of this type, mainly from the air-operating companies, which could only be met by adopting the machine unchanged.

The transmitting portion of the machine differs from the normal British standard in that it is designed for single-current operation, and a relay must be interposed in the circuit to give a double-current output. The single-current signals are obtained from six contacts connected in parallel, one providing the start and stop signals, and the other five, released in turn by five cams, are controlled from the tape by means of peckers to provide the five code elements.

Automatic Message Numbering.

Where automatic transmitters are used to pass large quantities of traffic over point-to-point circuits, it is very desirable that the messages should be serially numbered, so as to guard against the possibility of loss, and assist in tracing back in case of a query. The simplest method of achieving this is to perforate a series of tapes with the required serial numbers and insert them into the automatic transmitter in turn before each message tape, but this involves continuous attendance if lost circuit time is to be avoided, and a certain amount of care to ensure that tapes are inserted in the right sequence.

A more convenient method is to provide a second automatic transmitter solely for the purpose of transmitting the serial numbers. This transmitter is loaded with a continuous tape perforated with the required sequence of serial numbers, and automatic means are provided for switching between transmitters as required.

A method of achieving this was developed in 1947 by the Post Office in conjunction with Creeds and British Telecommunications Research, Ltd. In this system, each message was required to be followed by ten "letter shift" signals and each serial number by five "letter shift" signals. Electronic equipment monitoring the output from the transmitters recognised these sequences, and initiated the switching between transmitters. The transmitters used were similar to the Automatic Transmitter No. 2A, but were fitted with electromagnetic clutches, so that they could be controlled from the electronic equipment, and, in addition, the numbering transmitter was fitted with tape reels, to carry the numbering tape, and associated driving mechanism. These were known as the Transmitters, Automatic, Nos. 2B and 2C respectively (Creed Models 6S/4M and 6S/4N). A numbering transmitter could be associated with either one or two message transmitters, the latter arrangement enabling transmission to proceed from one message transmitter while a tape was being loaded into the other, thus avoiding lost circuit time between messages.

The present method employed by the Post Office makes use of the ganged transmitters mentioned earlier. The end-of-message condition is recognised by the absence of tape at the sensing point, i.e. the message tape has completely passed through the transmitting head, and the end of number is the "letter shift" signal; this, of course, imposes the limitation that a letter shift cannot be employed in the body of the serial number.

In order to recognise these conditions, the message transmitter is fitted with a sixth pecker which rises and closes a pair of contacts ("tape out" contacts), when there is no tape at the sensing point, and the numbering transmitter has a seeker mechanism which operates and closes a pair of contacts when all code hole peckers rise at once, i.e. when the "letter shift" signal is sent. The numbering transmitter is also fitted with tape reels and driving mechanism.

A ganged transmitter can be fitted with any combination of message and numbering heads, and those so far employed in the Post Office are the Transmitters Automatic No. 3A (three message heads), No. 4A (three numbering heads) and No. 5A (two message heads and one numbering head). These are the Creed models Nos. 71, 72 and 74. The switching between transmitters is controlled by relay sets which can be attached to the transmitters or mounted separately.

Development work is proceeding on the provision of "tape out" contacts and "letter shift" recognition on the Automatic Transmitter No. 2D. Although a group of these machines for the provision of automatic message numbering will occupy somewhat more space than the ganged transmitters described above, they will have the advantages of the extremely low distortion of the striker transmitter and a double-current output.

Reperforators.

The reperforator used by the Post Office is the Reperforator No. 2, the latest model being the Mk. III (Creed Model 7TR/3), see Fig. **8**.

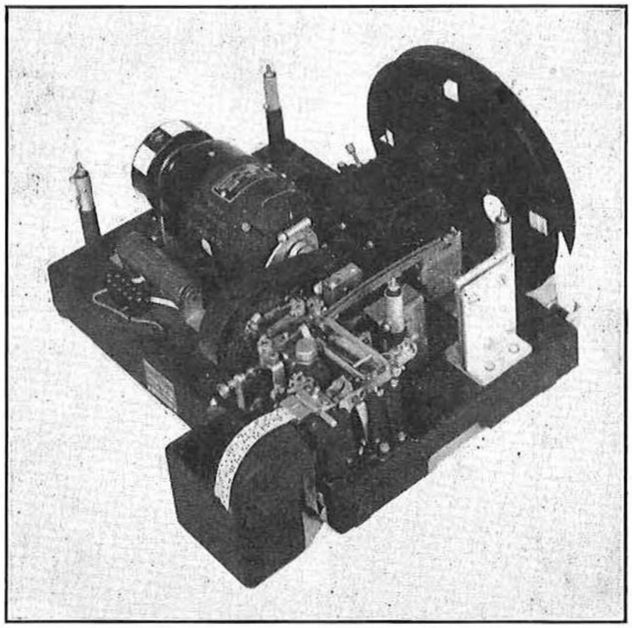


FIG. **8**.—REPERFORATOR NO. 2, MK. III.

The mechanism of the reperforator is similar in many respects to the receiving portion of a teleprinter. It comprises a receiving electromagnet which releases the receiving cam shaft on receipt of a "start" signal and subsequently controls the position of a setting blade in accordance with the code elements of the received signal. As in the teleprinter, the setting blade (see Fig. **9**) is moved forward for each code element; for marking elements it strikes the hammer-setting pin, but for spacing elements it passes beneath the pin. The setting pin is traversed behind five hammers, and the hammers corresponding to marking elements of the code are set downwards to engage with their appropriate punches. After the five code elements have been received, the hammer frame moves forward, the hammers engage with their punches and perforate the paper tape. Normal arrangements are made for feeding the tape forward prior to perforation.

The Reperforator No. 2 is a comparatively simple machine and has given, and continues to give, very satisfactory and trouble-free service.

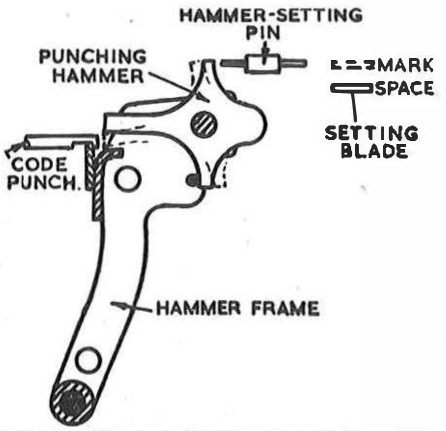


FIG. 9.—SKETCH OF HAMMER MECHANISM OF REPERFORATOR NO. 2.

Printing Reperforators.

The use of a reperforator at a tape relay centre to avoid manual retransmission presents some difficulty in that it is necessary for the operator to be able to read 5-unit code in order to read the address of the message, or else a monitoring teleprinter must be provided, which, of course, adds to the cost of the installation and doubles the amount of accommodation required. This difficulty has been overcome by the introduction of the printing reperforator, in which the message is printed and perforated simultaneously on the tape. In order that the printing may be legible, it is either necessary to use a wide tape with room for printing beside the perforations (Creed Model 86) or else to use the "chadless" method of perforation in which the code and feed holes are not punched completely out, but take the form of small lids attached by a narrow neck of paper to the main portion of the tape. The latter method has been adopted by the Post Office and the machines used are the Printing Reperforator No. 1 (Creed Model 85), shown in Fig. **10**, which includes a keyboard and transmitter, and the

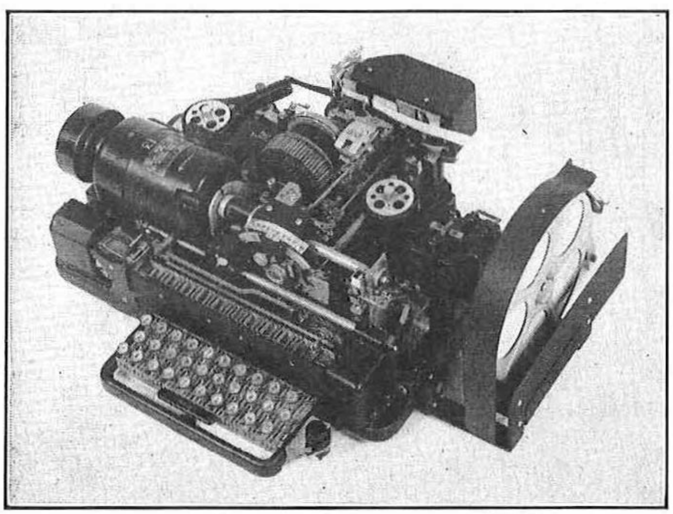


FIG. **10**.—PRINTING REPERFORATOR, NO. 1.

No. 2 (Creed Model 85R) which is a receiving machine only. A portion of chadless tape is shown in Fig. **11**; it will be observed that the printing is displaced relative to the corresponding perforations, it being, of course, impracticable to perforate and print simultaneously in the same position.

These machines are derived from the Teleprinter No. 7 by removing the page attachment and substituting a perforating unit, a tape reel being mounted at the side of the machine. The paper tape is led past the typehead, and

FIG. **11**.—SPECIMEN OF CHADLESS TAPE.

selection and printing take place as in the Teleprinter No. 7. At the same time the positions of the five receiving combs, which determine the character to be printed, are transferred via a system of levers to five punches, and the corresponding code holes are punched in the paper tape eight spaces ahead of the printed character. In order to obtain chadless perforation the die plate, into which the punches enter, is cut away on one side, as shown in Fig. **12**. Spring-loaded paper-layers are provided in the die plate which normally lie flush with the surface of the plate. When the punches are withdrawn after perforating the tape, the paper-layers push the paper lids back into the plane of the paper, so that they are not torn off by the die plate as the tape is fed forward.

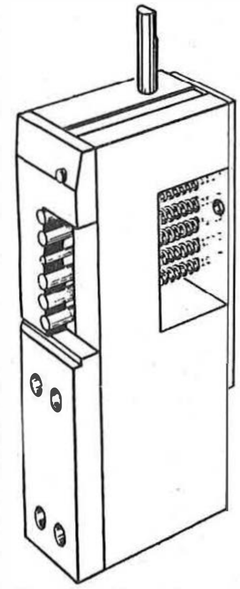


FIG. **12**.—DIE PLATE OF PRINTING REPERFORATOR, NO. 1.

Perforating and Reperforating Attachments.

A keyboard and perforating mechanism, almost identical with that of the Perforator No. 45 described earlier, can be provided in place of the normal keyboard on a Teleprinter No. 7. With this machine (Teleprinter No. 7BPK/N3) a message can be transmitted to line from the teleprinter, and at the same time a perforated tape can be prepared which can be used for subsequent transmission of the same message to other addressees by means of an automatic transmitter. In many cases the machine is used solely for the preparation of perforated tapes, and is not connected to line, the page copy of the local record being used as a check on the accuracy of the perforated tape.

A current development is the modification of the perforating attachment to dissociate it from the keyboard and control it from the receiving combs by means of Bowden cables, i.e., it will become a reperforating attachment. When connected for local record this will provide exactly the same facilities as the perforating attachment, but when the machine is connected to line a perforated record of the received signals can be made which can be used for subsequent retransmission.

Conclusion.

The series of machines which has been described appears to meet adequately the needs for point-to-point working, switched systems, and the simpler tape relay networks. The trend of development is now towards machines suitable for the more complicated semi-automatic or fully automatic tape relay systems. In these it is generally necessary for the machine to recognise certain characters, or sequences of characters, which provide routing instructions, and indicate the beginning and end of messages, separation between address and text, etc. Whether this recognition will be effected mechanically within the machine, or externally by electronic equipment is a question which has not yet been resolved.

The advantage of operating at higher speeds for cross-office transmission has already been mentioned and work is also proceeding on this problem.

Inter-dialling between a Director Area and a surrounding Non-director Area

J. A. LAWRENCE, A.M.I.E.E.†

Part 1.—Engineering problems and possible solutions, with particular reference to the London Director Area.

U.D.C. 621.395.636

Inter-dialling, by subscribers, between a director area and a surrounding non-director area raises a number of problems from both engineering and administrative viewpoints. Part 1 of this article discusses the engineering problems and some possible solutions, with particular reference to inter-dialling between the London director area and its associated fringe area. Part 2 of the article will deal with those aspects of the practical application of the preferred solution which may be of immediate use in and around London.

INTRODUCTION

In Great Britain the continued demand for telephone service has made it necessary to consider ways and means of increasing the proportion of calls which may be dialled by subscribers. Present methods, which permit subscribers to dial calls to objective exchanges within 15 miles chargeable distance are, in favourable circumstances, capable of providing a considerable measure of relief for manual boards. Unfortunately, these methods cannot be applied equally well universally. In particular, subscriber-dialling across the boundary of a director area, in both directions, gives rise to some special problems. It is the purpose of Part 1 of this article to examine the engineering aspects of these problems with particular reference to inter-dialling between the London director area and its associated fringe-area, and to discuss a number of possible solutions.

The engineering viewpoint cannot of course be considered without reference to the administrative viewpoint. The administrative difficulties which arise in extending subscriber-dialling facilities to and from a fringe-area may well be the more difficult to overcome. However, to enable the present discussion to proceed certain assumptions have been made. These are firstly, that the tariff structure which would be used would be similar in type to the present tariff structure; secondly, that the dialling procedure required of subscribers should be as simple and uniform as is practicable; and finally, that all non-director exchanges affected would have four-digit local numbering schemes. This last assumption is made merely to simplify discussion: it does not imply that three-, five- and six-digit non-director numbering schemes would need to be modified. The method of dealing with such variants will be explained in Part 2.

NUMBERING PRINCIPLES

The British Post Office Director system[1] is a register-translator system in which the control of routing and switching is vested in a type of register-translator known as the director. In common with other systems employing register-translators for routing control it becomes possible, in an area so equipped, to allocate dialling codes for use by subscribers without reference to the layout of the switching and line plant. In such systems the dialling codes may be included with each subscriber's directory entry or may be shown separately in the directories in some suitable form.

In planning a numbering scheme for a given area, dialling codes may be allocated either arbitrarily or systematically. If allocation is arbitrary the codes are allocated over the area as a whole without regard to any local grouping of exchanges into sub-areas. If systematic allocation is used the grouping of exchanges into sub-areas is taken into account in the build-up of the dialling codes. Either method can be arranged to provide a given capacity for exchange codes and, therefore, to satisfy the requirements for an area of given ultimate size.

As an area increases towards its designed ultimate size the tendency is for subscribers located within the area, but fairly well off-centre, to have at least as great an interest in dialling across the area boundary outwards as in dialling to the more distant parts of the area. Moreover, the tariff scheme may be such that, at points near the area boundary, subscribers will be beyond permitted maximum dialling range of a substantial number of exchanges located within the area but well within permitted maximum dialling range of a fairly large number of exchanges located outside the area.

If the numbering scheme for an area is an arbitrary scheme in which each code appears once only and in which the dialling procedure is uniform, it follows that, for outward cross-boundary dialling either a basically different dialling procedure must be used, or cross-boundary dialling codes must be allocated within the scope of the arbitrary numbering scheme. The maximum possible size of an area depends upon the capacity of the numbering scheme for dialling codes. If the use of a special outward cross-boundary dialling procedure is rejected, it follows that the maximum effective size of an arbitrarily numbered area will need to be made less than the maximum possible size. In such circumstances the arbitrarily numbered area becomes associated with a surrounding belt of territory which may be regarded as an extension of the inner area for outward calls, but not necessarily for inward calls, which require further consideration. Such circumstances exist in the neighbourhood of London, the London director area numbering scheme being an arbitrary numbering scheme because it uses lettered dialling codes derived from exchange names. Surrounding the director area, which is the area contained within a circle of 12½-miles radius centred on Oxford Circus, is a non-director fringe-area. Since the tariff scheme is based on point-to-point charging, the fringe-area takes the form of a circular belt surrounding the director circle and, strictly, at the present time the fringe-area is 15 miles wide and so is the 12½- to 27½-miles belt. Because, however, the present maximum chargeable distance is 15 miles from any originating exchange, it follows that many exchanges in the 12½- to 27½-miles belt are beyond the maximum permitted multi-metering range of many director exchanges. If dialling codes for all exchanges in the 12½- to 27½-miles belt were published to all director subscribers a considerable number of interceptions would be needed. To reduce the number of necessary interceptions to manageable limits it is most convenient to narrow the fringe-area. For this reason the recognised fringe-area is the 12½- to 20-miles belt, i.e., it is 7½-miles wide instead of 15.

Thus the fringe-area arises directly as a result of the method of numbering employed. It will be shown later

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[1] "Telephony," Vol. 2—J. Atkinson.

that systematic numbering could have avoided the introduction of a fringe area: it does not, however, follow that systematic numbering would, necessarily, have produced so satisfactory a numbering scheme for the London area as is the present director numbering scheme.

The Present London Director Exchanges—Possible Maximum Dialling Range using Director-Type Numbering.

Fig. **1** shows, in a slightly simplified form, the present situation in and around the London director area. The central area of five miles radius is considered as a point for

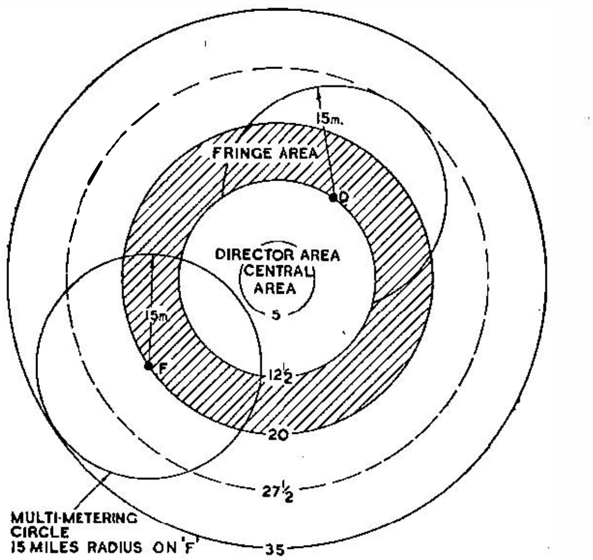


Fig. 1.—Multi-Metering Dialling Ranges Around London.

charging purposes and this concession is assumed, for simplicity, to apply equally to all director area subscribers. In practice the charging concession does not apply to director area subscribers located within the 10- to 12½-miles belt (not shown in Fig. **1**). The number of exchanges within 15 miles chargeable distance of a director exchange is therefore slightly smaller for those exchanges within the 10- to 12½-miles belt than is assumed in subsequent calculations.

If subscribers are to be permitted automatic access to all objective exchanges within 15 miles chargeable distance, a director area subscriber located at D, just inside the 12½-miles radius circle, would require automatic access to the whole of the London director area plus automatic access to fringe-area and outer-area exchanges included within the 15-miles radius circle centred on D.

A circle of 27½-miles radius centred on Oxford Circus would, therefore, just enclose every exchange located within 15 miles chargeable distance of any director exchange. If the dialling procedure to be used by director area subscribers to obtain access to exchanges located within the 12½-miles to 27½-miles belt is to be similar to that used for calls between director exchanges, it follows that the director area method of allocating exchange codes must be extended to include all exchanges located within the 27½-miles radius circle, all codes (when viewed from within the director area) must contain three digits and no code must be repeated. Hence, at all exchanges located within the 12½-miles radius circle the directors must have a code capacity equivalent to the ultimate number of exchanges likely to be required within the 27½-miles radius circle, even though automatic access to many of the exchanges so coded might have to be barred (because of charging) at any given originating point.

At the time of writing there are 203 working codes allocated within the director area numbering scheme. Of these, 174 are three-letter codes for pronounceable exchange names. In the 12½- to 27½-miles radius belt there are 211 exchanges; calling for a present total of at least 414 codes for the 27½-miles circle. A recent forecast suggests that the director area may require about 250 working codes within the next 20-30 years. Allowing a similar margin for the 12½- to 27½-miles belt the foreseeable requirements would amount to at least 510 codes or, say, at least 600 codes to allow for forecasting errors and code wastage.

The present design of director can provide translations for about 650 three-digit "name" codes of the two-letter plus one arbitrary figure type which, of course, may include about 250-300 three-letter codes if desired. It is therefore just possible, technically, to permit any director area subscriber to dial all objective exchanges within 15 miles chargeable distance using either two-letter plus one figure codes uniformly or a mixture of three-letter and two-letter plus one figure codes with the three-letter codes confined to the 12½-miles circle. The principal engineering problems likely to be encountered would be those of fee determination and of routing in the particular case of calls to objective exchanges not directly connected to one of the central tandem exchanges, since more routing digits might then be required. The maximum possible size of the present director network is therefore the area of the 27½-miles radius circle.

Present London Fringe-Area Exchanges—Possible Maximum Dialling Range Using Director-Type Numbering.

A subscriber located within the fringe-area at such a point as F in Fig. **1** would require automatic access to the whole of the central area of the London director area (the 5 miles radius circle) plus automatic access to exchanges included within the 15 miles radius circle centred on F. At the present time the number of objective exchanges within 15 miles chargeable distance of any exchange located within the London fringe-area is of the order of 200. Typical cases are Romford with 198, Byfleet with 174 and Reigate with 165, and the use of dialling codes containing at least three digits is unavoidable.

In the interests of the subscribers, dialling codes should be easy to understand, as short as is practicable and, as far as possible, uniform in make-up. Non-director routing and switching methods cannot satisfy such conditions on the scale required and it follows that routing and switching must be based on the use of register-translators located either at originating fringe-area exchanges (which are at present non-director exchanges) or at tandem switching centres to which fringe-area exchanges are, or can be, directly connected. In effect, the principles (although not necessarily the practice) of director operation need to be extended to fringe-area exchanges to provide for interworking both with other fringe-area exchanges and with London director exchanges. If routing and switching are assumed to be based on register-translators using three-digit exchange codes, and the numbering scheme is arbitrary (to permit the use of letters as components of the exchange codes), then there are two methods by which the codes could be allocated to meet the basic requirement that it should be technically possible for any fringe-area subscriber to obtain automatic access to all objective exchanges within 15 miles chargeable distance.

Method (i). To consider the 35-miles radius circle centred on Oxford Circus as a single numbering plan area.—Each dialling code used by subscribers located within the 12½-20-miles belt would need to appear once only within the confines of the 35-miles radius boundary. The existing exchanges located within 35-miles radius of Oxford Circus are distributed as follows:—

	Limit of Circular belt (centred on Oxford Circus) Miles	Number of exchanges (1950)	Estimated requirements for codes (Minimum)
Director Area	0 – 5	77	300
	5 – 12½	95	
Fringe Area	12½–20	97	600
Outer Belt	20 – 25	78	
	25 – 30	81	
	30 – 35	124	
Total	0 – 35	552	900

The estimated minimum requirement for 900 three-digit codes is beyond the capacity of the existing type of director (800 codes) using all possible combinations of three digits. It might, however, be practicable to increase the present director code capacity to 900 codes by opening out the digit "0". Assuming this to have been done it would then be possible to provide all fringe-area exchanges with lettered dials and to permit them to dial:—

(*a*) three-letter codes for access to exchanges located within the 12½-miles circle (or if preferred two letters plus one figure code using the numerical equivalent of the third letter as the figure),

(*b*) two-letter plus one figure codes (with the figure arbitrary) for access to other fringe-area exchanges and to exchanges located within the 20- to 27½-miles belt outside the present fringe-area. This would exhaust the letter figure combinations.

(*c*) three-figure codes for access to exchanges located within the 27½- to 35-miles belt using up the unpronounceable codes as figure codes.

From the engineering point of view the principal problems would be:—

(*a*) Difficulties with routing which, because of the limited capacity of the present type of director for translation digits, would require an examination of tandem switching economics in order to avoid expensive "toll" routings.

(*b*) The rather low ratio of maximum code capacity over initial requirements (1·6 to 1).

(*c*) The uneconomic use of a large proportion of the director equipment in recognising (and barring) excess-fee codes which, at any given exchange, would amount to nearly four times the permitted multi-fee codes.

(*d*) The fact that because of (*b*) there would be no simple way of extending the untimed multi-metering dialling range at some future time (e.g., if and when multi-metering is extended to six units).

Hence the setting up of a single numbering plan area of 35-miles radius centred on Oxford Circus and arbitrarily numbered is barely practicable and would require that, at fringe-area exchanges, subscribers would have to dial three-figure codes for access to exchanges located in the 27½-35 miles belt; further, it would be difficult to secure an economic extension of dialling range (i.e., beyond 15 miles).

Method (ii). To allocate dialling codes separately with respect to the location of each originating fringe-area exchange.— This would require, ultimately, the setting up of about 200 separate numbering schemes (i.e., one per fringe-area exchange). Each numbering scheme could, however, be contained within a circular boundary and would be capable (potentially at least) of permitting subscriber-dialling up to at least 27½ miles chargeable distance from each originating exchange. To be able to expand a numbering scheme to such an extent would, however, call for the use of "all-figure" codes and each fringe-area exchange would need to have its own dialling code list and each such list would have little or nothing in common with the dialling code list for any other exchange, i.e., the code dialled at any given fringe-area exchange to obtain access to some specified objective exchange would, generally speaking, need to be peculiar to the originating exchange.

If arbitrary numbering were to be used it is considered that Method (i) (i.e., the single numbering plan area) would be the only feasible one.

Exchanges Located Outside the 20-Miles Radius Circle—Possible New Fringe-Area.

The most straightforward way in which exchanges located outside the 20 miles radius circle might ultimately be brought into the general scheme without involving any new numbering principles would be to regard the whole of the 35-miles radius circle as one "director" type area—not necessarily an area in which all exchanges are standard director exchanges but one in which all inter-exchange routing would be controlled by director-type translators. Since, however, the setting up of a single arbitrary three-digit code numbering plan for the 35-miles radius circle exhausts the capacity of the director-type register-translators it follows that a new fringe-area bordering on the 35-miles radius boundary would be created.

The Disadvantages of Extending the Present "Director" Type Numbering Scheme to its Ultimate Limits.

The setting up of what amounts to a 35-miles radius director area in the manner just outlined is not regarded as being either technically or economically sound because:—

(i) Extensive modifications to existing exchanges would be required.

(ii) The register-translating equipment provided at the various exchanges located within the 35-miles radius circle would tend to become barring equipment rather than routing and charging equipment as its distance from the area centre increased. Thus, at an exchange located near to the boundary a translator having a capacity for, say, 900 codes would at the present time be required to "bar" (or perhaps intercept) at least 500 codes.

(iii) Subscribers located within the 20- to 35-miles belt would not be able to dial across the 35-miles radius boundary without calling into use special cross-boundary dialling equipment which would have to be provided in addition to the equipment catering for the 35-miles radius circle codes, many of which, as already indicated in (ii), would be barred codes.

(iv) The register-translating equipment provided for the 35-miles radius circle would possess only a small reserve for development within the circle and no reserve for a future extension in dialling range beyond 15 miles except where the objective exchanges then brought within dialling range were located within the 35-miles radius circle.

(v) Generally speaking the barring facilities mentioned in (ii) above would be more economically employed as routing and charging facilities, either actively in permitting cross-boundary dialling (see (iii) above), or as a reserve against a further extension in dialling range (see (iv) above).

Thus while an extension of the method of numbering at present used in director areas (i.e. arbitrary numbering) is possible and could eliminate the present fringe-area problem, the method is not economical and is not capable of catering for any future extension of subscriber-dialling range beyond the present limit of 15 miles. Also a new and more difficult fringe-area problem would ultimately appear. Hence it becomes desirable to consider arresting the growth of the London director numbering area at, say, its present limit of 12½-miles radius and seeking another solution to the fringe-area problem.

A Theoretical Application of Systematic Numbering Principles to the Problem of the London Area

An application of the principle of systematic numbering can produce a more economic solution to the various problems which arise in and around the London director area than can arbitrary numbering. A number of variations are possible but it will suffice here to describe a method which appears likely to yield the best overall solution.

In Fig. 2 the London area is shown subdivided into

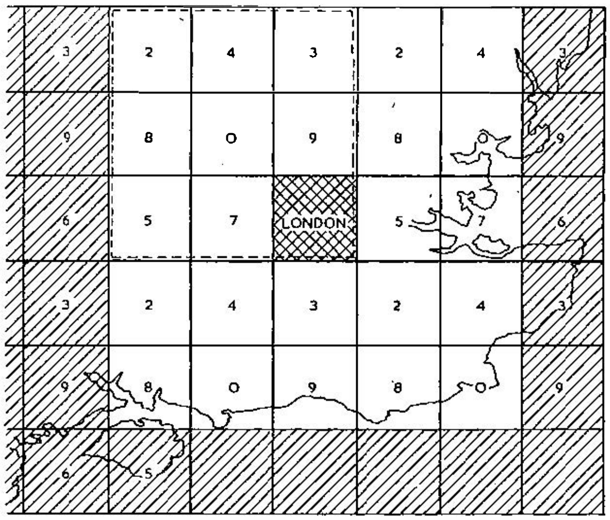


Fig. 2.—Principles of Systematic Numbering for London and Surrounding Areas.

arbitrary map "squares". The central shaded area, which represents, schematically, the London director area, is assumed to require ultimately 300 three-digit exchange codes. Surrounding the shaded area are two "rings" of unshaded squares. Each of the unshaded squares is of such a size as to cater for an ultimate of 60 three-digit exchange codes. Finally, outside the unshaded squares, are other squares (shown hatched) each of such a size as to cater for an ultimate of 100 three-digit exchange codes. In practice, the true shape of the areas shown as squares in the figure would depend upon the "local" distribution of exchanges. The principle involved in the subdivision would not, however, be affected.

The various sub-areas are numbered systematically with single digit codes. With the particular "system" employed in the example the only rule to be followed is that the repetition interval for any given digit must remain constant. It is then easily demonstrated that any group of nine areas consisting of a "central" single-digit area touching eight other areas forms a numbering plan area in which each single-digit sub-area has a unique code number. If the various exchanges in the various single digit sub-areas are now allocated two-digit codes in an arbitrary manner it follows that, in any numbering plan area containing nine single digit sub-areas, every exchange will have a unique three-digit code number. Assuming the use of register-translators, a subscriber located in any single-digit sub-area can dial to all objective exchanges located in his "home" sub-area and in the eight adjacent sub-areas.

The director area (the 12½-miles radius circle) is now regarded as a sub-area likely to require 300 exchange codes ultimately. In Fig. 2 the director area is so located that it could be allocated the single-digit code "6" but, since it is expected to require 300 codes, a single "first" digit "6" would be insufficient, yielding only 100 three-digit codes. The director area is therefore treated as a special case and is allocated the range of figures 2-0 inclusive as "first" digits and the "pairs" of second and third digits 71-70, 81-80, 91-90 and 01-00 (i.e., 40 pairs in all) as "following" digits. This yields a total of $9 \times 40 = 360$ possible three-digit codes. Exchanges located in any of the eight single digit areas touching the London director area may require dialling access to some or all of the 360 possible director exchange codes. The pairs of second and third digits 71-70 etc., to 01-00 must therefore be omitted from the numbering range of the single-digit areas affected, i.e., each of the single-digit areas bordering on the director area (the fringe-area) must be restricted to the numbering range X11-X60 where X is the single-digit area code. This gives a maximum of 60 three-digit codes for each of the fringe-area subdivisions. The "second" ring of single-digit areas, proceeding outwards, will also need to be 60-code areas because fringe area subdivisions may be permitted access to second ring subdivisions. The third and subsequent rings of single-digit areas are assumed not to require direct dialling access to the London director area because of distance. If the second ring of single-digit areas is also not permitted access to the London director area it becomes unnecessary to restrict the code range of the third and subsequent rings to 60 three-digit codes. Each single-digit area in the third and subsequent rings may therefore be 100 code areas if desired.

Thus, with systematic numbering, any subscriber may, within his own single digit sub-area, be permitted dialling facilities equivalent in scope to those permitted to director area subscribers and, in addition, may be permitted automatic access to all objective exchanges located in all of the single-digit sub-areas adjacent to his own sub-area without any basic need for a change in dialling procedure. If, therefore, it is possible to arrange that, around London, the average geographical area of the various single-digit sub-areas is of the same order as that of the present London director area the fringe-area problem peculiar to the London area can, for all practical purposes be eliminated and, moreover, the creation of new fringe-area problems can be avoided.

A Practical Application of the Systematic Numbering Scheme in and around the London Area

In the example given in Fig. 2 the numbering scheme is based on all-figure codes and has been applied uniformly to all exchanges to illustrate the principle involved. In practice it is not, in fact, essential to use all-figure codes for subscriber dialling both into and out of the director area. Subscribers located within the director area could, for example, continue to dial three-letter codes for all calls originating and terminating within the 12½-miles radius circle without affecting any facilities which might be made available to fringe-area subscribers for dialling into the 12½-miles radius circle. The fringe-area subscribers would not, however, dial the three-letter codes. Director area subscribers could also be permitted to dial outwards across the 12½-miles radius boundary to exchange located within the 27½-miles radius circle using, say, two-letter plus one-figure codes, again without affecting any "systematic" dialling facilities made available in the reverse direction. In effect, it is possible to devise practical numbering schemes which, while facilitating interworking between the director area and its associated multi-metering area do not call for a change in present dialling methods, it being remembered that, at the present time, letter codes are used only by director area subscribers.

Fig. 3 illustrates a practical application of the principles used in Fig. 2. It is not the only scheme which could be devised but, in the present circumstances, it represents what

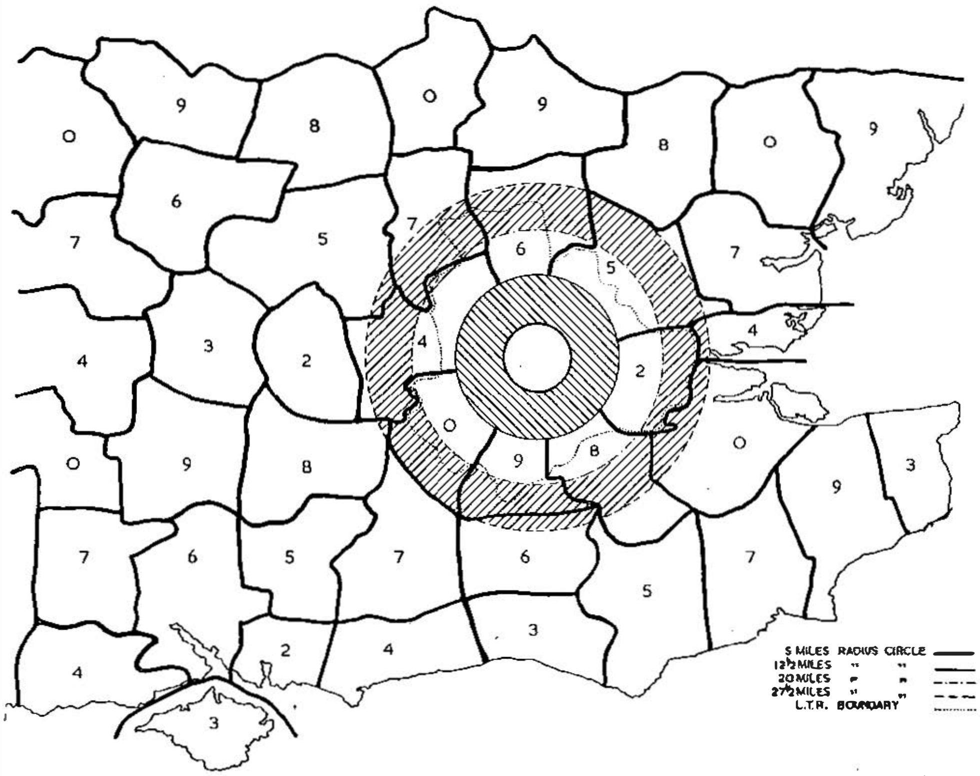


FIG. 3.—PRACTICAL APPLICATION OF SYSTEMATIC NUMBERING TO LONDON AND SURROUNDING AREA.

is considered to be a satisfactory compromise. Figs. 4 and 5 illustrate the extent of a typical "maximum" dialling area which could, ultimately, be made available to subscribers located within typical areas such as Area 4 (containing Watford) and Area 6 (containing St. Albans). Fig. 6 illustrates the extent of the dialling area which could ultimately be made available to subscribers located within the London 12½-miles radius circle. A typical comprehensive subscriber-dialling plan might therefore be based on the following dialling procedures and methods of code allocation.

(i) *Calls between director exchanges.*—No change in present procedure.

(ii) *Calls from director exchanges (i.e., from exchanges within 12½-miles radius circle) to objective exchanges located within the 12½-miles to 27½-miles belt.*—Subscribers would dial two-letter-plus-one-figure codes or one-letter-plus-two-figure codes or three-figure codes or a combination of all three. If any letters were used their allocation would depend upon exchange names and would therefore, in any event, be arbitrary with respect to exchange location. If three-figure codes were used their allocation would also be arbitrary because they would have to be selected from such "spare" codes as are at present available within the director coding scheme. Subscribers located within the 12½-miles radius circle could be permitted, ultimately, to dial to all objective exchanges within the present maximum multi-metering range (15 miles). Dialling to objective exchanges located at points outside the 27½-miles radius circle would require the use of special dialling equipment and a new dialling procedure.

(iii) *Calls from exchanges located at points outside the 12½-miles radius circle but within the 27½-miles radius circle to objective exchanges located within multi-metering range.*—The originating exchanges would all be located in systematically numbered areas. Some of the objective exchanges would, however, be located within the 12½-miles radius circle (i.e., they would be director exchanges). The

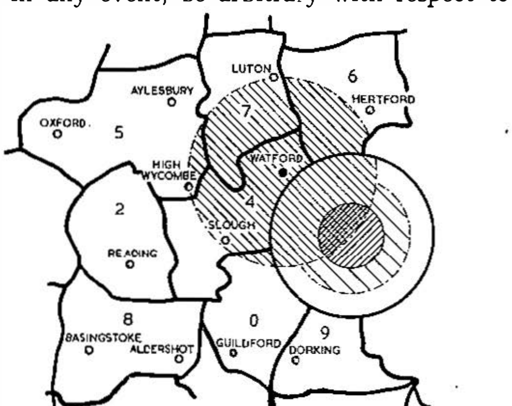


FIG. 4.—EXTENT OF MAXIMUM DIALLING AREA FROM WATFORD USING SYSTEMATIC NUMBERING.

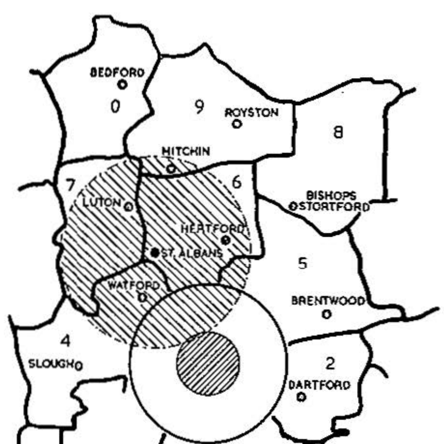


FIG. 5.—EXTENT OF MAXIMUM DIALLING AREA FROM ST. ALBANS USING SYSTEMATIC NUMBERING.

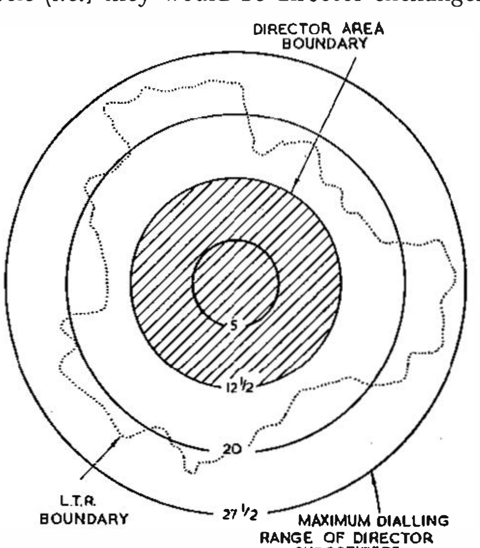


FIG. 6.—EXTENT OF MAXIMUM DIALLING AREA ULTIMATELY AVAILABLE TO LONDON DIRECTOR AREA SUBSCRIBERS.

remainder would be in systematically numbered areas. The codes dialled by a calling subscriber would contain, uniformly, three figures, allocated as follows:—

(*a*) For director exchanges a "first" figure selected arbitrarily from the range 2-0 inclusive followed by pairs of digits selected arbitrarily from the range 71-70, 81-80, 91-90, 01-00 inclusive.

(*b*) For other exchanges a "first" figure determined from the figure for the "area" in which an exchange was located, followed by pairs of digits selected arbitrarily from the ranges 11-10, 21-20, etc., up to and including 61-60 for 60 code areas and 11-00 for 100-code areas (see Fig. **2**).

This would permit any subscriber located within 15 miles chargeable distance of the London director area to dial to all exchanges within multi-metering range using only one dialling procedure. The permitted maximum multi-metering range could be extended, without any change in dialling procedure, to permit ultimately subscriber dialling to all objective exchanges located within dialling areas such as are shown in Figs. **4** and **5**. Each objective exchange would possess only one three-figure code number which would be used uniformly by all calling subscribers within three-digit dialling range of the objective exchange.

(iv) *Calls from exchanges located at points beyond 15 miles chargeable distance from the London director area to objective exchanges within multi-metering range.*—As for (iii) above except that access to London director exchanges would not be permitted.

Thus by adopting systematic numbering for all exchanges not located within the London $12\frac{1}{2}$-miles radius circle it would become practicable, ultimately, to provide all subscribers with dialling facilities comparable in scope with those which can be made available to London director area subscribers. It would not, however, be practicable to use codes containing letters for dialling into the director area from outside or for inter-dialling between exchanges not located within the director area. This may be regarded as a disadvantage, but in return for the use of all-figure codes at points outside the London director area, a number of advantages are to be obtained. Among these the more important are:—

(i) Each exchange outside the London director area would have only one code number which would be used uniformly by all callers within permitted multi-fee dialling range.

(ii) The block of code numbers allocated to London director exchanges (viewed from outside the area) could be such that the series of all-figure codes already allocated for dialling in to the London five-mile circle from fringe-area exchanges could be retained.

(iii) The equipment provided to handle routing and charging would be used efficiently and would contain large reserve capacity for future developments.

(iv) The fringe-area problem would virtually disappear.

The Preferred Long-Term Solution

Although the systematic numbering plan just described has a number of advantages over arbitrary numbering plans it is not the preferred solution because it has the important disadvantage that it restricts the code capacity of the numbering areas immediately around the director area to a maximum of 60 exchange codes each.

This is equivalent to a restriction in the size of a numbering area and, because the density of exchanges in the neighbourhood of London is high, a restriction in size results in a proportion of abnormally short dialling ranges. To provide for possible future extensions in dialling range (e.g., up to, say, 25 miles chargeable distance) it is desirable that the size restriction be removed. The problem reduces to that of finding at least 300 codes for the director area while retaining 100 codes for each of the surrounding single-digit numbering areas. In effect, the total number of codes required at a fringe-area exchange for access to eight 100-code numbering areas together with the director area is at least 1,100. It follows that some of the dialling codes need to be four-digit codes. An examination of the various ways in which four-digit codes might be used shows that the extra digit is most conveniently employed as a "director" prefix, i.e., calls from a fringe area exchange to director exchanges all consist of the same first digit followed by three code digits individual to the wanted exchange.

The preferred plan is therefore similar to that described in the previous section except that in numbering the fringe area there would be no restrictions on the selection of the second and third code digits, and that the allocation of codes to director exchanges for inward calls would be independent of the fringe-area allocation.

Routing.

As indicated earlier in this article the use of register-translators for the control of routing and charging is by far the most attractive and easily manageable solution. It can also be shown to be capable of providing an economic solution.

The present B.P.O. director system could, at least in principle, provide the desired facilities. A detailed study leads, however, to the conclusion that it would not be practicable to convert existing non-director exchanges to director type working (i.e., to a system in which all calls pass through the register-translator). It is instead found preferable, in a non-director exchange, to permit "own-exchange" calls (or, more generally, calls within the local numbering scheme) to be routed as at present and to call in a register-translator only when needed for an outgoing junction call. This requires that, to originate an outgoing junction call, a subscriber must dial a special code to direct his call out of the local numbering scheme to pick up the register-translator equipment. This special code must not be part of the local numbering scheme and should if possible consist of a single digit.

It will be shown in Part 2 that the most convenient code for this purpose is the digit "1" so that, in principle, all outgoing junction calls should pass via level "1" of the first selectors into register-translators associated with relay sets connected, in the usual manner, to this level. It is readily demonstrated that such a solution is an economic one and that it has the outstanding merit of permitting the gradual development of dialling facilities without calling for modifications to existing switching plant.

Dialling Procedure under the Preferred Plan.

Assuming the use of level 1 and that a fringe-area subscriber would have access to the director area and to a maximum of seven 100-code numbering areas, the dialling procedure would be:—

(i) "Own-exchange" calls (i.e., calls within local numbering scheme)	Directory number
(ii) Calls to areas other than director area	Prefix 1 followed by three code digits and four numerical digits
(iii) Calls to director exchanges	Prefix 1 followed by four code digits and four numerical digits.

In the case of (iii) the first of the four code digits would be uniform (e.g., "2") so that in the dialling instructions the prefix could be published as, say, "12" to be followed by the three-digit wanted exchange code and subscriber's number. The method of dealing with three-, five- and six-digit non-director numbering schemes under (ii) above will be explained in Part 2. The procedure used by subscribers connected to director exchanges would be as already described in dealing with the systematic numbering plan.

Charging.

The problem of charging has not been examined because once register-translators are adopted the problems of charging (and barring) become very much simplified provided that charging continues to be based on multi-metering with or without timing.

The present limit for multi-metering is 15 miles chargeable distance. If this range is extended to, say, 25 miles with timing if needed, it is believed that, in conjunction with the plan discussed in this article, considerable savings in operating costs would be achieved. The problems involved are however principally non-engineering problems and do not materially affect the present discussion.

CONCLUSION

It has been shown that the present $12\frac{1}{2}$-miles to 20-miles fringe-area problem could be eliminated either by extending the present director area network to the $27\frac{1}{2}$-miles radius circle or by retaining the present $12\frac{1}{2}$-miles radius director area and adopting systematic numbering at points outside this area.

Both methods require the general use of register-translators for routing, switching and charging, but of the two methods the second is considered to be the better from the engineering point of view because:—

(i) It virtually eliminates the fringe-area problem once and for all, whereas the extended director network would create a new fringe-area problem at and near its new boundary.
(ii) It is capable of a high degree of standardisation.
(iii) It is flexible and is economic in both switching and junction plant.
(iv) It possesses reserve capacity for future development, whereas a fully extended director network would be exhausted.
(v) It can be introduced piecemeal and with a minimum of disturbance to existing plant.
(vi) It does not require the provision of director type dials outside of the director area but would not prohibit their use for dialling into the director area.

(To be continued.)

Book Reviews

"Introductory Circuit Theory." Ernst A. Guillemin, Professor of Electrical Communication, Massachusetts Institute of Technology. John Wiley & Sons, Inc. (New York), distributed in U.K. by Chapman & Hall. 1954. 550 pp. 216 ill. 68s.

This is the first of a sequence of volumes designed to present to students the methods and concepts involved in the analysis and synthesis of modern communication networks. The present volume, as its title indicates, is intended to be an introduction to the theory of electric circuits. In the first three chapters the discussion is restricted to resistance networks, but in the next five chapters the treatment is extended to include the behaviour of general networks in the sinusoidal steady-state. The last two chapters discuss topics dealing with energy relations and the transient responses of lumped networks and are intended to provide the student with a background for the more advanced work in communication network design that is to be the subject of future volumes.

The author makes it clear at the beginning that he intends to make no distinction between the so-called "elementary" and "advanced" methods of treating the fundamental concepts of electric circuit theory. Thus, in his first chapter he discusses network geometry in terms of topological set theory; and in his treatment of network variables, he finds it necessary to introduce two new concepts which he calls a "tie-set" (defined as the dual of a cut-set) and a "maze" (defined as the dual of a tree). Mathematicians claim that the methods of topology render complicated situations in analysis spacially intuitive: and to judge by the superb ease with which they solve the most difficult problems, they must be right. But the average engineering student who is compelled to trudge through every step of a logical argument in order to credit its conclusion, may find the mathematical royal road of topology a very difficult highway to travel along. Nevertheless, this first chapter treats the topological aspects of circuit theory with a deep understanding of the difficulties that students generally encounter, and is probably the best chapter of its kind that has ever been written.

Each chapter provides a clear and interesting treatment of its subject from the modern viewpoint; thus, Thevenin's theorem, duality, source transformations, etc., are discussed in terms of the mesh and node-pair concepts first used by Gabriel Kron in his tensor analysis of rotating electrical systems. The author discusses the limitations of the various methods and warns the reader of possible pitfalls: the book is lucid, well illustrated, and is excellent as a mathematical text for students. It should also be pointed out to students that the present volume may be used as an introduction to Kron's advanced work in the field of spinning electrical systems that include communication networks as special cases.

I.P.O.E.E. Library No. 2181. H. J. J.

"Elementary Telecommunications Examination Guide." W. T. Perkins, M.Inst.B.E., A.M.Brit.I.R.E. George Newnes, Ltd. 320 pp. 181 ill. 17s. 6d.

The author states that this book is an examination guide covering Telecommunications (Principles) I and Elementary Telecommunications Practice of the City and Guilds of London Institute first-year course, and is intended for students as an addition to the standard text-books on the subjects.

The book is thus not a text-book in the usually accepted sense of the term. It consists of a collection, divided into subject sections, of questions and model answers, with the claim that the questions are typical of those set in the City and Guilds of London Institute examinations.

Inevitably, in a book of this type, the subject matter covered is limited by the questions selected, and, no doubt due to limitation of size, the book far from covers the syllabuses intended. The Principles I syllabus is very superficially covered as the book tends to concentrate more on the Practice syllabus. It is unfortunate that the Practice syllabus attempted, and as printed in the book, is out-of-date as this syllabus was amended in the 1951-52 session. This amendment deleted paragraphs 9 and 10 and modified paragraphs 8, 10 and 13 of the syllabus as given in the book. These changes make the whole of Section XI and about half of Section XIII of the book unnecessary. The space saved by using the up-to-date syllabus and omitting the material mentioned, would have permitted other rather unsatisfactory sections to be strengthened; for example, Section VII is weak on carbon resistors, and Section XII does not cover the need for polarising receivers, and does not cover inductors adequately.

Many questions set and answered are actual City and Guilds examination questions, but others consist of selected parts of City and Guilds questions. These latter are far too brief and simple and naturally not up to the City and Guilds standard for a whole question.

Used carefully, the book would be a very general guide to a student as to the way examination questions should be answered in the time available, but it is stressed that this guidance would be general only, due to the number of questions and answers given not being of the required standard.

S. W.

The Transistor

J. R. TILLMAN, Ph.D., A.R.C.S.†

Part 1.—General Introduction.

U.D.C. 621.314.7

A series of articles on the transistor is introduced by way of a short historical account and some considerations of possible uses of transistors in telecommunications.

Introduction.

THE series of articles, of which this is the first, is intended for readers who have not yet studied transistors. Space limits it to an outline, with descriptions of some of the more important details, of the developments which have taken place since 1948. Fuller details can be sought from the original papers, mostly by American authors, and from one or two text books.

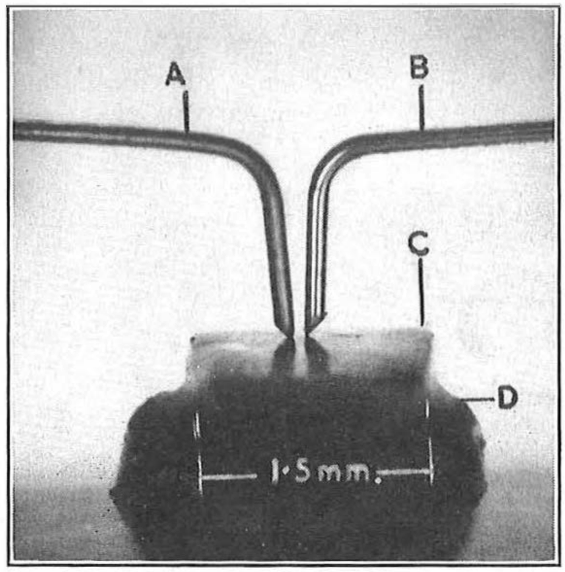
At first the subject was largely one for physicists; by now, however, much of it is more proper to the technologist and to the electrical engineer, who are faced with the problems, respectively, of manufacture and of deciding the scope for the transistor.

Some reflection of the fact that the subject enters many fields of science will be obvious in the articles. Thus, that accompanying this introduction gives a simplified physical explanation of the new mechanisms considered responsible for the properties observed. The next two articles deal with the chemical and metallurgical preparation of germanium, still the most prominent transistor material, and with the processes (metallurgical, mechanical, electrochemical, etc.), used in the making of transistors. Only then are the electrical properties and limitations dealt with, preparatory to the final article which deals with basic circuits.

Historical.

Although many attempts had previously been made to convert metal rectifiers into triodes, for instance by the insertion of a third electrode to control the flow of current between the usual two, it was not until 1948 that any experiment offered prospects of doing so successfully. In that year, Bardeen and Brattain, of the Bell Telephone Laboratories, were experimenting with germanium, a semi-conductor which had become prominent only a few years before. Point-contact diodes, made by pressing the pointed end of a thin metal wire (whisker) against it, would, with suitable preparation, offer little impedance to current flow with one polarity of applied voltage and yet pass little current with the polarity reversed, even when the applied voltage was as much as 100. They found that when the tip of a second whisker (now termed the collector) was placed within 0·25 mm. (0·01 in.) of that of the first and biased in reverse, the current, I_c, flowing between it and the germanium varied with the current, I_e, passing between the first whisker (now termed the emitter) and the germanium, if I_e was in the direction of easy flow. Further work showed that, with suitable preparation of the new triode, called a transistor, power gains of up to about 100 could be obtained; the input impedance to the emitter was low, perhaps a few hundred ohms, the output impedance at the collector was large, perhaps ten thousand ohms or more, and dI_c/dI_e ($= \alpha$) could be greater than unity.

Although the essence of a point-contact transistor, as shown in Fig. 1, is simple, great efforts have had to be made to understand and solve the many problems of mass-producing point-contact transistors of consistent properties and long life. One of the most important, now largely solved, is that of obtaining suitable germanium. Three steps are involved. First it is prepared with a purity several orders better than hitherto obtainable, by new metallurgical means; secondly, controlled but minute amounts of suitable impurity are added, and thirdly,



A—Emitter Whisker; B—Collector Whisker; C—Mono-crystalline Germanium; D—Base Support and Connection.

FIG. 1.—STRUCTURE OF POINT-CONTACT TRANSISTOR.

single crystals of great physical perfection are grown. Suitable surface treatments have also had to be found. The positioning of the two whiskers continues to present difficulties and involves accurate jigs and microscopes. The electrical forming of the collector, necessary to ensure good overall characteristics, had also to be investigated; although the volume of germanium affected by forming may be only $\simeq 10^{-8}$ cm^3, it may have a fine structure, dependent on the material of the collector whisker, the pressure applied and the duration, polarity and intensity of the forming current and voltage. Lastly, the encapsulation or enclosing of the transistor presents difficulties. Fully satisfactory solutions are still to be found to some of the problems, but, largely as a result of intensive work by the Bell Telephone Laboratories, the Western Electric Company of the U.S.A. has been able to mass-produce several types of point-contact units. In England, at least two firms are taking those steps which will enable them to begin mass production if demands warrant it.

While the technology of manufacturing point-contact transistors was proceeding, Shockley, in particular, was seeking new structures; and, beginning in 1949, he described and analysed very thoroughly the p-n junction and the junction transistor. Devoid of unstable whisker contacts, and needing no electrical forming, the new triode also offered some improvements in performance, particularly greater gain and lower noise. Bell were soon able to announce that they had made units (an early one being shown in Fig. 2, devoid of encapsulation), and that the performance was closely as expected. Their method of production was soon rivalled by another, from the General Electric Company of the U.S.A., which seems to offer some advantages in mass production; more recently still a third and possibly even simpler method of achieving much the same purpose has been evolved.

Before circuits could be engineered around the transistor, its electrical properties had to be thoroughly investigated. Several equivalent circuits, suitable for use when small

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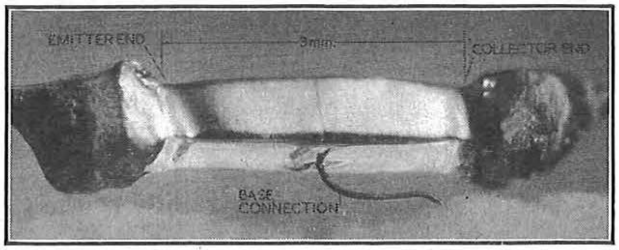

FIG. 2.—A GROWN N-P-N JUNCTION TRANSISTOR.

signals only are applied, have been proposed. In general, they are more complex than those for thermionic valves. The limitation to the bandwidth obtainable with a point-contact triode was soon found to come from transit-time phenomena and not from inter-electrode capacitances; none the less, some units have been made which are suitable for use as amplifiers up to tens of Mc/s. Junction triodes, however, have more significant collector capacitances, which impose limitations in addition to transit-time effects. It soon became obvious that the original method of demonstrating transistor action, i.e. with the emitter as the input electrode and the collector as the output electrode, was not the only way of putting transistors to work. For the junction transistor the table shows the alternative ways of use, with valve analogies (which must, however, be accepted with some reserve).

Input Electrode	Grounded Electrode	Output Electrode	Input Impedance	Output Impedance	Valve Analogy
Emitter	Base	Collector	Low	Very high	Grounded Grid
Base	Emitter	Collector	Medium	High	Grounded Cathode
Base	Collector	Emitter	High	Low	Cathode Follower

A property of point-contact units which circuit engineers were quick to utilise is the positive feedback produced, because $\alpha > 1$, by any impedance in series with the base. If the external impedance Z_e connected in the emitter circuit is low, the positive feedback can make the transistor unstable. When, for example, Z_e is a series tuned circuit, a simple oscillator results. Much the same property has been used to make a bi-stable trigger circuit, using only one point-contact unit. In order to permit the use of transistors having the wide spread of characteristics still observed for most types, however, designers have had to elaborate the otherwise simple circuits. None the less, some useful applications have been achieved, and the possibility of the widespread use of transistors in electronic digital computers must not be discounted.

To What Extent Will the Transistor Replace the Thermionic Valve?

From time to time since its discovery, the transistor has been hailed as destined to replace the thermionic valve on a wide scale. Before the prospects of it ever doing so can be assessed, much more must be learned about the new unit. As later articles will show or imply, there are some functions of the thermionic valve which the transistor, as at present constituted, cannot fulfil; nor can it, if at all, until several severe difficulties are overcome. Those properties of valves of importance to circuit designers are, for instance, little affected by ambient temperature, partly because the cathode temperature is little affected and partly because the cathode current is limited by space charge to a value much below the total emission proper to the cathode temperature; on the other hand, that part of the collector current of a transistor (particularly a junction transistor) which is not a function of I_e is very temperature-sensitive (changing perhaps 10 per cent. per °C). Although temperature limitations are of less importance for some other semi-conductors now being developed as transistor materials, other limitations, particularly of the bandwidth obtainable, remain. Moreover, transistors are more easily damaged by thermal and electrical shock, and possibly by mechanical shock.

None the less, there may well be a strong urge to use the transistor in radio and television receivers, particularly with the advent of the surface barrier type. Not only are space and power drain reduced, but the conditions of use of the accompanying components, e.g. resistors and capacitors, are eased. However, the transistor should not be looked upon merely as a device for doing, in much the same way, some of the jobs now done by thermionic valves. Some of its properties are not paralleled in valves and may much simplify electronic equipments. Thus junction transistors, suitably proportioned, can be made to work symmetrically, emitter and collector reversing their roles according to the potentials applied; the simultaneous use of n-p-n and p-n-p units also facilitates circuit design.

In many applications, though perhaps not for the world of entertainment, the crucial test of the transistor will be its consistency and reliability, points about which it is still too early to be conclusive.

Possible Early Uses of the Transistor in Telecommunications.

Despite their admittedly limited properties, the transistors now becoming available in Great Britain may well find several uses in the Post Office systems. A line amplifier, restricted by bandwidths to use only on audio circuits, or as a channel amplifier of carrier systems, has already been designed and is undergoing a field trial. If two-terminal amplifiers are found to be of use, designs using transistors (some have already been completed in the U.S.A.) will probably prove more economical than valve units used so far. An abundant supply of cheap and reliable junction transistors might well make engineers reconsider the possibilities of a handset including a microphone of better quality (though less efficient) than the present carbon inset, assisted by a transistor to achieve the present signal levels to line.

Junction transistors may also have to be seriously considered in the design of any new systems of multi-channel V.F. telegraphy and V.F. dialling and signalling. Most equipments handling currents of audio or lower frequencies can in fact be redesigned around the transistor, to the exclusion of all but a very few valves, but not necessarily economically or with sufficient reliability.

Newer designs of junction transistor and the surface barrier transistor have much reduced thicknesses of the base regions and much reduced collector capacitances, with consequently much increased bandwidths. They appear, superficially, to offer hopes of widespread use in carrier telephony; some changes to present-day systems might be entailed however (e.g. closer spacing of repeaters). They may also challenge point-contact units in the fields remaining of interest to the latter, e.g. switching at speeds of 10^6 or more per second.

The introduction of transistors to telecommunications will necessitate new approaches to electronic circuit design and analysis, which may at first appear more difficult than those for valve circuits. Some new approaches have already been made, with moderate success, but until they are put to more difficult tests with circuits of greater complexity than have been designed so far, it is too early to decide their relative merits.

Conclusions.

By raising, in this introduction, many of the points that will be explained more fully in the later articles, it is hoped to give the reader a broad picture into which the details can be fitted with some understanding of their necessity and of their connections with the subject as a whole.

Part 2.—Outline of the Theory of Point-Contact and Junction Transistors.

F. F. ROBERTS, B.Sc.(Eng.), A.M.I.E.E.†

The nature of conduction by electrons and holes in germanium is outlined and transistor action explained in terms of the injection and collection of holes or electrons in excess of the equilibrium concentration.

Some Relevant Properties of Pure Germanium

THE characteristic electrical properties of point-contact and junction transistors, in particular the low impedance from emitter to base and the high impedance from collector to base in conjunction with the current gain from emitter to collector greater than or just less than unity, cannot be explained in elementary terms of electrical conductors and insulators. Some of the details of the modern theory of the solid state of matter must be employed. That theory indicates the dominant importance of (*a*) the number and distribution of the outer or valency electrons belonging to each atom in the solid, and (*b*) the arrangement of the atoms in the crystal structure of the solid.

Germanium, the material currently used for an essential portion of most transistors, is element No. 32 of the Periodic Table of the elements, occupying column IV of that Table, below the elements carbon and silicon and above the elements tin and lead (the atoms of all of these elements having 4 available valency electrons). The crystal structure of germanium, indicated in isometric projection in Fig. 3, is that of carbon in the form of diamond, and is

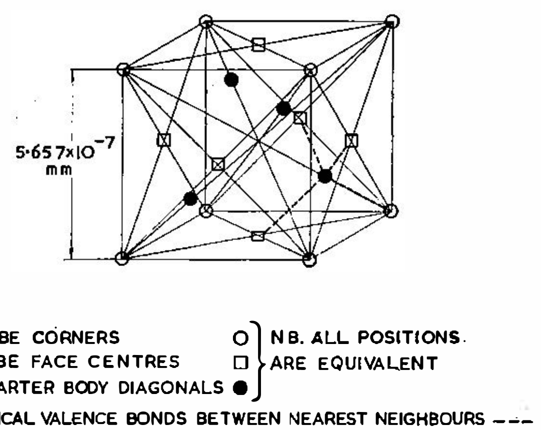

Fig. 3.—Arrangement of Atoms in the Unit Cube of the Germanium Crystal Structure.

similar to that of silicon and of tin in the "grey" form. Each atom of germanium in a perfect and absolutely pure crystal has four nearest neighbours symmetrically disposed about it, and is bonded to each of its neighbours by one of its four valency electrons acting in conjunction with one valency electron from each neighbour. Each valence bond thus consists of a pair of electrons which may be regarded as spending most of their time in the region immediately between the centres of the two atoms concerned. The great strength of the valence bonds gives germanium its relatively high melting point (about 950°C) and its mechanical hardness.

The partial fracture of a valence bond, that is, the removal of one of its electrons, requires 0·72 electron-volt of work (that is the work done in moving an electron between points separated in potential by 0·72 volt). At temperatures approaching the absolute zero (—273°C), all the bonds are intact in a pure and perfect crystal, and no electrons are available to move under the influence of any externally applied electric field: the germanium is then an insulator. At 25°C the random thermal vibrations of the atoms result in the partial fracture of one bond in about every thousand million, setting free an equal number of electrons and leaving an equal number of one-electron bonds. The free electrons contribute directly to the electrical conductivity, their contribution, σ_n (in mhos per millimetre) being given by the product of their concentration n (in numbers per cubic millimetre), of their mobility μ_n (in millimetres/second per volt/millimetre) and of their charge q (in coulombs). Each one-electron bond also contributes directly by moving in the opposite direction (rather like the bubble in a tilted spirit-level) as a result of electrons from successive neighbouring complete bonds moving in to fill the vacancy in the single-bond, creating new vacancies behind them. The vacancies in the one-electron bonds behave electrically like mobile positive charges equal in magnitude but opposite in sign to the charge on the electron. The vacancies are now generally referred to as "holes," and their contribution to the conductivity may be written as $\sigma_p = p\mu_p q$, where p is the hole concentration and μ_p their mobility. A crystal of germanium containing equal numbers of mobile electrons and holes (i.e. $n = p$) is termed an "intrinsic" semi-conductor since its electrical conductivity is a property of the germanium itself and does not depend upon the presence of any foreign atoms. At 25°C a millimetre cube of intrinsic germanium contains about 3×10^{10} mobile electrons and 3×10^{10} mobile holes and has a resistance between opposite faces of about 600 ohms; at —40°C the resistance is about 20,000 ohms and at +40°C it is about 300 ohms, the changes being mainly due to the rapid variation of n and p with temperature (μ_n and μ_p vary comparatively slowly over this temperature range).

Intrinsic germanium is of no use itself for transistor construction, but it is a desirable first step towards the preparation of suitable material.

Majority Carriers in "Doped" Germanium

Before transistor action can be made to occur, two conditions must be fulfilled: (i) the equality between the numbers of mobile electrons and holes present in equilibrium with one another in the germanium must be permanently disturbed, so placing either electrons or holes in the majority, and (ii) it must be possible temporarily to inject into the germanium extra charge carriers of the same sign as those normally present in the minority. The first condition is achieved during the preparation of the crystal by arranging that each atom in about every hundred million of germanium is replaced by a suitable foreign atom. If electrons are to be made the majority carriers, suitable foreign atoms are those in the 5th column of the Periodic Table, in particular arsenic and antimony, since these atoms will dissolve substitutionally in the germanium crystal lattice and will have one outer electron remaining after completing the double bonds to the four neighbouring germanium atoms. The spare electron is only loosely bound to the atom (binding energy about 0·04 electron-volt) and is, in fact, free and mobile within the germanium at all temperatures of interest for transistor applications. If, on the other hand, holes are to be the majority carriers, indium or gallium (3rd column of the Periodic Table) is generally

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chosen for the foreign atoms, these requiring only three electrons to saturate their bonding capacities, so leaving over one-electron bonds (holes) which likewise are free and mobile within the germanium at all temperatures of interest. The germanium is called n-type (n for negative) if electrons are the majority carriers, and p-type (p for positive) when holes are in the majority. The foreign atoms are called donors when they make the germanium n-type, and acceptors when they make it p-type, in accordance with their electron-adding or electron-subtracting effect. Germanium containing added donors or acceptors is said to be "doped." When the donor or acceptor impurity concentration (N_d or N_a respectively) is at least 10 times the carrier concentration in intrinsic germanium, the majority carrier concentration is substantially equal to the added impurity concentration, except that where donor and acceptor impurities are present together in the same region of the germanium only the excess $N_d - N_a$, of donors over acceptors, or vice versa, is to be counted.

Since the electron and hole concentrations, n_i and p_i ($n_i = p_i$), in intrinsic germanium increase rapidly with the absolute temperature T (they vary approximately as $\exp(-4350/T)$) these concentrations will eventually dominate any added concentration due to donor or acceptor impurities, and all germanium therefore behaves like intrinsic germanium at sufficiently elevated temperatures. For n-type germanium suitable for transistors, having a resistivity of 10 ohm-mm. at 25°C, the resistivity rises to a maximum of about 13 ohm-mm. at 90°C, and falls again to 10 ohm-mm. at about 120°C as the transition to intrinsic behaviour sets in.

Minority Carriers in Equilibrium and their Injection in Excess in Doped Germanium

It is a general property of germanium and similar semiconductors that, as the majority carrier concentration is permanently increased by the addition of donor or acceptor impurities, the equilibrium concentration of minority carriers automatically becomes reduced in the same proportion, resulting in a product np of concentrations of majority and minority carriers which is a constant, equal to $n_i p_i$, characteristic of the material at any given temperature. Hence, in material suitable for transistors, although the equilibrium concentration of majority carriers is practically constant over the working temperature range, that of minority carriers is very temperature-dependent.

The second pre-condition for transistor action, namely the possibility of temporarily injecting into the germanium an excess of minority carriers above the equilibrium concentration, is found empirically to be easily satisfied by a positively biased point-contact on suitable n-type germanium, and can be both explained theoretically and realised practically by means of a junction between suitable adjacent regions of n-type and p-type germanium in a single monocrystalline portion of the material. Fig. 4 shows schematically such a p-n junction. When the p-type material is biased positively relative to the n-type, holes are driven from the hole-rich p-type into the n-type and electrons from the electron-rich n-type to the p-type material, the carriers of each type becoming *excess minority* carriers on crossing the junction; at the same time *excess majority* carriers enter the outer ends of the crystal (through the ohmic connections assumed to be made there) in numbers equal to the excess minority carriers in each region and thereby prevent the build-up of any space-charge in the material (except within a layer about a micron (10^{-3} mm.) thick enclosing the plane of the junction, where a permanent space-charge double-layer is spontaneously maintained). The presence of the excess minority and majority carriers causes the product np to exceed the equilibrium value $n_i p_i = n_i^2$. The recombination in pairs, by mutual annihilation, of excess carriers of opposite sign, leading to the restoration of a corresponding number of complete valence bonds, tends continuously to re-establish the equilibrium; the recombination occurs on the average at a characteristic time τ_m after the injection of each minority carrier, and τ_m is generally known as the "lifetime" of that carrier in that particular sample of material. Several experimental methods are available for measuring τ_m, which is as significant a property for transistor material as the resistivity. Typical useful values of τ_m range from 1–100 μsec. for present types of transistor.

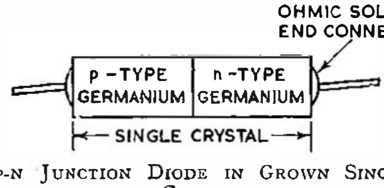

Fig. 4.—p-n Junction Diode in Grown Single Crystal of Germanium.

The ratio of hole current flow to electron current flow in a p-n junction diode of the type indicated in Fig. 4 is given by

$$i_p/i_n \simeq 0{\cdot}7\ (N_a/N_d)\ (\tau_n/\tau_p)^{\frac{1}{2}}$$

where N_a is the acceptor concentration in the p-region, N_d the donor concentration in the n-region, and τ_n and τ_p the electron and hole lifetimes as minority carriers in the appropriate regions. The formula just given shows that an excess hole concentration can be injected into n-type material, with as great an efficiency as desired, by way of a p-n junction on to the given material from p-type material of sufficiently large N_a and τ_n. Such a junction would be a good emitter for a p-n-p junction transistor (shown schematically in Fig. 5), though the formula for

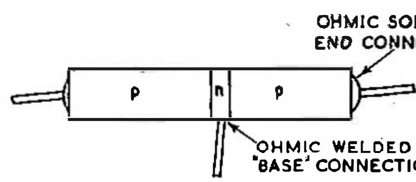

Fig. 5.—p-n-p Junction Transistor in Grown Single Crystal of Germanium.

the injection efficiency in the transistor is more involved than that given above. The observed hole-injection efficiency of almost any point-contact emitter on n-type germanium may be explained by the assumption that a surface region one micron or less in thickness (due perhaps to oxidation) is present on the germanium and contains a higher concentration of holes than electrons, in this respect resembling a p-type region.

Collector Action

A p-n junction, like that of Fig. 4, having the p-type region biased negatively relative to the n-type region, passes a saturation current i_s nearly independent of voltage for voltages greater than about 0·2 V and less than 20-50 V (according to the material). The current i_s is given by the sum, $i_{ns} + i_{ps}$, of currents due to the extraction of minority carriers passing in opposite directions across the junction from both the n-type and p-type regions. The ratio i_{ps}/i_{ns} is equal to the ratio i_p/i_n already quoted for the corresponding currents under carrier injecting conditions, the values of i_{ps} and i_{ns} separately depending directly on the equilibrium concentrations and inversely on the lifetimes of minority carriers in the regions from which they are flowing. But when the concentration of holes is greatly increased in the n-region close to such a negatively biased p-n junction, the hole current flow i_p will increase proportionately and the junction behaves as a perfect collector for all holes incident upon it from the n-type side. (It would behave equally effectively for electrons incident upon it from the p-type side.) Since the rate of flow of holes towards such a collector junction is not significantly influenced by the magnitude of the bias within the limits quoted above, the high impedance of a junction transistor collector is qualitatively accounted for. The current gain of the junction transistor is determined primarily by the proportion of minority carriers injected by the emitter which diffuse across the base region to the collector junction (i.e. assuming that the emitter efficiency has been made 99 per cent. or more), and this proportion is limited only by the loss of minority carriers by recombination in transit and by sideways diffusion out of reach of the collector junction (in particular to the adjacent free surface of germanium where recombination may be very rapid).

Two additional influences must be invoked to account for the observed current gain in point-contact transistors, typically 2-3 for emitter bias currents of 1-5 milliamperes, or more at small emitter bias currents. Firstly, owing to the different geometry (as compared with the junction transistor) of the emitter and collector with respect to the germanium of the base material, the probability of an injected hole from the emitter reaching the collector by diffusion alone is reduced by a factor of the order of 10. Because this factor appears to be much smaller with normal collector biases on typical units, it is necessary to assume that the electric field is large enough over an important part of the base material between emitter and collector to cause drift to dominate diffusion of the holes. Secondly, it is necessary to postulate some current-multiplying process either in the emitter-collector path through the base-material or at the collector contact itself. A simple theory which treats the collector as an ohmic contact can in fact explain current gains of up to about 3 for n-type germanium base material, but this theory does not account for the observed high collector-to-base impedance under normal conditions or the rectification property of the collector as a diode. Two other theories are known, however, which can explain the gain and impedance characteristics of the collector, and as yet no conclusive experiment has established the superiority of one or other theory. One of the theories, that of the so-called p-n hook collector, will be outlined in a later article of this series, when the circuit properties and limitations of transistors are being considered.

Summary of Transistor Action

Transistor action may loosely be defined as an effect leading to the possibility of power amplification by means of electronic (in contrast to ionic) conduction in the solid state, not depending upon thermal or photo-electric effects. Taking the common-base emitter-input circuit (Fig. 6(a) as the fundamental one for physical interpretation (though not necessarily the best for practical application), and representing this ideally by the equivalent circuit of Fig. 6(b), the power amplification may be written (for matched generator and load) as $(\alpha^2/4)\ (r_c/r_e)$, where α is the emitter-to-collector urrent gain, r_e is the emitter-to-base slope resistance and r_c is the collector-to-base slope resistance, all under the working bias conditions. For both point-contact and junction transistors practically all of the power amplification arises from the ratio r_c/r_e in the above expression, and this ratio can be accounted for by regarding the emitter and collector as diodes biased in the low- and high-impedance directions respectively.

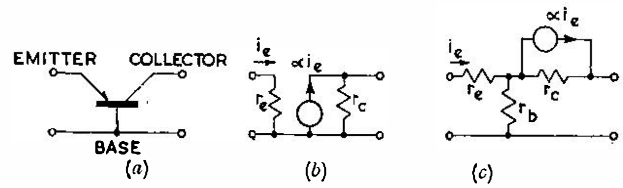

Fig. 6.—Circuit Representation and Equivalent Circuits of Transistor with Emitter Input and Collector Output.

The overall current gain α may be expressed as the product of three factors, $\alpha = \gamma\beta\alpha_c$, where γ is the emitter injection efficiency for minority carriers, β is the transmission factor, being the proportion of minority carriers injected by the emitter which arrive just in front of the collector, and α_c is the current multiplying factor of the collector itself. For a p-n-p junction transistor, γ may be written as $\gamma = i_p/(i_n + i_p)$, where the currents are those crossing the emitter junction, as discussed previously. For an emitter junction made by the alloy process (to be described in a later paper of this series) γ is over 0·99, and values as high as 0·99 can be obtained with "grown" junctions (also to be described). An alloy junction collector gives $\alpha_c = 1$ very closely, while grown collectors can give α_c values of as high as 1·1, there being normally no current-multiplying mechanism in simple junction collectors similar to that in a formed point-contact collector. The transmission factor β may be greater than 0·99 for a junction transistor having a thin base region with long minority carrier lifetime, and can be lower than 0·2 for a point-contact transistor at a collector voltage below 1 V.

The equivalent circuit of Fig. 6(b) implies that the transistor is truly a one-way amplifier (like a thermionic vacuum triode as a low-frequency amplifier) and that any signal applied to the collector-base terminals suffers infinite attenuation on its way backwards towards the emitter-base terminals. In reality all transistors have appreciable backwards transmission, owing to the finite (non-zero) resistivity of the germanium forming the base region. The collector-to-base current, flowing from the immediately active portion of the base region to the point of connection of the metallic base terminal, causes a potential drop which appears in series with the emitter-base circuit. The effect is represented in the equivalent circuit by adding a resistance r_b (the base resistance) in common with the emitter and collector circuits, as in Fig. 6(c). The presence of r_b sets a limit. to the performance of the transistor itself and complicates the design of transistor circuits.

(To be continued.)

An Experimental Register-Translator for Universal Subscriber-Subscriber Dialling

S. W. BROADHURST, A.M.I.E.E.†

U.D.C. 621.395.34:621.318.572:621.374.5

This article describes, in outline, an electronic register-translator using an ultrasonic mercury delay line in the register for temporary digit storage by pulse technique. The digital information received by, and stored in, a number of registers is continuously compared with information held in a common translator, the speed of operation being such that during the interval between successive dialled digits a register can examine every translation available to it. At the appropriate time (depending on the class of call, its routing, etc.), the register detects coincidence with information wired permanently into the translator and the relevant translation is passed into the register's store. The stored translation plus that part of the dialled number not needing translation, and certain other controlling signals, then circulate in the delay line until sent out at a time determined by instructions received with the translation.

Introduction

In a fully automatic telephone system having universal subscriber-subscriber dialling facilities, register-translators must be used if code lists are to be avoided, and the numbering scheme and the network layout are not to be inter-dependent.

A register records the number received from a subscriber's dial or from an incoming junction. The translator supplies further information such as the route and rate of charge for the call indicated by the number held in the register, and a sender, which is usually part of the register, sends out the combined information to set up the whole or part of the outgoing connection to the wanted number. In the director the register, translator and sender are all combined in one piece of apparatus, but modern ideas tend to the use of one translator common to a number of registers.

Once a national numbering scheme has been laid down and a tariff structure agreed, the facilities to be provided by a national register can be restricted to those necessary to operate the agreed layout. However, at the time that the experimental equipment about to be described was designed, no specific problem was in mind. It appeared possible, because of electronic developments then taking place, that universal registers capable of working into any type of network and dealing with any national numbering scheme could be made economically and this course was followed. By "universal" is meant that one apparatus is capable of acting as an originating, transit or terminating register for both local and junction traffic. Hence as, for example, dial tone must be given when the apparatus is acting as an originating register but not in other cases, a universal register is dependent on some system of indicating the class of service for each incoming call and this is assumed to exist.

The experimental equipment is wholly electronic and although relay contact symbols are used in the illustrations these are introduced for explanatory purposes only.

Basic Problems and Solutions

Outline of the Storage Problem.

The first problem to be solved in the design of such a universal register is that of digit storage. Present ideas on the handling of long-distance calls involve the dialling of up to 11 digits, and it is possible for this number to be still further increased. It is most desirable, however, that subscribers should have to dial fewer digits for local and short-range calls, and this can be achieved by the use of prefix digits for the longer distance calls. As the bulk of the traffic will be for local and short-range calls, most of the digit storage capacity of universal registers is idle for most of the time the register is in use. It follows therefore that the storage equipment used should be of a type whose size and cost are negligibly affected by the storage capacity required. Delay line storage fulfils these requirements. In the experimental register an ultrasonic mercury delay line, approximately 11 in. long, is used for digit storage. This line, together with a short electrical delay line, can store 200 pulses spaced at one microsecond intervals. Using five pulse positions for each digit gives a capacity of 40 digits which is adequate for the storage of the longest dialled number, together with its translation and other instructions relevant to the call being set-up, e.g., the meter fee to be charged.

Translation Problems.

A national numbering scheme for this country would require a selection of up to 10,000 working exchange codes out of a total of 100,000 possible codes, i.e. each exchange would have a five-digit national code[1]. It would clearly be impracticable to provide every exchange with the whole of the routing information necessary to enable its register to set up the complete route for a call to any subscriber in the country. Not only would the translator be of immense size but a routing change anywhere in the country would mean translation changes in every exchange. For these reasons it is certain that at least two registers will be involved on any long distance call and that, most probably, there will be a register at every switching centre. Under these conditions, the routing information to be supplied by the translators at the originating or transit exchange will consist of three parts,

1. Information to enable the call to be routed through the switches of the exchange to the outgoing circuit.
2. Information to route the call through the network to the next register.
3. Information to enable the next register to advance the call to another register or to its destination.

At terminating exchanges, only item 1 is necessary, and if every exchange is fitted with registers item 2 is redundant. In general, item 3 will usually consist of instructions to the register to repeat the whole or part of the number dialled by the caller.

In addition to the routing information, translators may have to supply registers with metering instructions; also, depending on the class of service of the caller, special service instructions may have to be given.

Numbering Problems.

Depending on the numbering scheme and the tariff structure it is possible that the charge for a trunk call and the route it must take to the next register in the connection can be determined after the caller has dialled less than the maximum number of code digits. In the extreme case the first digit of a systematically arranged numbering scheme could do this. Thus, if all Northern Ireland exchanges had codes starting with the digit 8 a register in London receiving the first digit 8 would, given that the present tariff structure remains, have sufficient information to know the cost of the call and its routing as far as Belfast. It follows that it

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[1] Barron, D. A. "Subscriber Trunk Dialling", *I.P.O.E.E.*, Paper October, 1952. (To be published as a Printed Paper in due course.)

may be desirable for a universal register to apply for a translation after each digit dialled by the caller and be capable of starting to set up the outgoing connection before the caller has dialled the complete number.

A universal register also has to take account of the possibility that subscribers' national numbers may differ in length depending on whether their local numbers contain three, four, or five digits. Also any exchange identified by a particular national code may have a mixed four-digit or five-digit numbering scheme. Because it is clearly impracticable for every exchange in the country to be given sufficient information about all the others to enable its registers to be told how many digits to expect on every call, the difficulty arises of telling the originating register when it can release.

A further difficulty arises in connection with the method of identifying calls to spare codes. The problem in this case is to be able to route such calls to N.U. tone, without having to use a translation code terminal for every spare code. (In a national numbering scheme about 90,000 codes will be spare.)

Solutions to the Foregoing Problems.

In the experimental register-translator it is arranged that the digital information stored in the register is continuously compared with information held in a common translator in a manner described in a previous article[2]. The comparison is done at a speed such that even though the caller uses a keysender, the register can examine the whole of the information wired into the translator during the interval between the receipt of successive digits from the caller. At some time during the receipt of incoming digits a register will have stored a code or a portion of a code which is also wired into the translator and the register can detect the coincidence. At this stage, the translator is enabled to pass the required translation into the register's store. The translation is always accompanied by a "start setting up" (S.S.U.) signal, which also goes into the register's store and is used to tell the register how many more digits if any, it must receive from the caller before starting to set up the outgoing call. Because sending need not take place as soon as the translation is received and because the register is continuously comparing its stored information with that in the translator it is possible to change the translation before sending actually commences. This feature can be used to offset some of the difficulties of dealing with spare codes. Thus, suppose that of 10,000 codes starting with the digit 7 all but one are spare; then it can be arranged that any register receiving the first digit 7 will receive a translation which would route the call to an N.U. tone circuit if the register started to send. If, however, the S.S.U. signal is arranged to delay sending until after the receipt of the fourth digit and the subscriber happens to dial the one working code in the group, then because this code will be written in the translator the register will find a second coincidence between its stored code and the translator codes and a new translation can be caused to replace the old. By this method the number of items stored in the translator may be considerably reduced.

There will always be at least two registers involved on junction calls and it can be presumed that the terminating register can obtain from its translator all the information pertaining to the terminating exchanges it controls. Hence, as the terminating register is continually comparing its stored information with its translator codes, it can be told by the translator whether it expects a 3-, 4- or 5-digit number. This can be done by the S.S.U. signal. The originating register can be caused to start sending at any convenient time and can be arranged to hold itself in circuit until the terminating register acknowledges that it has received sufficient information to enable it to complete the setting up of the call. Thus, the difficulty of subscribers' national numbers having varying lengths is overcome.

The Storage System

A picture of the ultrasonic delay line is shown in Fig. 1,

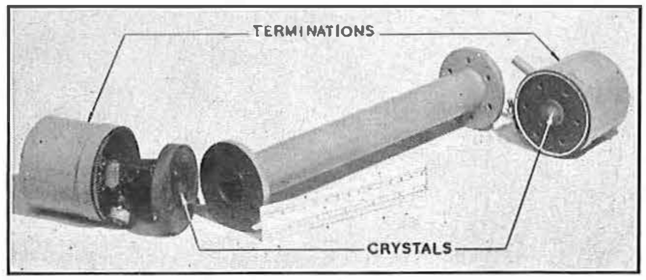

Fig. 1.—195 μS Mercury Delay Line.

and a block schematic diagram of the register's storage system is shown in Fig. 2. The store consists of an ultrasonic delay line, D, in series with an electrical delay line, E. The

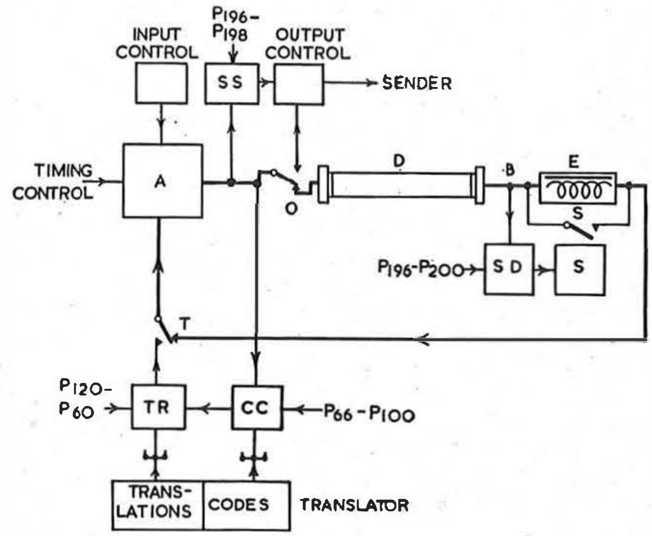

Fig. 2.—Block Schematic Diagram of Storage System.

ultrasonic delay line comprises a column of mercury terminated at each end with a quartz crystal arranged so that voltage pulses applied to one of the crystals produce, by the piezo-electric properties of the material, mechanical impulses which are applied to the mercury column and propagated along the line to the other crystal to cause it to generate electrical pulses corresponding to those applied to the input crystal. These output pulses are delayed by a time depending on the length of the mercury column. In the register this delay is 195 μS so that a pulse from A (Fig. 2) applied to the input of D, appears 195 μS later, at the input of E. The electrical delay line, E, gives a further 5 μS delay to the system. Pulses emerging from E are amplified, re-synchronised in device A, and caused to re-enter the circulating system at the same point in a timing cycle of 200 μS as the original signals applied to the input crystal. (The circulating path is indicated by thickened lines.)

The signals injected into the delay line D consist of pulses of alternating current at a frequency of 10 Mc/s, each pulse having a duration of 0·8 μS. When a register is idle none of its 200 one-microsecond pulse positions has a

[2] Flowers, T. H. "Introduction to Electronic Telephone Exchanges; Register-Translators", *P.O.E.E.J.* Vol. 43, p. 177.

pulse in it, but when a number is to be stored, each digit is coded into a pulse pattern consisting of a selection of two out of a group of five pulse positions and injected into the line at point A. A master pulse supply generating a repeated cycle of 200 pulses at 1 μS intervals is provided to control the system. These pulses are numbered p_1 to p_{200}, and for the purposes of this text the 1 μS time interval during which a particular pulse p_n occurs is called "cycle time p_n."

The circulating path may be represented by a ring (Fig. 3) divided into 200 equal divisions. These divisions

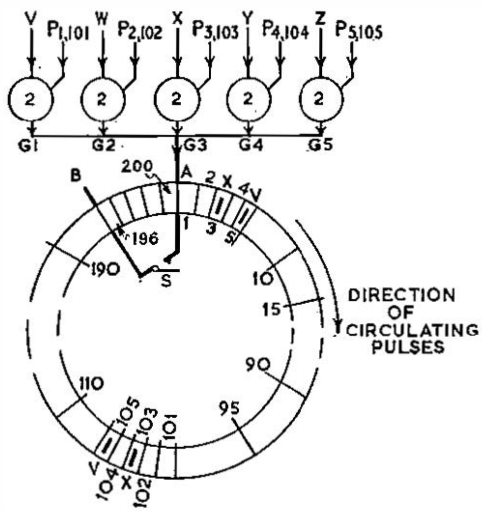

FIG. 3.—INCOMING DIGIT STORAGE.

(1-200) represent the positions successively occupied by any pulses circulating in the system, and the division numbers, of which only a few are shown, indicate the time in microseconds that must elapse before a pulse entering the system at A occupies the division in question; thus, a pulse entering at time p_n appears at B at the time $p_n + 195$. Access to the circulating system for the purpose of reading the circulating pulses is restricted to points A and B. As there is no delay except in the delay lines themselves, then for timing purposes point A (Fig. 3) consists in Fig. 2 of the whole of the path connecting the output of E to the input of D, including switches O and T.

Due to the time relationship between the master pulse supply and the register cycle divisions, and because information is always put into the delay system at point A, it is possible to predict the times at which pulses will pass points A or B, or when pulses will be circulating in E. It is, therefore, possible to arrange switching at points O or T to occur when no pulses are passing through the external circuit. Also it can be arranged to short-circuit E by switch S at a time when no pulses are circulating in E. The functions of the switches O, T and S will be referred to later.

OUTLINE OF CIRCUIT OPERATION

Description of Symbols Used.

Certain of the conventions used in Figs. 3–6 may require some explanation. The two basic symbols, the circle and the double square, represent respectively the gate and the trigger.

A gate is a switching element having any number of controls or inputs and any number of outputs, the inputs and outputs being distinguished from each other by the direction of the arrows shown on the connecting leads.

When a gate is shown with an inscribed numeral the numeral indicates the least number of inputs which must be simultaneously in the operated condition for the gate to give an output. Thus, if one of the input leads carries a pulse the gate can only give a pulse output. When a gate is drawn without an inscribed numeral it will give an output when any one of its inputs is in the operated condition.

A trigger is a locking switch having two stable positions, each position being represented by a square "box." Each box is shown with a separate input lead, and if either lead carries an operate condition an output is given on the lead, if any, drawn on the other side of the box. A trigger has the property that it will continue to give an output condition after the original operating condition has been removed. To change over or restore the trigger an operate condition must be received on the input to the second box.

Triggers and gates are assumed to have no operate or release lags. The conventions shown are logical symbols and do not specify the type of circuit to be used.

Some of the conventions are shown having input leads terminating in a small circle. Such leads are known as "inhibiting" or reset leads. An operate input on such leads always overrides the conditions on any other lead connected to the switch concerned.

Incoming Digit Distribution.

Each digit received by the register is coded to mark two of the five wires V, W, X, Y and Z (Fig. 3), and any decimal digit requiring to be stored appears as a D.C. potential on two of the five gates G1 to G5. (There are just 10 combinations of five things taken two at a time.) Each gate is connected to a pair of pulses from the master control, and, providing a gate is also marked by D.C., it will pass pulses to the input of the delay line at the times indicated by the control pulses. Thus, if gates G1 and G3 are marked by the incoming digit, pulses will be put into the delay line during cycle times p_1, p_{101}, p_3 and p_{103}. At the end of cycle time p_5 the pulses will be circulating in the delay line in the positions marked V and X.

Each digit is allocated two out of five pulse positions and each digit is stored twice. The D.C. marking conditions relating to a particular incoming digit are removed after a brief period, but as long as the D.C. marking conditions persist any marked digit will continue to be pulsed into the delay line twice in every time-cycle of 200 μS.

There is only one input to the circulating system and it is necessary to arrange that new information relating to further incoming digits is not allowed to occupy the same register cycle divisions as the old. To effect this without the use of an incoming distributor it is arranged that, as soon as a digit has been stored and the D.C. marking conditions to gates G1-5 have been removed, the pulses circulating in the delay line are advanced by five register cycle divisions. This process is known as "shifting" and operates in the following manner. At point B (Fig. 2) a shift detector, SD, is allowed to operate between cycle times p_{196} and p_{200}; during this time any pulses originally put into line D between cycle times p_1 and p_5 will pass point B. If SD detects the presence of any such pulse it notes the fact and, at some point in the next 200 μS time-cycle, operates S to short-circuit the electrical delay line E. It is arranged that E remains short-circuited for a time just less than one complete cycle. During the time that E is short-circuited the total length of the circulating system is reduced from 200 to 195 μS and the circulating pulses will take only 195 μS to pass through the complete system. Hence, in one cycle of 200 μS the stored pulses will be advanced in space by five register cycle divisions. Thus, Fig. 3 not only represents the position of the pulses corresponding to digit VX at the end of cycle-time p_5 before the shift, but also represents the position of the same pulses at the beginning of cycle time p_1 after the shift has taken place.

The shifting process occurs after the receipt of every incoming digit. Fig. 4 shows the divisions occupied by a seven-digit number at cycle time p_1 after the seventh digit has been received and shifted, the two appearances of the

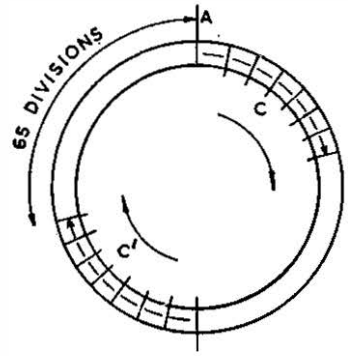

Fig. 4.—Position of Pulses of a Seven-Digit Code at Cycle Time p_1.

number being indicated by C and C′. During cycle time p_{66} the first digit of group C′ will be passing point A, and from cycle time p_{66} to p_{100} inclusive the whole of the information in group C′ will have passed point A. On the assumption that the codes requiring translation will never exceed seven digits in length, then, if stored codes are continuously examined at point A for the period p_{66}-p_{100}, no code of seven digits or less will be overlooked.

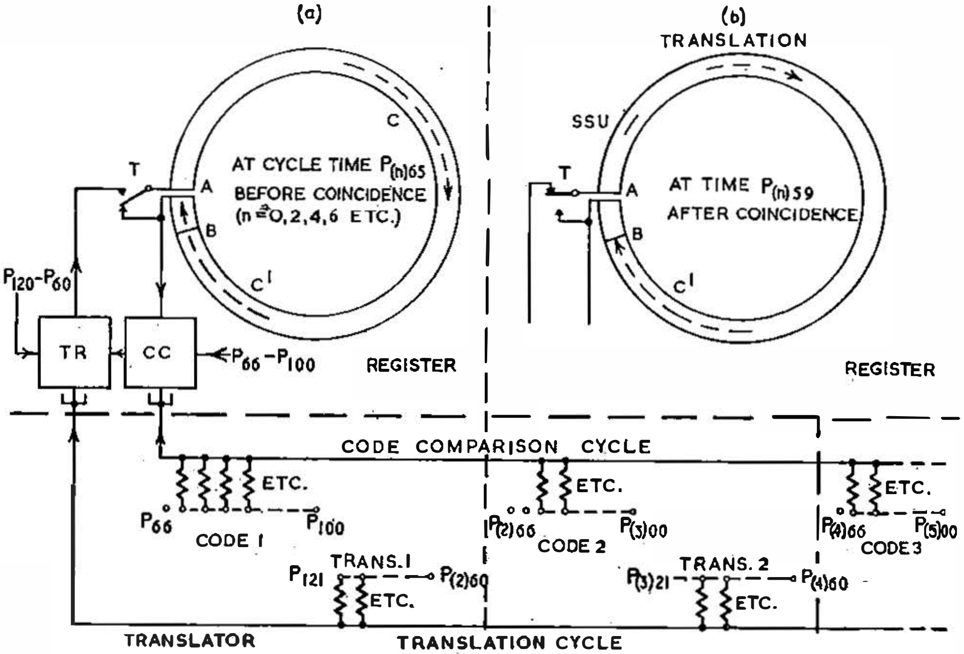

Fig. 5.—Code Comparison and Translation.

Referring to Fig. 2, the stored pulses passing from A into D are continuously offered to a comparator CC. The other side of the comparator is connected to an output from the translator on which appears, in coded pulse form, the codes for which a translation is provided. CC is only operative from cycle times p_{66} to p_{100} and its circuit arrangements are such that only if the codes on its two inputs remain identical throughout this period will device TR operate later to enable a coded translation to be put into the delay line via switch T.

The Translator.

The translator is common to as many registers as may be desired and its operation may be followed by reference to Fig. 5. Two pulse-cycles are provided in the translator, the code comparison and the translation cycle. Each cycle consists of a selection of 1 μS pulses in a pulse train 20 mS long, the pulse trains being synchronised with the pulses controlling the registers. The code comparison portion of the translator is equipped with groups of terminals, the first set of which is joined to pulses p_{66}-p_{100}, the second to pulses p_{266}-p_{300}, the third to pulses p_{466}-p_{500}, and so on, each group of terminals being allotted to a different code. The pulse terminals corresponding to the codes are connected by decoupling elements to a common output to the comparator circuits in all the registers. In every register the comparator CC is operative to the pulse series p_{66} to p_{100}. Fig. 5(*a*) shows a stored code C′ at cycle time p_{65}; the pulses corresponding to the code are about to pass point A and the input to the comparator. At the end of cycle time p_{100} the code C′ will have passed point A. Between the two times, pulses from the translator terminals in the code 1 terminal group which are connected to the code comparison common will have appeared one at a time at the other input to the comparators. Only if the translator code corresponds in every pulse position with C′ will CC permit the device TR to operate; otherwise the circuit waits until time p_{66} in the next cycle, i.e., time p_{266} from the point of view of the translator. From p_{266} to p_{300} the second set of code terminals is compared with the code C. This process continues until ultimately an identity is established, when TR permits T to operate and connect the input of the delay line to the output common of the translation cycle. This common is associated with groups of pulse terminals in the series p_{121}-p_{260}, p_{321}-p_{460}, and so on, each group being cross-connected to the common to give the pulses of the translation relating to the code immediately preceding it in time.

During the time that the translation is being put into the delay line, the delay line circuit is broken at T for 140 μS, during which time one appearance of the stored number, C, is lost. Fig. 5(*b*) shows the state of the circulating system at cycle time p_{59} just before T restores. One appearance of the original number dialled by the caller has been lost, but the other, C′, is still available for further code comparisons if required. A translation has been put into the half of the line originally occupied by C, although not necessarily in the same positions.

With this method of translation the number of codes examined in one translator cycle of 20 mS is 100. The number can be increased either by extending the length of the cycle or by increasing the number of cycles and giving each register a corresponding increase in the number of comparator circuits.

Sending.

As mentioned previously, the translation includes a special code called the start-setting-up (S.S.U.) signal. This signal may be put into the delay line in any position. Usually the translation will be so placed in the circulating system that any new digits dialled by the caller will queue up behind the translation proper, a sufficient gap being left between the translation and the S.S.U. signal to accommodate the portion of the dialled number not needing translation.

As each new digit is received the storage is shifted and further comparisons are made between the stored information and the translator so that the translation can be changed if necessary.

While this process is going on, a detector SS (Fig. 2) connects itself to the input of the delay line by the pulses occurring at cycle times p_{196}, p_{197} and p_{198}. The S.S.U. signal consists of the first three pulses out of a group of five register cycle divisions. Depending on its placing by the translator it will appear at the input of SS either immediately the translation has been received or at some later time depending on the shifting process due to further digits being dialled. When the signal is detected by SS at cycle times p_{196}-p_{198} it causes an output control to signal that sending may commence. When sending is about to commence two sets of information are circulating in the two halves of the delay line system. This is shown in Fig. 6. The first set consists of the translation (T) followed by the digits

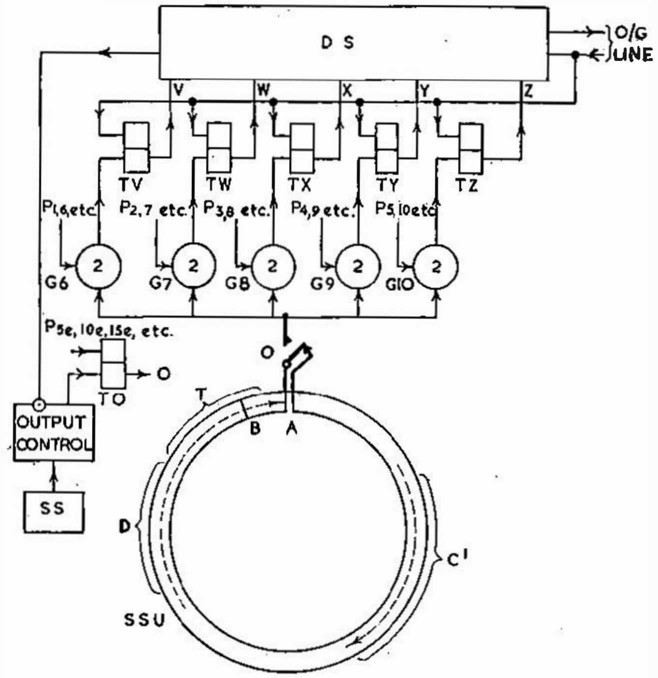

FIG. 6.—SENDING-OUT.

(D) dialled after the translation has been obtained, and the second consists of the complete dialled number (C′) unchanged. It is the first set which has to be sent out. This is done by causing switch O, Fig. 2, to operate under the control of SS at a time just prior to the time that the beginning of the longest translation will appear at point A. Fig. 6 shows this arrangement in more detail.

The output control operates a trigger device TO which in turn operates switch O. Because the stored digits are to be sent one at a time it is necessary to ensure that switch O will restore immediately after the cycle time corresponding to the last pulse position of any coded digit. Each digit occupies two divisions of a group of five and the last possible position for one of the two pulses of any stored digit will pass point A coincidentally with one of the pulse series p_5, p_{10}, p_{15}, etc. By deriving "end" pulses from this series it is possible to arrange that TO and consequently O, resets at these times and remains reset unless the output control is allowed to be operative. After the operation of O, the first pulse of the translation T will be passed to a set of five gates, G6, G7, G8, G9 and G10. Each gate is connected to a train of pulses, the pulses in each train being spaced at 5 μS intervals. Thus, G6 is connected to the pulse series p_1, p_6, p_{11} . . . . . p_{196}, G7 to pulses p_2, p_7, p_{12} . . . . . p_{197}, and so on. Hence a pulse emerging from the delay line will find one and only one of the gates marked, and will pass through the gate to operate one of the triggers TV, TW, TX, TY or TZ. In a similar manner the second pulse of the digit will be read off and stored. The triggers TV-TZ give outputs to a digit sender DS and when a digit is stored in DS an output from the sender inhibits the output control. Trigger TO is reset by one of the "end" pulses to release switch O before another digit can be sent.

The digit sender converts the stored digit into the signals required to set up the outgoing connection. These will usually be in the form of coded "two out of five" V.F. signals, but can, of course, be converted into any type of signal depending on the outgoing circuit. When V.F. signalling is used the coded signals remain on the line until an acknowledgment signal is received. This signal restores the triggers TV-TZ and resets DS which, in turn, frees the output control to enable the next digit to be sent.

MISCELLANEOUS FEATURES

The experimental equipment includes in its design other features which may be desirable in a national register-translator, such as the ability to distinguish the class of service from the incoming line termination and to provide, if necessary, different translations for different classes. The registers are equipped with V.F. receiving and sending equipment, and are capable of receiving either ordinary loop-disconnect dial pulses or coded V.F. signals, depending on the type of incoming line. Sending may be done by any desired means under the control of instructions from the translator, and high-speed V.F. signalling between registers is provided for. Built-in sequences under the joint control of the class of service and the translator instructions enable the set-up of the connections to be checked at various stages, a signal acknowledgment feature being built into the line signalling system.

It is intended that on outgoing junction calls the originating register shall not release until it has received a "backward prove" signal from the terminating register to indicate that the full complement of digits has been sent forward. This overcomes the difficulty of accurately locating the S.S.U. signal in the translation when the number of digits in the wanted subscriber's number cannot be known at the originating exchange. In such cases the signal is located in the translation in some position which will cause it to be detected after some convenient number of digits has been received, all digits subsequently received being transmitted as they come in.

The fact that the number dialled by the caller is stored, unchanged, in one-half of the delay line enables a "second trial" facility to be built into the register. If the first attempt to set up the call should fail or require the use of an alternative route, the stored number can be used to initiate a second attempt to set up the call; it can also be used for fault-indicating purposes.

CONCLUSIONS

Certain features of the universal register-translator call for further comment. The storage of large amounts of information by the use of pulse techniques is a feature of electronic switching which, when fully exploited, should lead to considerable economies. In the equipment described, the pulse storage takes two forms: permanent storage of the translations in which the memory is in the form of wire connections to pulse terminals; and the temporary storage of information in a circulating system. As pulse techniques develop and their reliability increases, it will be possible to use delay lines of greater capacity to realise still greater economies in the system as a whole. It is doubtful if dynamic storage is suitable for the storage of permanent information because if the information is changed or the slightest fault occurs the stored information must be re-written, and this is not easy. The method adopted in the universal translator obviates these difficulties and gives a form of translator which is most suitable when the time available to obtain a translation is very small.

ACKNOWLEDGMENTS

The design of the universal register is the work of a team of engineers at the Research Station and acknowledgments are due to its members for their assistance.

A Small Experimental Electronic Automatic Telephone Exchange

F. SCOWEN, B.Sc., A.Inst.P., A.M.I.E.E.†

Part 2.—Speech Path and Register-Marker Equipment.

U.D.C. 621.395.34:621.318.572:621.395.722

Part 2 of this series describes in some detail the t.d.m. equipment that forms the speech transmission paths through the exchange and explains the operation of the common control register-marker equipment.

Pulse Supplies.

THE pulse trains used in this exchange are four in number, but the capacity of the common transmission path is for 99 pulse trains. In a fully equipped exchange there would be 99 lines, each of which would have its own individual pulse supply. These individual pulse supplies are produced from only 20 sources of pulse supply, divided into two groups, one of nine and the other of 11 pulse supply sources. Each pulse supply source in the group of nine generates a pulse train of 9 microseconds pulse repetition time, and a pulse from the first pulse train, $p_{1/9}$, is followed 1 microsecond later by a pulse from the second pulse train, $p_{2/9}$, and 2 microseconds later by a pulse from the third pulse train, $p_{3/9}$, and so on. Each pulse supply source in the group of 11 generates a pulse train of 11 microseconds pulse repetition time and pulses from the first pulse train, $p_{1/11}$, the second pulse train, $p_{2/11}$, the third pulse train, $p_{3/11}$, and so on, follow each other at spacings of 1 microsecond. In Fig. 9 are shown two of the group of nine

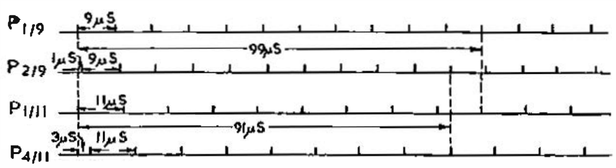

FIG. 9.—FOUR OF THE 20 PULSE TRAINS USED IN THE MODEL EXCHANGE.

pulse trains, $p_{1/9}$ and $p_{2/9}$, and two of the group of 11 pulse trains, $p_{1/11}$ and $p_{4/11}$. It will be seen from the figure that pulses in pulse train $p_{1/9}$ and in pulse train $p_{1/11}$ coincide once every 99 microseconds, and if those two pulse trains are connected to a coincidence gate which gives an output pulse only on the coincidence of a pulse from each pulse train, the output pulse train will have a pulse repetition time of 99 microseconds. If pulse trains $p_{2/9}$ and $p_{4/11}$ are connected to a similar coincidence gate the output will again have a pulse repetition time of 99 microseconds, but the pulses occur 91 microseconds after those of the pulse train produced at the output of the coincidence gate to which pulse trains $p_{1/9}$ and $p_{1/11}$ were applied. There are 99 ways in which one of the group of nine pulse sources can be combined in a coincidence gate with one of the group of 11 pulse sources, and each of the 99 combinations will give rise to a distinct pulse train of 99 microsecond pulse repetition time. Thus the 99 separate pulse trains can be generated by the use of 20 pulse generators and 99 coincidence gates. This method of pulse generation shows savings not only in the provision of pulse generators, but also in the simplification that results when this form of pulse generation is combined with the construction of master and slave selectors. In this model exchange the coincidence gates are built into the modulator and gate equipment connected to the subscribers' lines, and into the slave selectors.

Modulators, Gates, Demodulators and Common-Transmission Paths.

Fig. 10 shows the equipment used to provide a unidirectional t.d.m. transmission path through the switch; for example, from a subscriber's line to a cord circuit.

The pulse train used in the modulator shown in the figure is that which may be derived from the two pulse trains $p_{x/9}$ and $p_{y/11}$; these two pulse trains are connected to the modulator. When there are no pulses on the pulse leads the point X is at earth potential and the sum of the currents flowing through R2 and R3 is equal to the sum of the currents flowing through R1 and MR1. Equal currents flow in R2 and R3 and their series rectifiers MR2 and MR3 and the current in R1 is less than that flowing in R2 or R3. When a pulse is present on either of the two pulse leads the current through the corresponding rectifier MR2 or MR3 is reduced to zero, but point X remains at earth potential and current still flows through MR1. When coincident pulses are present on both pulse leads the currents in MR2 and MR3 are both reduced to zero and MR1 ceases to conduct. If capacitor C1 is uncharged the current through R1 flows into C1 which, however, has a capacitance sufficiently large for the potential of the point X to be sensibly unchanged during the duration of the coincident pulses (about 0·8 microsecond). If a positive hold signal of, say, 10V amplitude is applied to the terminal HOLD IN then, during coincidence between pulses from $p_{x/9}$ and $p_{y/11}$, MR4 will be so biased that the current through R1 will not charge capacitor C1. The current through R1 will then flow through MR6 and will charge the stray capacitance (C3) of the common transmission path, H_a. The potential of H_a will rise until it is equal to that of the upper plate of capacitor C2, after which the current from R1 will flow through MR5 to capacitor C2. The amplitude of the pulse generated on the common transmission path, H_a, is thus equal to the potential of the upper plate of capacitor C2. The potential of the upper plate of that capacitor is 4·5V plus the amplitude of the audio-frequency signal across capacitor C2 and resistor R5 at the time of the coincidence of the pulses from pulse trains $p_{x/9}$ and $p_{y/11}$. Thus the pulses at point X will have a pulse repetition time of 99 microseconds and, when a hold signal is present, will have an amplitude of 4·5V plus the instantaneous amplitude of the audio-frequency signal across the secondary winding of the transformer. Up to 99 similar modulators, each with its individual combination of 9- and 11-phase pulse supplies, may be connected to the common highway, H_a, each being connected to H_a through a decoupling rectifier, MR6.

Once every microsecond a discharging pulse is applied to the junction between MR8 and R8. It appears during the time interval separating successive 9- or 11-phase pulses and discharges the highway capacitance; rectifier MR7 prevents the potential of the highway H_a from dropping below earth potential. If the discharge pulse were not applied some of the charge on the highway from one communication pulse would remain and would be present on the highway during the time the highway is being used by another subscriber, so causing inter-channel cross-talk.

Valve V1 is connected as a cathode follower and transfers the amplitude modulated pulse trains from highway H_a to the inhibiting gate which precedes valve V3. The gate is similar to that used in the modulator; the opening pulse, which appears every microsecond, lasts for 0·3 microsecond and the pulses on highway H_a' are equal in amplitude to those on the highway H_a, but they appear on highway H_a'

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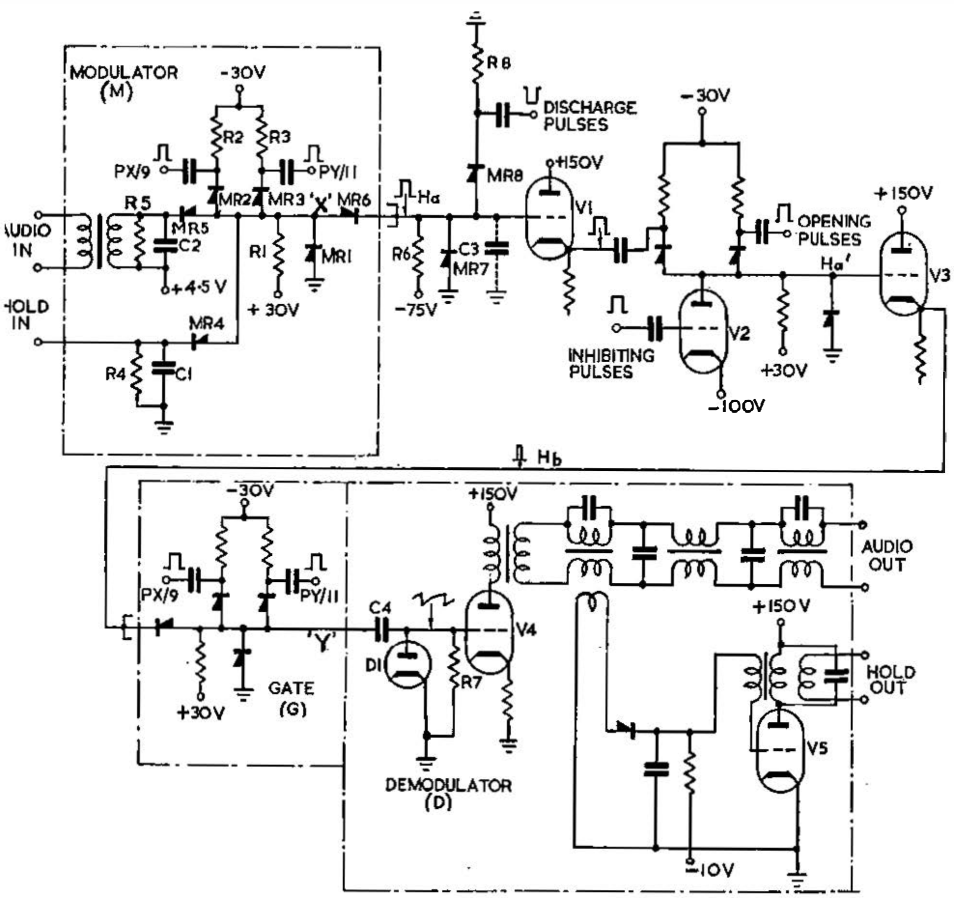

Fig. 10.—Unidirectional T.D.M. Transmission Path Through the Switch.

only during the periods that the opening pulses are present. Valve V2 has its grid biased beyond cut-off and normally no anode current flows. If a positive-going pulse is applied to its grid, anode current flows and prevents the potential of highway H_a' from rising during the presence of the pulse. This valve performs the inhibiting functions of gates G1 and G2 in Fig. 6—see Part I[1].) It is essential that an inhibiting pulse should overlie the pulse it is to inhibit; it is for this reason that the highway pulses are first limited in duration to 0·3 microsecond before they are presented to the inhibiting gate. Valve V3 is a cathode follower which conveys the signals on highway H_a' to highway H_b.

To highway H_b are connected the receive gates, one of which is shown in the figure. It operates in a way similar to that of the other gates, and, when a pulse of pulse train $p_{x/9}$ coincides with one from pulse train $p_{y/11}$, the potential of lead Y rises to the instantaneous potential of highway H_b. If there is a pulse at the instant of coincidence, the pulse on the highway in effect passes through the gate to lead Y. These pulses, through diode D1, charge the right-hand plate of capacitor C4 negatively and between successive pulses the charge leaks away through resistor R7. Thus the potential on the grid of valve V4 follows a saw-tooth wave-form whose amplitude is equal to that of the pulses on highway H_b that were generated by the modulator that is supplied with pulse trains $p_{x/9}$ and $p_{y/11}$. This saw-tooth wave-form has a larger modulation frequency component than has the pulse train on the highway and the use of the capacitor, diode and resistor enables a lower-voltage-gain amplifier to be used. The amplification is provided by valve V4 which is followed by a low-pass filter. The filter has a cut-off frequency of about 5 kc/s and the first half-section provides a peak of attenuation at 10 kc/s, the pulse repetition frequency. There is a substantial component at this frequency in the amplified saw-tooth signal and that component is taken from the tuned circuit in the low-pass filter, rectified and used to bias an oscillator to its operating state. The oscillator oscillates only when the 10kc/s signal is present, and that signal is present only when the pulse train formed by coincidence of pulse trains $p_{x/9}$ and $p_{y/11}$ is on highway H_b; this pulse train is, in its turn, only present so long as a hold signal is present at the modulator. Thus the hold signal presented at HOLD IN appears at the HOLD OUT terminals (as an A.C. signal) of the demodulator whose gate lets through the pulse train used by the modulator. The A.C. "hold out" signal can, of course, be rectified where necessary to provide another "hold in" D.C. signal.

The loss from AUDIO IN to AUDIO OUT is sensibly flat from 300 to 4,000 c/s and the harmonic distortion is so small that some 20 or 30 stages of modulation and demodulation in tandem could be used without the total distortion becoming greater than could be tolerated for commercial speech.

Master and Slave Selectors.

The master and slave selectors combinations have to perform two functions. One is the selection and identification of one pulse from a number of pulse trains that may be present on a lead and the other is the memorising of a selected pulse train. The first function is employed only when a connection is first set up whereas the second is employed during the time a connection is in being. It is, therefore, worth while to divide these two functions between two types of equipment and the master selector is designed to perform the first function and the slave selector the second.

The master selectors have to isolate one pulse from a set of interlaced pulse trains and then have to discover the 9- and the 11-phase pulse trains from which the pulse has been generated. The isolation is performed by a blocking oscillator. Such an oscillator can be constructed to remain quiescent until a pulse is applied, when it immediately generates a pulse and blocks itself for a period from operating to a further pulse.

Fig. 11 is a block schematic diagram of a master selector and one of its associated slave selectors. The first pulse that arrives at the blocking oscillator causes it to operate and produce a pulse on its output lead; the oscillator then blocks itself and remains blocked and incapable of generating another pulse for about 150 microseconds. The output pulse lags behind the input pulse and is further delayed in delay unit T so that the pulse leaving that delay unit is delayed 1 microsecond behind the pulse that fired the blocking oscillator. This isolated pulse is now presented to 20 gates, each controlled by its own 9- or 11-phase pulse. If the isolated pulse was from the pulse train $p_{1/99}$ originally generated by coincidence between pulse trains $p_{1/9}$ and $p_{1/11}$, the delayed pulse will coincide with one pulse from each of the pulse trains $p_{2/9}$ and $p_{2/11}$, and the isolated and delayed pulse will find open the two gates that are controlled by pulse trains $p_{2/9}$ and $p_{2/11}$; the pulse will pass through

[1] Vol. 47, p. 3.

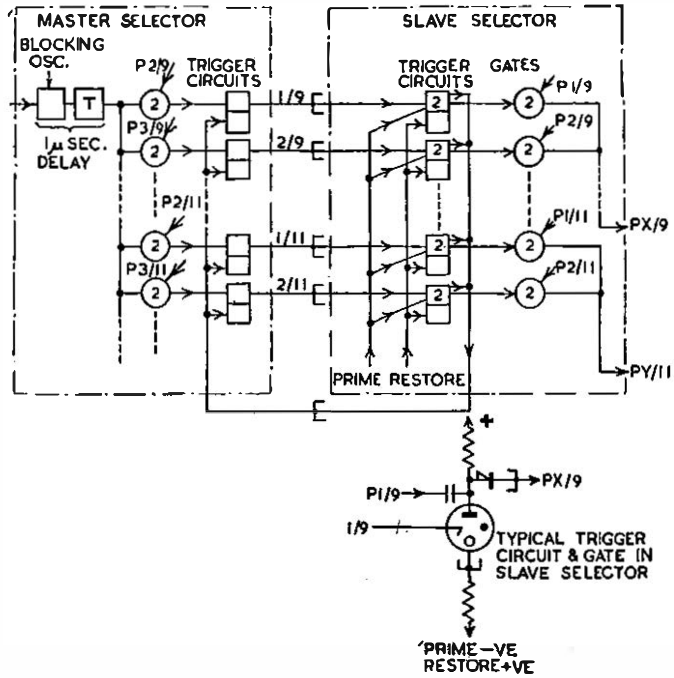

FIG. 11.—MASTER AND SLAVE SELECTORS.

those two gates to operate the two trigger circuits to which those gates are connected. The outputs from these trigger circuits put marking signals on to a pair out of 20 marker leads; in the example quoted, the marking is put on leads 1/9 and 1/11.

The 20 marker leads are multipled to all of a master selector's slave selectors. In a slave selector each lead is connected to a trigger circuit and to each trigger circuit is also connected a priming lead. A trigger circuit will operate only when its marker and priming leads are simultaneously stimulated. It is arranged that the priming leads of only one slave selector are stimulated at a time and the identification of the isolated pulse is transferred from the master selector, over two of the 20 marker leads, to the primed slave selector and the identification of the pulse is stored in the two operated trigger circuits in the slave selector. A signal from the slave selector on the operation of its two trigger circuits is transmitted back to the master selector to restore its two operated trigger circuits and the master selector is ready, as soon as its blocking oscillator has unblocked, to select and identify another pulse. It is arranged that, when a slave selector has stored the identification of a pulse in its trigger circuit, no more priming signals are sent to it until the stored information has been cleared. Each trigger circuit in a slave selector controls a gate and each gate controls one of the 9- or 11-phase pulses. Thus if, as before, the master selector isolated and identified a pulse from the pulse train $p_{1/99}$ formed by coincidence between the pulse trains $p_{1/9}$ and $p_{1/11}$, marking signals would be put on to the marker leads 1/9 and 1/11, and in the primed slave selector the corresponding trigger circuits would have been operated; these trigger circuits would have opened the gate circuits that controlled the pulse trains $p_{1/9}$ and $p_{1/11}$, and those pulses would appear on the pulse leads $p_{x/9}$ and $p_{y/11}$. Those pulses would be present on those leads until the slave selector was restored by the appearance of a restoring signal on the restore lead. The restoring signal is generated when the hold signal on the slave selector's associated trunk disappears.

Register-Marker.

Fig. 12 is a block schematic diagram of the register-marker. The register transmits dial tone to the calling line, receives and counts the dial pulses of the called line's number, transmits N.U. or busy tone to the calling line if the called line is non-existent or busy and transmits ringing control signal forward to the called line if it is free In the register there are devices that perform functions similar to those of the familiar A, B and C relays in existing step-by-step automatic equipment

When a calling line is connected to the register-marker (see Part 1) the calling line's hold signal appears on lead 1 in the register-marker and unit A operates. Unit A has two outputs; one through end-delay unit ED causes unit B to operate, and the other is connected to trigger circuit TG1 and through start-delay unit SD1 to unit C. When unit B operates it does four things:—

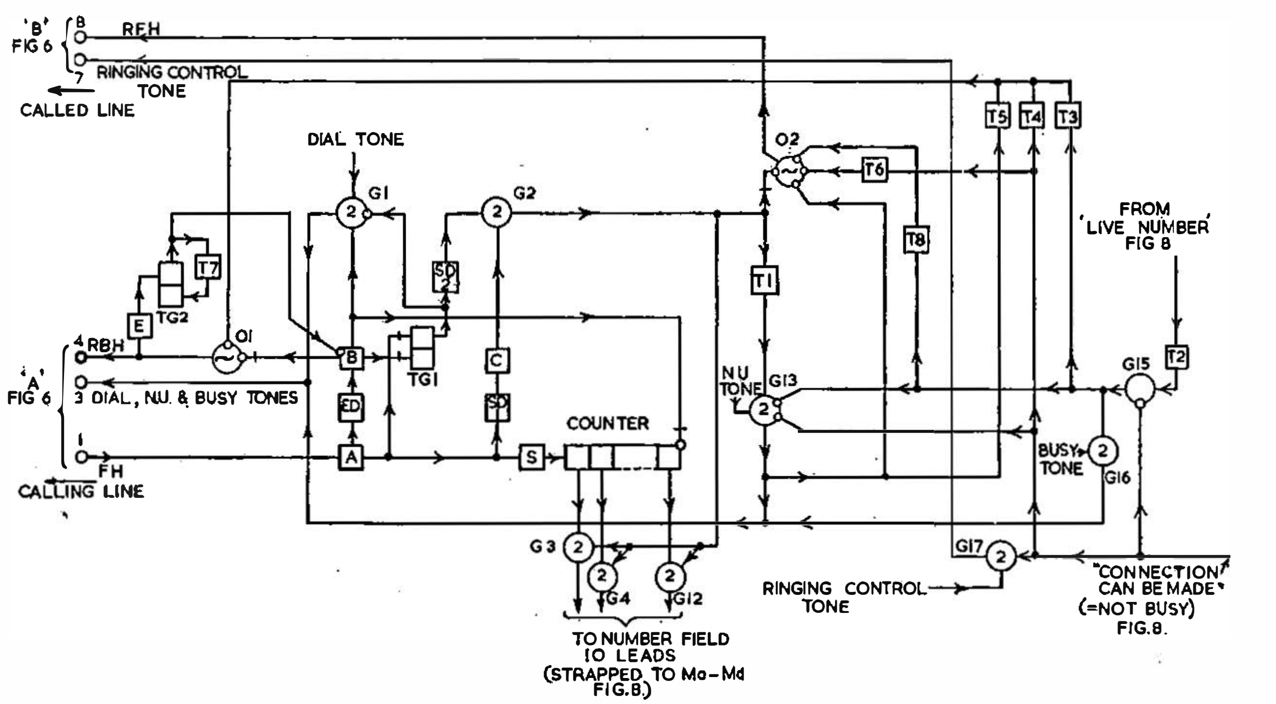

FIG. 12.—BLOCK SCHEMATIC DIAGRAM OF REGISTER-MARKER. (Note. Figs. 6 and 8 are in Part 1., see Vol. 47, pp. 3 and 4.)

(i) It permits oscillator O1 to oscillate and to feed a signal to lead 4 and back towards the calling line; this is a register-backward-hold signal which prevents the breakdown of the connection between calling line and register-marker during dialling.

(ii) It opens gate G1 and allows dial tone to be transmitted over circuit 3 towards the calling line.

(iii) It prepares trigger circuit TG1 to operate to the first dial pulse.

(iv) It prepares the counter to receive and store the dial pulses. When the single digit number of the called line is dialled, unit A restores during each dial pulse and the outputs from the unit disappear during each pulse. End-delay unit ED maintains the signal from A during the pulses so that unit B remains operated during dialling. The first pulse from unit A operates the trigger circuit TG1 whose output closes gate G1 and cuts off dial tone, and the train of pulses sets the counter so that, at the end of the pulse train, the counter is in a state corresponding to the number of pulses in the train and, therefore, to the called line's number. At the first pulse unit C restores, and because of the start-delay of unit SD, unit C does not again operate until after the last pulse has been received. When, after the receipt of the dial pulse-train, unit C does re-operate, its output opens gate G2 and allows a signal from the operated trigger circuit TG1 to open the 10 gates G3-G12 so connecting the 10 outputs from the counter to the marking equipment of the register-marker. The counter output lead that corresponds to the called line's number will have a marking signal on it and that marking signal is transmitted through the open gate to the number field so marking one of the 10 points in that field. The output from unit C also allows oscillator O2 to operate and to generate and transmit a register-forward-hold signal over lead 8 on the B-side of the register-marker. Also, after a time delay T1 and unless prevented as described later, the output from unit C opens gate G13 to transmit number-unobtainable tone over circuit 3 to the calling line. The marker leads (Fig. **8**, M_a-M_d—see Part 1) of the four lines may be connected to any of the 10 points in the number field and, if such a connection has been made for the number that has been dialled, a signal from pulse lengthener A (Fig. **8**) will be transmitted to the live number lead of the register-marker (Fig. **12**). In that event gate G13 will close before the signal from unit C, delayed by delay unit T1, reaches it and hence number-unobtainable tone will not be transmitted to the calling line.

If the dialled number is that of a live line and there is a free cord circuit, a signal will appear at the output of one or other of the pulse lengtheners E, F of Fig. **8**. The appearance of a signal at either of those two outputs indicates that the connection can be completed and the signal is transmitted to the CONNECTION-CAN-BE-MADE lead in the register-marker. The live number signal is delayed by delay unit T2 and after that unit's delay, and if not prevented by gate G15, opens gate G16 to allow busy tone to be sent to the calling line. If, however, the connection can be made, the signal to that effect prevents the delayed live number signal from opening gate G16, the delay introduced by T2 being greater than the time taken to mark the called line, select a free cord circuit and send a connection-can-be-made signal to the register-marker. The connection-can-be-made signal also opens gate G17 to allow ringing-control tone to be transmitted to the called line, over which ringing current is sent in response to the tone.

The output signals from unit C and from trigger circuit TG1 make oscillator O2 oscillate and its output is sent forward over the hold wire to the called line. Some milliseconds after the live number or the connection-can-be-made signal has been received, oscillators O1 and O2 are inhibited and register forward- and backward-hold signals disappear. The register-marker then drops out of the connection and becomes free for connection to another calling line.

(To be continued.)

Book Reviews

"Soft Magnetic Materials for Telecommunications." Edited by C. E. Richards and A. C. Lynch. Pergamon Press, Ltd., London. 346 pp. 184 ill. 63s.

A symposium was held at the Post Office Research Station (Dollis Hill) in April, 1952, on Soft Magnetic Materials; the 35 papers presented there, together with some of the ensuing discussion, are now collected together in this book. The authors of the papers include many of the leading European workers in ferromagnetism and their subjects are, in the main, current researches.

A fair balance is achieved between the different approaches to the subject: those of the theoretical physicist wishing to understand the many finer points and attributing mechanisms to them; of the experimental physicist devising crucial experiments and new means of measurement; of the chemist and metallurgist preparing the soft magnetic materials in powder and strip form; and the engineer assessing the relative importance of the effects in his applications. Undue elaboration of points is commendably avoided. Judging from the book, the general state of the subject would seem to be that many measurements remain to be made on present-day materials, that theory lags in explaining many of the accepted data, that the engineer is sometimes hard pressed to express the properties in forms suitable to his use, but that there is no reason to believe that new and better magnetic materials will not be produced long before all these defects are remedied. The differences of opinion and overlapping which exist here and there between papers is no detriment to the book. But the criteria used for deciding the order of the papers seem obscure: the general reader could have been helped by a definite grouping of the papers, with, admittedly, a rather large "miscellaneous" group, or by a paragraph or two in the introduction, advising him of the order in which he should read the papers as already laid out. For, while the book is primarily one for the specialist and, perhaps, particularly for the new worker in the field of ferromagnetism, both of whom can hardly fail to be stimulated by it, the non-specialist should not pass it by.

The index is good, helping to show connections between papers, but some authors have forgotten that the general reader likes to see definitions of the newer technical terms, and even some of the older ones, when he meets them. The translations have been well made, and the many illustrations and tables of results are very informative. Indeed, the whole presentation is in keeping with the high standing the book is likely to achieve in the next few years, that is, until new discoveries, materials and techniques displace its subject matter. The price is a little high.

I.P.O.E.E. Library No. 2170. J. R. T.

"The Properties of Tin." The Tin Research Institute. 55 pp. 2s. 6d.

This booklet, which was first published in 1934, has been revised and rearranged by C. J. Faulkner and constitutes a comprehensive reference work on the properties of tin. The data given generally refer to tin of 99·99 per cent. purity and where appropriate, values are given for white grey and liquid tin. The various values have been selected from works by acknowledged authorities and references are quoted. The booklet therefore provides a useful bibliography of works in special fields of tin physics.

N. F. S.

Multiple Access Telephone Equipment for Repeater Stations

A. S. THOMAS†

U.D.C. 621.395.724:621.395.623.8

In a large repeater station the number of speaker circuits required for use during maintenance and construction operations has necessitated their termination on an operator-attended speaker rack. Some of the disadvantages of this arrangement have been overcome in a trial installation at Bristol repeater station in which provision has been made for multiple access to speaker circuits from a number of convenient points within the station. The author describes the equipment giving this facility and comments on the experience gained in its use.

Introduction.

To enable construction and maintenance work on long-distance circuits to be performed satisfactorily a network of speaker circuits is required for the use of repeater station staffs. At the larger stations serving many routes and employing groups of staff on separate and distinct duties, the speedy distribution of speaker traffic may present difficulties. With the normal arrangement of terminating such circuits on a speaker rack attended by an operator, incoming calls must be connected over an extension circuit to the officer concerned, possibly at the remote end of the station or in another room; even then, the call may be answered by an officer engaged on some duty other than that which concerns the caller, in which case shouted instructions may have to be resorted to.

With this difficulty in mind the South-Western Region suggested, at a "Headquarters Conference on Maintenance of Repeatered Circuits" held in 1947, that certain changes in practice should be introduced; and, in particular, that arrangements should be made to give multiple access to speaker circuits on panels mounted at various points throughout a repeater station, with a means of indicating the called party required. This proposal appeared to have many advantages apart from removing the need for a speaker rack operator, and it was agreed that a field trial should be carried out in Bristol "A" repeater station.

Equipment for this purpose—now known as "Multiple Access Telephone Equipment"—was in fact tried out in a simple form after Swindon "B" repeater station had been burnt out in 1949. On this occasion service at Swindon was restored by the installation of four mobile repeater stations, and the Multiple Access Telephone Equipment (M.A.T.E.) proved quite satisfactory; valuable experience was then gained which helped to determine a suitable design for the main field-trial installation at Bristol.

Facilities Provided.

The main facilities provided by the M.A.T.E. are as follows:—

(1) Calls can be originated or received at any access point.
(2) Access panels provide for visual and tone (or bell) calling signals; and for visual engaged signals.
(3) Exchange lines and any type of speaker circuit may be connected to an access-panel key position.
(4) "Call-in" facility to attract the attention of a wanted officer from any access point.
(5) Several officers can simultaneously obtain connection to speaker circuits, via local battery telephone switchboxes, by sharing an access position.
(6) Circuit conditions provide different calling tones to indicate the officer required to answer a particular call; the tones are broadcast over a loudspeaker system.

Outline of Equipment and Operation.

The main units comprising the M.A.T.E. are the access panel (each accommodating 20 speaker circuits) and the telephone panel serving one or more access panels. These circuits, constructed from stock items, are normally rack-mounted, but where this is not practicable a suitable wall-mounting is used. Switchboxes to give sharing facilities at access positions are connected by jumpers to a connection strip at the rear of the access panel, and a Yaxley switch incorporated in the switchbox permits the choice of any of 12 speaker circuits.

A typical circuit termination for the M.A.T.E. is shown in Fig. 1, from which it will be seen that an incoming

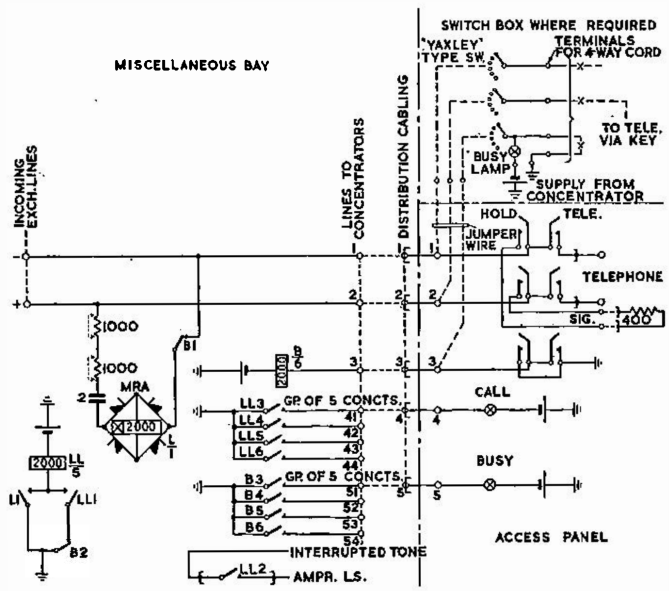

Fig. 1.—Typical Circuit Termination at M.A.T.E.

call operates relay LL via L1 and lights the associated lamps at each access position. An interrupted tone of frequency appropriate to the circuit in use is simultaneously connected to the station loudspeaker via LL2 and the required officer answers the call at the nearest access panel.

"Call-in" facilities (not shown) are provided on the telephone panel so that another officer may be brought to the telephone if necessary, by broadcasting an announcement.

Outgoing calls can be originated from any access panel.

The UP side and the DOWN side of a through 4-wire circuit at an intermediate station would each take a separate access-key position. The keys would be adjacent and slight wiring changes in the access panels have to be made. When either of these access keys is operated, a hybrid transformer terminates the required 4-wire section, speech and signalling then being as at a terminal station.

Equipment Details.

Access Panels.—Fig. 2 shows the face of the access and telephone panels. A label strip runs along the top edge of each access panel, and immediately beneath this is a row of lamps with green opals to show the circuits which are in use. Below these lamps is, firstly, a row of calling lamps,

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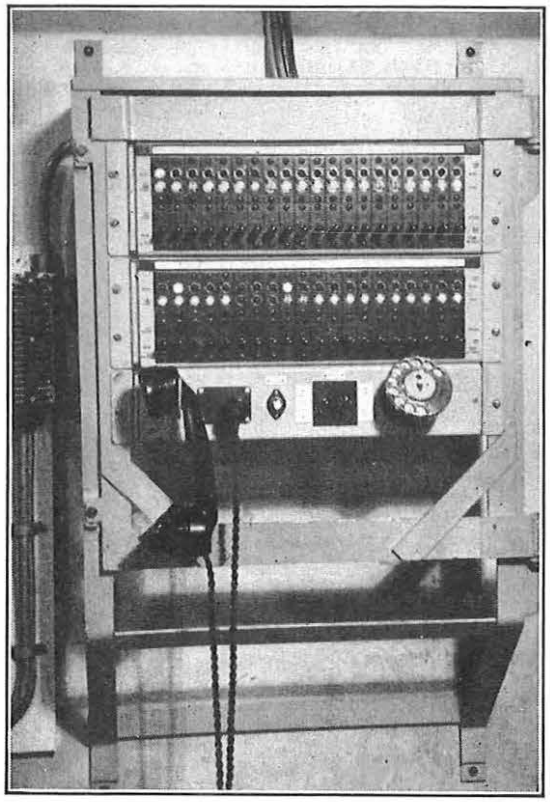


FIG. 2.—WALL-MOUNTED ACCESS AND TELEPHONE PANELS.

whose opals are so marked or coloured that an indication is given as to which section of the staff is wanted, and, secondly, a row of keys. This arrangement allows the operator to observe quickly which key has to be operated when answering a call, the designation of the circuit being subsequently given by the glowing of the BUSY lamp. The opals used for calling lamps at Bristol are white for audio-maintenance circuits, white with a black bar for H.F. system maintenance and red for Works Order duty circuits.

Locking keys have been used so that ringing or hold facilities can be given on any key position. The calling frequency, other than 17 c/s, to be used on any circuit is selected by keys on the telephone panel.

Two connection strips are mounted on brackets at the rear of each panel case. One strip makes common to each key position (*a*) the 17 c/s supply, (*b*) the multi-frequency ringing supply channel from the telephone panel, and (*c*) the "hold" coil. It is also the terminal point for the SIGNALLING or HOLD wires from the keys. Thus, by suitable strapping, any one of conditions (*a*), (*b*) and (*c*) can be connected to a particular key. The other strip carries the five incoming circuit wires to each key, i.e., the transmission pair, the busying, calling-lamp and engaged-lamp wires.

Telephone Panel.—Mounted from left to right are (*a*) a telephone hook, (*b*) a jack for the handset telephone, (*c*) a press-button for switching the telephone to the loudspeaker system, (*d*) two keys for selecting the method of calling, and (*e*) a dial. Inside the case are the miscellaneous components used in the speaking circuit. A small connection strip for terminating the incoming supplies and the loudspeaker circuit is mounted on the rear outside face of the case.

Switchbox.—Fig. 3 shows two switchboxes, one open and the other closed. The front vertical face carries the Yaxley switch and an ENGAGED lamp. The remainder of the box is hinged to the top of the front face and on its top inclined surface is mounted a label holder for displaying the designations of the 12 selected circuits together with their switch positions.

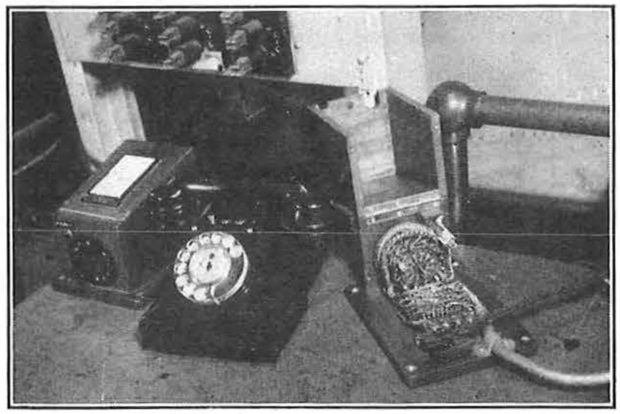


FIG. 3.—THE SWITCHBOXES.

The circuits with power-supply wires are cabled from a connection strip, to which they have been connected from the access panels, to a small connection strip on the base of the box. This latter strip also accommodates the wiring from the switch contacts. The telephone cord terminates in the box and is thence wired to the moving-arm terminals of the switch.

Local battery telephones are used in conjunction with the switchboxes so that speech is possible on "speaker" circuits. Each telephone is fitted with a locking press-button key which in its unoperated position isolates the telephone from the switchbox. Consequently, interference with busy circuits is avoided either when operating the Yaxley switch or when the handset might be accidentally removed. A free circuit having been selected by the switch, the key is depressed, so engaging the circuit and connecting the telephone to line.

Several of these boxes can be used at one access point. Calling, other than by dialling, has first to be done from the access panel.

Loudspeaker System.—A common amplifier for the loudspeakers would normally have been used, but at Bristol each loudspeaker has its own amplifier. Tones and speech are obtained from the 2-wire side of a hybrid transformer fed on one leg of the 4-wire side with calling signals when applied and on the other leg with speech from the "call-in" circuit. Two calling-signal tones of 300 c/s, for Works Order circuits, and 500 c/s, for maintenance circuits, are used, the tones being interrupted by the contacts of a relay energised by ½-sec. pulses.

Cabling and Racking.—Calling and miscellaneous equipments are cabled to the distribution frame in accordance with normal practice. Power supplies to access points are cabled direct from the fuse mountings on the relay and miscellaneous rack, the rear of the existing speaker racks being used to provide this miscellaneous rack.

Access panel multiple cabling is taken from the "local" side of the distribution frame along both sides of the station. The cable is run on the underside of existing runways, distribution points being teed-in at convenient intervals. The connection strips used for the distribution points are fixed to U-shaped mountings clipped to the runway bearers, and cabling is taken from these points to access and telephone panels as required. There are four such appearances along the south side and five along the north side of the repeater-apparatus room at Bristol, catering at present for nine access positions.

The lamp wires are limited to five distribution points to avoid overloading the relay contacts, i.e., calling- and engaged-lamp relay contacts each feed only five appearances.

Three loudspeaker-amplifiers cabled to the distribution frame are dispersed to advantage about the station.

Access and telephone panels are mounted at the most convenient points, and to achieve this three types of mounting are used: rack, table and wall. The table mounting is simply two "L"-shaped pieces of iron strapped together to form a frame, while the wall mounting is of gate construction to allow easy access to the rear of the panels (see Fig. 2).

Experience gained from the Field Trial.

The trial has shown that during full staffing periods no improvement results in the speed of answer, and during very busy periods there is a slight degradation due to the absence of an operator. Excessive delay is prevented by the officer-in-charge answering any call which does not receive attention within a reasonable time. During periods of light staffing, however, there is considerable improvement compared with the use of a speaker bay, the operator of which would not be in attendance at such times.

As regards effective co-operation, an improvement has been realised, as anticipated, and the "call-in" facility is much used, with the loudspeaker system adjusted to attract immediate attention but without being too obtrusive.

The time spent in originating calls has also been reduced. Prior to the field trial, delay was often encountered, resulting in the caller having to walk to the speaker rack to ascertain the reason. When a required circuit was engaged, the caller had either to rely on the operator calling him when the circuit was free and he was available, or make further attempts. The caller can now see at a glance when a circuit is free.

Conclusions.

One of the main advantages of the scheme has been the convenience of being able to answer calls at any point or room in the station. This is most advantageous during periods of short staffing and would be so at all times at any station which has not enjoyed the luxury of a speaker-rack operator.

Another great convenience is the facility of being able to maintain more than one call at a time, which is especially helpful at test-rack positions. Formerly, walks between the test and speaker racks became necessary to ensure co-operation in setting up a second call whilst still retaining an existing call.

While the trial equipment was in the design stage it was feared that an officer, when transferring from an access position to a more convenient one, would omit to restore the speak keys at the first position. This, however, has not been so in practice.

Interrupted calling-tone signals have been found to be quite effective; a call bell would have been discordant and would have caused confusion with alarm bells. It is preferable to keep the volume of the loudspeakers low to prevent disturbance in the working of the station and consequently it is essential that an adequate number of loudspeakers be provided.

Prior to the trial it was decided not to use 800 c/s tone for a calling signal as it was thought that its use might interfere with loudspeaker monitoring of circuits under test. However, during the trial it became desirable that the two maintenance groups of circuits should have individual calling tones. An 800 c/s tone has, therefore, been allotted to the H.F. maintenance group and 500 c/s is retained for the audio-maintenance group.

One difficulty encountered in designing the field equipment from standard components was the excessive current taken by the multipling of calling and engaged lamps. It is understood that this will be overcome in production models by the employment of neon lamps.

Acknowledgments.

The author wishes to record his appreciation of the encouragement given by Dr. N. W. J. Lewis and the co-operation of the Engineering and Factories Departments and colleagues in the South-Western Region.

Book Reviews

"Television Receiver Servicing, Volume 1: Time-base Circuits." E. A. W. Spreadbury. Iliffe. 310 pp., 167 ill. 21s.

How many readers of this journal have, at one time or another, been faced with the problem of finding faults in their own television receiver or, worse still, that of the man next door? At a guess the proportion is high and particularly so if the engineer concerned is in any way connected with the radio side of Post Office activities. To those who are liable to suffer in this way this book should come as a welcome relief for it deals, in a very practical way, with the servicing of television receivers. It is intended primarily for professional radio service engineers and assumes a fair knowledge of the techniques used in servicing sound receivers. Nevertheless it will prove very valuable to the experienced "amateur."

Symptom: Blank Screen is, appropriately enough, the title of the first chapter which goes on to analyse the possible causes of this symptom and shows how they can be investigated one by one in a logical sequence. Although more complex than a sound receiver, the television set has the saving grace that, once something can be seen on the screen, it does give a fair indication of the particular part of the set in which to look for the trouble. Subsequent chapters go on to describe how the various parts, the timebases, sync. separator, efficiency diode, E.H.T. supply, etc., can be tested and dealt with.

As the sub-title implies, the scope of the book is limited to those parts of the television receiver that are peculiar to television itself, i.e. the tube, timebases, etc., but a second volume is in preparation dealing with the other parts. The two volumes together will be almost indispensable to the service man new to the field of television servicing. To the "amateur" serviceman they will be extremely valuable and save him from exhibiting *symptom: blank face!*

T. K.

"Battery Chargers and Charging." Robert A. Harvey, B.Sc.(Eng.), A.M.I.E.E. Iliffe & Sons, Ltd. 400 pp., 284 ill. 35s.

This book deals with its subject in a logical order. There are chapters on the history of the secondary cell, its construction, the chemistry of charging, charging from D.C. and A.C. mains, after which the different applications of secondary cells are dealt with. Motor Vehicle, Electric Vehicle, Locomotive, Emergency Lighting, Telephone Exchanges and Repeater Stations, Marine, Railway, Mining, Aircraft and Country House Batteries each have a chapter dealing with their special requirements. Some 25 pages are devoted to Telephone Exchange and Repeater Station Batteries and while, of course, the whole of this subject cannot be compressed into this space, the author has given a very lucid account of Post Office systems and, which is equally important, the reasons for adopting them. Details of all commonly used charging equipment, motor generators, metal rectifiers, mercury arc and valves are given and the merits of each are considered. The treatment is descriptive rather than mathematical. The diagrams and illustrations are excellent, and the material is presented in a readable form.

The author obviously prefers rectifiers to motor generators but somewhat overstates the case for the former when he says (page 76) that with A.C. mains motor generators are used occasionally in an emergency when nothing else is available. In quoting the efficiency of mercury arc rectifiers (page 96) for 100 V D.C. output, the arc drop, which results in the efficiency falling rapidly as the output voltage is reduced, is not mentioned. The overspeed governor, which the author considers essential on D.C. to D.C. motor generators, is an unnecessary complication if the generator is self-excited, as so many of them are; they also operate without the lack of stability for which the author criticises them.

I.P.O.E.E. Library No. 2183. A. E. P.

Further Developments in Kiosk Trailers

J. J. MOFFATT, A.M.I.E.E., Assoc.I.Mech.E., and A. G. J. FAGG

U.D.C. 656.135:629.118.7:621.395.721.2

Trailers designed for lifting, transporting and placing on site telephone kiosks have been successfully employed in the field. In this article the authors refer to a number of improvements now introduced which include the fitting of spring-operated assistor gear to reduce manual effort to a minimum

Introduction.

THE earlier type of single kiosk trailer, described in this Journal,[1] confirmed the advantages expected to result from its use and hence justified the provision of an appreciably larger number for more widespread use at the centralised assembly points that have been set up.

Continual use of the earlier type indicated that a number of teething troubles existed. These were, however, of a relatively minor character and the trials confirmed that the method of approach to the problem of handling such fragile structures was sound in both theory and practice for all but exceptional conditions. Accordingly, the same principle of gripping, lifting and turning, and carrying has been retained but the method employed has been improved.

Fundamentally, the earlier type of kiosk trailer consisted of a pair of pneumatic-tyred road wheels which supported a framework including a pair of rotatable interconnected radius arms. An encircling clamp was mounted on the extremities of the radius arms for gripping a telephone kiosk above the position of its mass centre. The radius arms were fixed to a large diameter pulley sheave and were moved through an arc of approximately 120° by means of a wire rope passing around the sheave from a hand-operated worm winch. Double-purchase tackle was used to minimise the operating effort required. This method enabled a kiosk to be picked up in its vertical position, as assembled, and placed in an approximately horizontal position on the trailer simply by turning the operating handle. All points of contact between the trailer and kiosk were faced with rubber to prevent damage to the kiosk paintwork. A castor wheel was provided at the forward end and two steady posts at the rear.

Gripping the Kiosk.

During the course of the 12 months in the field, it became apparent that the rubber facing applied to the back bolster and clamping plate was not adequately robust and did not completely prevent movement of the kiosk in the clamping arrangement during the early stages of the lifting action. The transference of the wear to balata strips did little more than mitigate the problem. The clamping arrangement has therefore been modified and simplified to assist manufacture. The elimination of all resilient parts in the clamping members and the use of oak bearing blocks satisfactorily overcame the slipping problem.

After the trailer is placed around a kiosk prior to loading (Fig. 1), the radius arms are turned into the appropriate loading position. This is indicated when a white line on the nearside radius arm makes a continuous straight line with the white line on the casing enclosing the worm and gear. This position is of necessity a guide and is accurate only if the trailer and kiosk are standing on level ground and the trailer chassis is horizontal.

Lifting and Turning the Kiosk.

The larger number of trailers of the latest type that have been obtained, permitted the elimination of the wire ropes which frayed and stretched somewhat after continual use. The pair of rotatable interconnected radius arms are now secured to a segment of a gear wheel which is moved through approximately 120° by means of a worm wheel. To reduce the manual effort required to turn this worm gearing the driving shaft is chain-geared to the operating handle located at the front nearside of the trailer (Fig. 1).

FIG. 1.—PLACING THE TRAILER AROUND A KIOSK.

Assistor Gear.

The effort exerted by the operator of the earlier type of trailer when raising or lowering the kiosk varied appreciably according to the outreach of the centre of gravity of the kiosk from the pivoting point of the radius arms. In order to reduce the maximum effort required a system of assistor gear (Figs. 2 and 3) has been included in the later type.

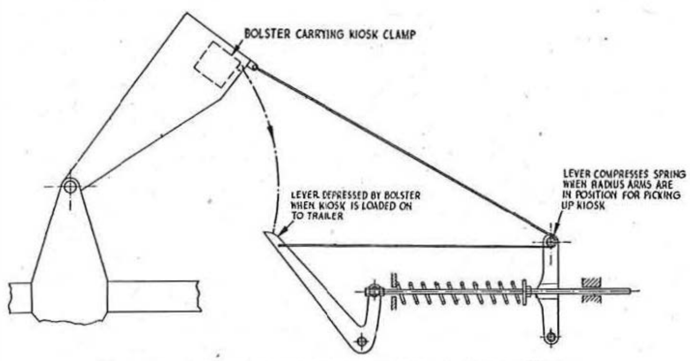


FIG. 2.—SCHEMATIC DIAGRAM OF ASSISTOR GEAR.

The assistor gear consists primarily of a strong spring mounted in the centre of the chassis. This spring is compressed by a lever when the bolster is farthest from the central vertical position and is moving downwards. The stored energy in the spring is utilised to assist the operator when the bolster is moving upwards with the kiosk. Similarly, when the radius arms are in the position for loading the kiosk, the spring is compressed by means of a second lever via a steel rope attached to the bolster. The energy stored in the spring then assists the operator in the initial lifting of the kiosk during loading and unloading. The extent of the assistance afforded to the operator by the gear is such as to reduce the manual effort by approximately 50 per cent. at those stages when the maximum effort is exerted.

[1] *P.O.E.E.J.*, Vol. 44, p. 112.

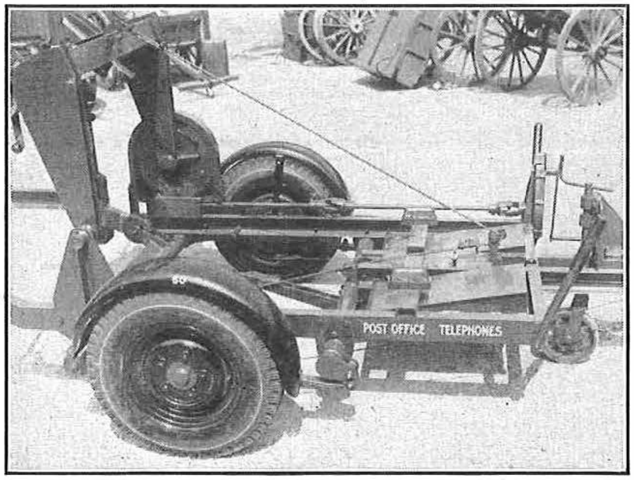


FIG. 3.—DETAIL OF TRAILER SHOWING ASSISTOR GEAR.

Travelling.

During the 12 months' trial period it became evident that a number of items, such as the rear steady posts, front castor wheel and wheel ramps, required strengthening to survive the treatment encountered under actual working conditions.

Due to variations in the height of towing connections on the vehicles used for towing it became apparent that there was insufficient clearance beneath the rear of the trailer when intersections of severe road cambers were met. In order to give greater clearance, the rear of the chassis has been swept upwards and the trip rollers raised slightly to raise the rear of the kiosk in the travelling position. The kiosk remains held in this position by the clamp and rests upon two rubber buffers at the forward end and upon the pair of rubber-faced trip rollers at the rear. Lowering the height of the front buffers has enabled the low centre of gravity of the original laden trailer to be retained (Fig. 4).

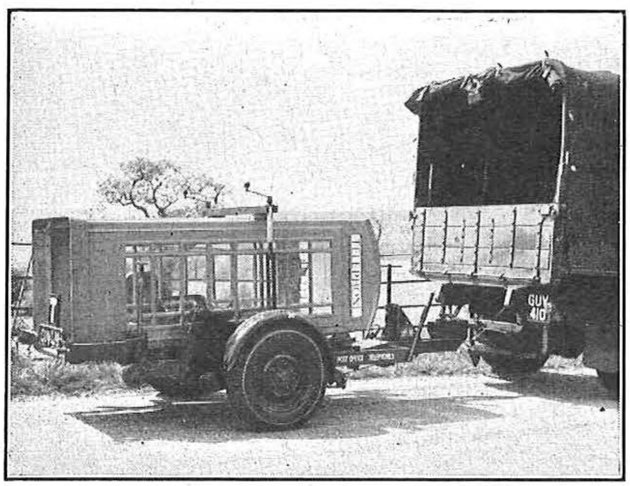


FIG. 4.—THE LOADED TRAILER ON TOW.

When the trailer is travelling unladen, the radius arms are wound down so that the bolster rests on the assistor lever with the two clamping arms clipped together. The clamping plate is stowed across the front of the chassis in such a way that one padlock will secure the clamping plate and the pair of wheel ramps.

As with the earlier type of trailer, the balance of the laden trailer about the road wheels is as nearly complete as practicable, consistent with the normal small downward load on the tow bar required from the road-towing aspect. Also, by the use of quarter elliptic springing and low centre of gravity, the smooth travelling has been retained.

Placing on Site.

The design of the trailer caters for the handling and carrying of a No. 6-type kiosk from any one of its four sides and it is desirable from the practical point of view to know, prior to loading, which way round the kiosk is to be placed on its working site or if any obstruction is to be avoided. Without this knowledge it may be necessary after arrival at the site to unload the kiosk and again pick it up from a more suitable side. Adjustment of the front castor wheel and rear steady posts is necessary to suit the variety of conditions met when placing a kiosk. To assist in this operation, a broad arrow is painted on the nearside of the chassis in line with the position taken by the front edge of the kiosk when placed down (Fig. 5).

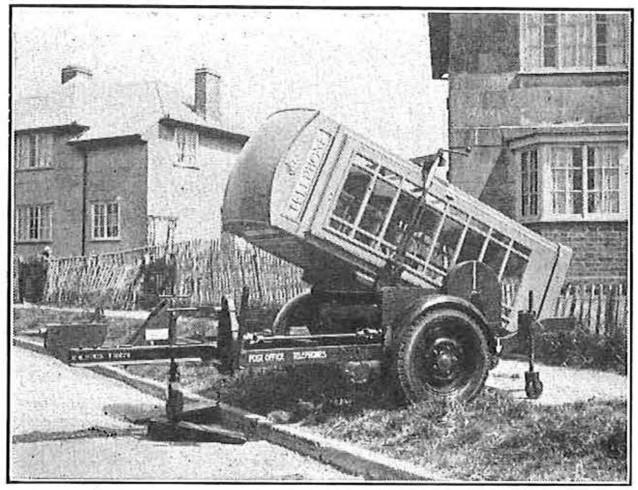


FIG. 5.—PLACING A KIOSK ON SITE.

Performance.

Normally, two men are necessary to operate the trailer successfully. The time taken to load a kiosk is of the order of 3½ minutes. Naturally the time taken to place a kiosk varies considerably with the local conditions appertaining to the site, but a normal figure would be about 10 minutes. In unfavourable circumstances, e.g., on a hillside, more than two men are required to manœuvre the laden trailer as the total weight is approximately 27 cwt.

Conclusions.

Although many improvements have been included in the later model no finality in the design is suggested and doubtless further developments will be required as more experience is gained.

Experience with the early trailer has shown that to enable the work of kiosk erection to be carried out expeditiously it is necessary to ensure that the site foundations are completed, and the service pipes are located correctly before the kiosk is delivered. Much time and labour can be saved by the progressive flow of centralised assembly, glazing, painting and apparatus installation work. The use of quick-setting cement by the party erecting the kiosk for filling in the bottom of the kiosk and the timely connection of the lines all combine to give rapid results, which are gratifying both to the men concerned with the work and to the public.

It is desired to express appreciation of the co-operation given in the production of the improved trailers by the Low Loading Trailer Co., of Bedford, England.

New Chemistry Laboratories at the Research Station

U.D.C. 727.5:542.1

This note describes the new chemistry laboratories at Dollis Hill which are equipped on a "unit" basis, five standard units of equipment being used in various combinations according to the requirements for individual laboratories.

IT is hardly possible to review progress in any branch of engineering without finding many instances where the rate of advance has been directly related to the appearance of new or improved materials. Nowhere does this apply with greater force than in communications engineering, as is borne out by the long existence of the Chemical Test Sections of Inspection Branch and the chemistry laboratories of the Research Branch and the wide ranges of complementary functions which these carry out. A chemistry laboratory existed in the early "wooden-hut" days of what was then the Research Section and in 1926 this was one of the first to be rehoused in a permanent building on the Dollis Hill site. Despite the transfer of some related activities to new laboratories in the Main Research Building in 1933, the growth of the chemical work was so rapid that a serious accommodation problem arose within a few years. Plans for new laboratories were made, but the outbreak of war prevented their realisation though staff increases had aggravated the problem.

The war years and the immediate post-war period saw further increases in the demand for chemical work and changes in its main emphasis. The proportion of work of a more or less routine type, or concerned with the investigation of faults, decreased; and the study of new materials and techniques increased. These changes have arisen partly from the necessity to know and understand the real merits of the bewildering variety of new materials, mostly of artificial origin, which industry now offers to designers, so that soundly-based advice on the selection of materials for the construction of new equipment could be given, and partly from the need to encourage the development and production of materials to meet specific engineering requirements which cannot be met by established products. More extensive familiarity with commercial manufacturing processes and a deeper knowledge of the fundamental factors which determine the properties of all kinds of materials have become essential; problems are liable to arise in an ever-widening field, yet to be more highly specialised in their nature. The present total staff of the four chemistry groups is about 34, of whom about 18 are university graduates or have comparable academic qualifications.

These factors led to the decision, as soon as post-war conditions permitted, to carry out only a limited amount of modernisation of the existing main chemistry laboratory and to set up "individual" laboratories in additional accommodation which had been made available, comprising a total area of about 1,800 sq. ft. in the existing chemistry building and 1,500 sq. ft. in the adjacent block. It was intended that each individual laboratory should be under the control of one senior research worker and/or, where practicable, devoted to one kind of work. In the interests of general working efficiency and economy of space, group technical offices have been abolished and each senior worker's office is in his own laboratory (see Fig. 1). Writing tables are provided only for those other officers whose work justifies this provision; "knee-holes" are provided at suitable points in the benching layout at which officers can sit and take notes, etc., at the bench. One large room which was set free in this way has been re-arranged to provide office accommodation for the Divisional clerical staff and extra writing facilities for occasional use and to house the large number of books on

FIG. 1.—A SMALL INDIVIDUAL LABORATORY.

specialised "materials" topics to which frequent reference is necessary in the day-to-day work of the Division. In the space allotted for laboratories, there have been constructed seven individual laboratories each of about 180 sq. ft. area and one of 320 sq. ft. area; one general laboratory of 360 sq. ft. area; a small personal laboratory for the use of the head of the Division; a balance room; a small additional store room; a photographic dark room and a small laboratory of 100 sq. ft. area for electrical measurements.

To allow for easy and economical rearrangement of the laboratories to meet changes in the future needs of the work, it was hoped originally to avoid the necessity for fixing benches or other laboratory furniture permanently to the structure of the building, and a scheme was devised whereby almost any chemical bench layout could be obtained by suitable combinations of four standard, self-supporting units together with short sections of plain benching. Each unit was designed to incorporate all necessary services and to be capable of easy connection to various "ring-main" services and other units, as desired, by means of unions or plugs and sockets. A high degree of flexibility could thereby have been obtained, combined with convenient and efficient working conditions for the staff. Unfortunately, this scheme was found to be in conflict with certain building traditions and, together with many of its potential advantages, had to be abandoned though some of the features of the "unit" system have been retained.

Although the runs of benching are in most cases continuous and are assembled on fixed frameworks to suit the separate laboratory layouts, they are in fact combinations and permutations of five basic units. Thus, certain 4 ft. 6 in. runs are regarded as "Bench Units" and are exactly similar in all the new laboratories (see Fig. 2). Mounted on the cover (removable for ease of maintenance) of a skirting at the back of the bench-run is a group of sockets providing a range of electrical power supplies, and immediately in

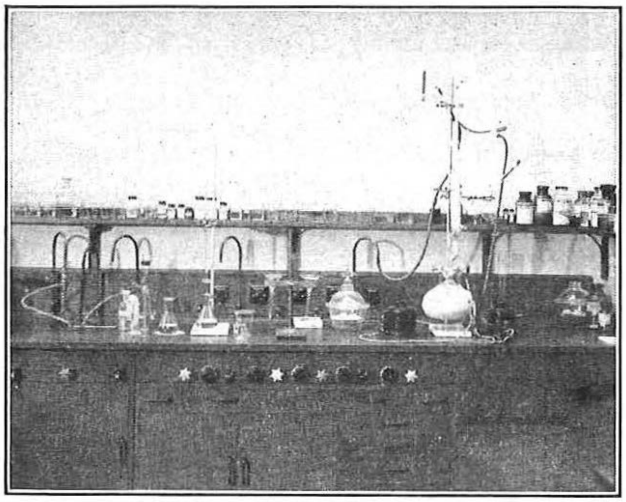


Fig. 2.—A Small-Sink Unit (left) and a Bench Unit.

front of this are outlets for gas and water (both in duplicate), compressed air and vacuum. The water bends discharge normally into a narrow, leadlined drainage channel near the back of the bench unit. All the controls for these services are mounted on the front supporting rail of the bench, which is set back from the front edge to reduce the risk of accidental operation of the switches or valves. Beneath each bench unit is a removable unit containing an assembly of drawers and a cupboard, the shapes and sizes of which have been worked out to give safe and convenient storage for smaller pieces of chemical apparatus.

Adjacent to one or both ends of a bench unit is a "Small-Sink Unit" which, in effect, is a 1 ft. 6 in. length of benching into which a chemical sink is fitted. This is provided with two rear-mounted, front-controlled water bends and under it is a fixed cupboard (see Fig. **2**). An alternative type of small-sink unit is provided in addition with a front-controlled steam point. The sinks of these units are intended merely for the discharge of water and chemical wastes and so are only 11 in. long by 9 in. wide internally. For "washing up," a "Large-Sink Unit" (see Fig. **3**) is provided in each laboratory. This consists of a

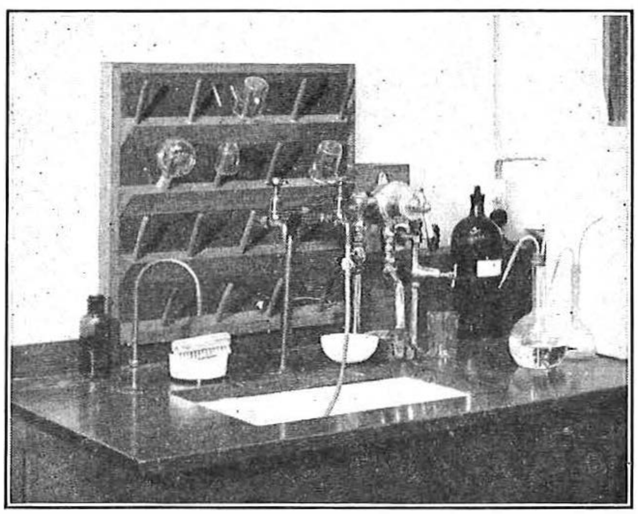


Fig. 3.—A Large-Sink Unit.

sink let into the front of a 3 ft. 6 in. length of benching and provided with a double chemical water bend and hot water supply. The lower portion of these units again consists of cupboards. Mounted on the wall behind each of them is a draining rack for drying apparatus.

The last of the standard parts is a 3 ft. 6 in. "Fume Cupboard Unit" (see Fig. **4**) one of which is fitted in most of the laboratories. The main portion consists of a conven-

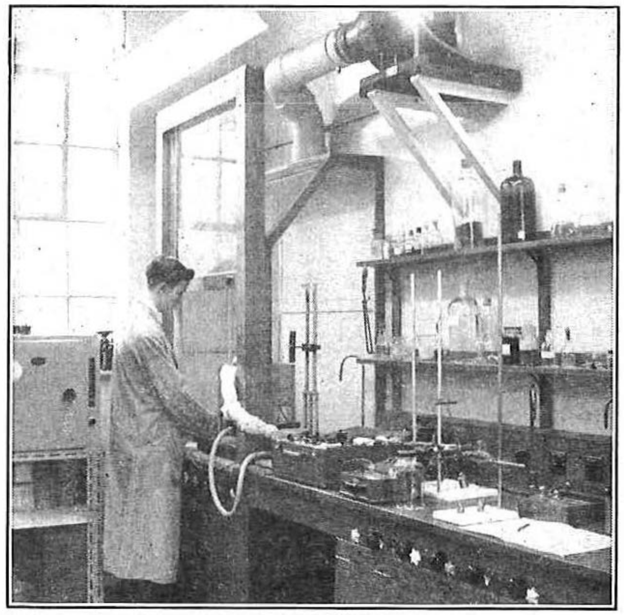


Fig. 4.—Fume Cupboard and Bench Units in a Small Individual Laboratory.

tional glazed structure mounted on an acid-resisting composition bench slab. Each fume cupboard is provided with front-controlled water, gas, compressed air, vacuum and steam services and a steam bath, and has its own extractor fan. The space beneath the working bench is again utilised as a storage cupboard.

The new general laboratory, mentioned earlier, includes two special benches in addition to the standard units of furniture. One of these, (seen in the background of Fig. **5**) is

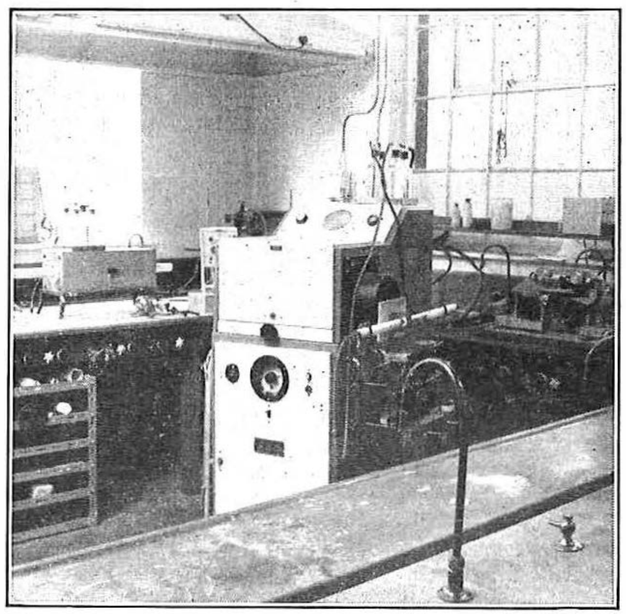


Fig. 5.—New General Laboratory.

a heat-resisting bench slab used to accommodate furnaces. It is provided with a complete double set of the ordinary services and is piped in addition for purified hydrogen and nitrogen. It is provided also with a large internally lighted hood and an extractor fan to remove hot air. The second bench in this laboratory (in the foreground of Fig. **5**), again comprehensively furnished with services, is covered with chemical lead sheeting and is intended mainly for larger scale preparative or "messy" work. The ordinary bench tops throughout the new laboratories are of oiled teak which is thought to be preferable for general use to most of the modern finishes.

One of the new laboratories is intended ultimately for work involving radioactive tracer elements. Accordingly it is provided with two fume hoods, one of a slightly different design from the standard units for the safe handling of the more hazardous of these materials. It is entered through a small ante-room in which the staff can wash in a region free from risk of radioactive contamination. The waste system here will ultimately be carried out in polythene piping (to facilitate monitoring) and provision is made for inserting suitable delay tanks in the path of the liquid effluent.

Most of the services in the new laboratories are taken from the usual station sources but a larger pump has been installed to provide the compressed air service. The rough vacuum service is furnished by two pumps, each with reservoirs and appropriate traps, of which one is installed in each block. Steam is obtained from a 30 kW, 3-phase, automatically-controlled, electrode boiler installed in the larger individual laboratory (see Fig. 6). With the aid of adjustable, thermostatically controlled mixing valves, steam from this source is mixed with cold water to give the hot water supplies to the large sinks. Since many items of current work in these laboratories involve handling materials of extreme purity, it was necessary to minimise the risk of contamination by dust and a new ventilation system has been installed. Air from outside is purified by mesh filters and an electrostatic precipitator, warmed and discharged into the laboratories through louvered apertures

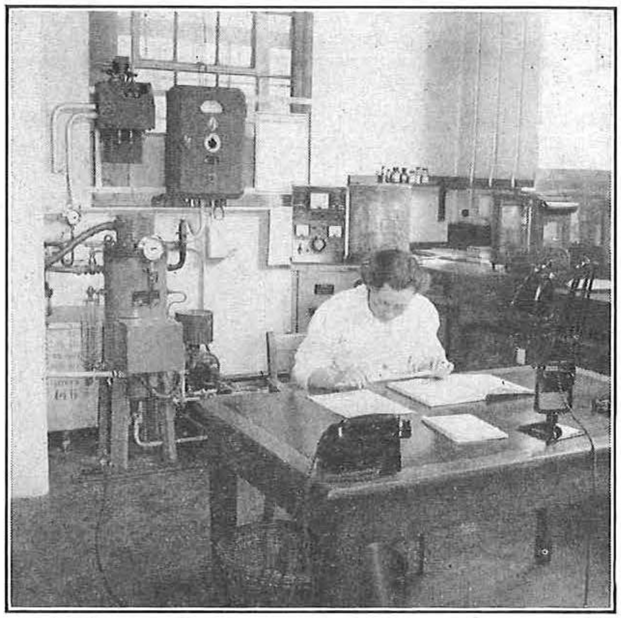


FIG. 6.—LARGE INDIVIDUAL LABORATORY, SHOWING 30-KW ELECTRODE BOILER FOR STEAM SUPPLY.

at a rate sufficient to maintain a slight positive pressure (about $\frac{1}{4}$ in. W.G.) throughout both buildings. Normally it is intended that windows shall not be opened and the excess air is discharged through conventional flap valves. Slightly sunk gullies are provided in the floors of each laboratory to facilitate the disposal of liquid spillages. Artificial lighting is by fluorescent tube lamps throughout.

E. A. S.

New Workshop Building at the Research Station

U.D.C. 725.4:621.7

This note describes a new 3-storey building recently erected at Dollis Hill, which houses a main workshop divided into three sections, various small shops, tool and material stores, laboratories, drawing office, etc.

THE old Research Branch workshop building at Dollis Hill, which was erected in 1931 to replace the original wooden army-type hut, consists of a corrugated iron structure 245 ft. long by 38 ft. wide, in two sections under a single roof. It was designed to house an assembly shop and machine shop in one section, and a wood-working shop and mill-wrights shop in the other. Owing to lack of office space in the workshop, the engineering and drawing office staff were accommodated elsewhere on the site. By the end of the second world war, conditions in the workshop were such that no further staff or plant could be accommodated and lack of assembly space was causing considerable difficulty.

Although plans indicating a proposed permanent building had existed prior to the war, it was not until 1947 that authority was sought for the erection of a new building designed to house the whole of the engineering, drawing office and workshop staff under the control of the Research Services Section. Sketch plans, submitted by the Ministry of Works Architects Division and based on the specified requirements were approved by the Engineering Department in January, 1950, and work was commenced in August of that year. In order to provide additional staff accommodation and storage space it had been decided to excavate the whole of the area occupied by the building and this work was still proceeding at the east end when building operations commenced at the west end in March, 1951. The building was virtually completed in May, 1953, although it was not until June that the work of transferring the machine-tool plant to the new quarters could proceed.

The main frontage of three storeys is 252 ft. long, facing south (Fig. 1). Accommodation is provided on the first floor for controlling and engineering staff, while the second floor is occupied by the drawing office (Fig. 2) and photo-printing staff. The ground floor consists of a number of small shops for such purposes as coil-winding, wiring, jig-boring, etc. and a large tool and material stores which serves not only the workshop but also the whole of the Research Station. Provision has been made for the installation at the east end, of a passenger-goods lift, operating between the ground, first and second floors, and a goods lift operating between the ground floor and basement to facilitate the movement of heavy stores.

The workshop proper extends northwards as a single-storey building of three bays, each of 20 ft. span, with north lighting. It is divided into three sections separated by large metal folding doors and glazed screens. The east-end section is occupied by the mill-wrights and heavy metal workers while the west end houses the wood-working staff and machines. The middle portion comprises a combined machine and assembly shop (Fig. 3). A lifting beam with a runner capable of lifting 4 tons extends the whole length of the ground floor and provides for the handling of machines and heavy equipment. Distribution of power to the various

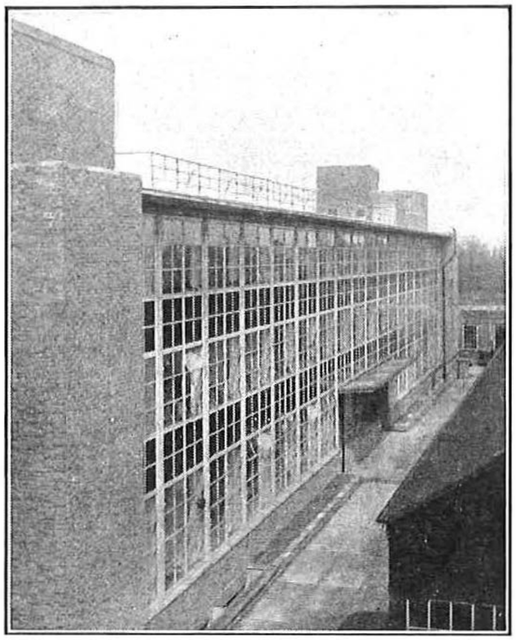


FIG. 1.—FRONT OF NEW WORKSHOP BUILDING.

FIG. 2.—DRAWING OFFICE.

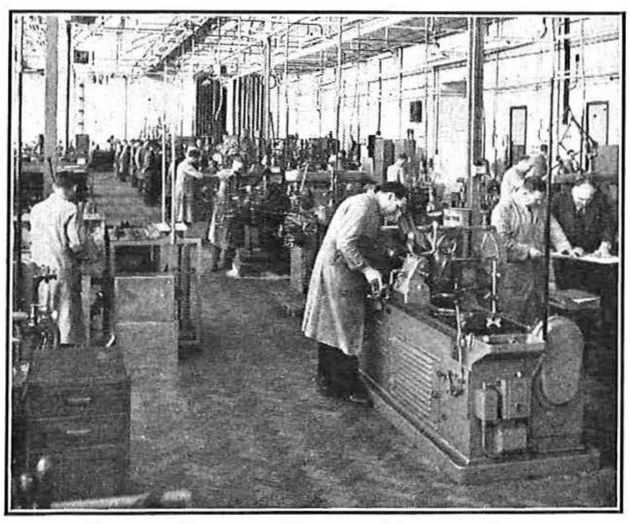


FIG. 3.—GENERAL VIEW OF MACHINE SHOP.

machines is by enclosed overhead bus-bars fed from cables at the east end of the building. Machines can be plugged in at convenient points by means of special fuse units; a system which provides for a certain amount of flexibility in the layout of plant.

Illumination in the new building is, in general, by fluorescent tubes, those in the workshops being double tube anti-stroboscopic units as a safety measure. The heating of the building is by low-pressure hot water radiators, augmented in the workshops by roof space heaters provided with electric fans which can be also used in hot weather to assist ventilation. The existing heating plant is temporary and feeds only the new building. It is intended that at some future date the whole of the heating plant of the Research Station, complete with mechanical stoking, will be concentrated at this point.

Excavation of the whole of the workshop site has provided space for a line of offices and laboratories under the north side of the workshop; these, as a result of a falling ground level, have natural lighting and ventilation (Fig. 4).

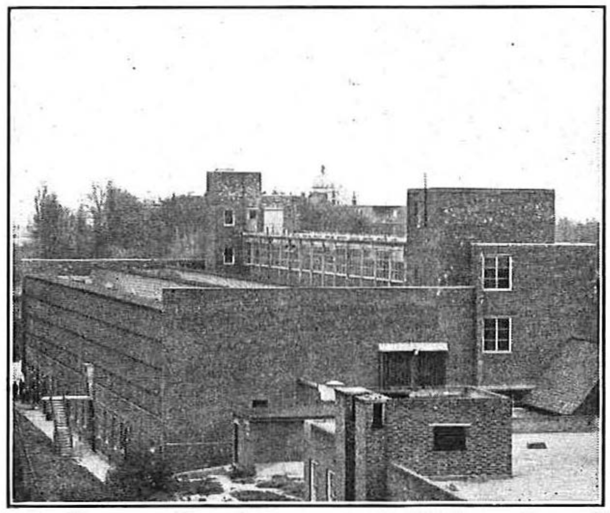


FIG. 4.—VIEW OF NEW BUILDING FROM WEST OF SITE. (THE STEPS ARE A FIRE ESCAPE FROM WORKSHOP FLOOR LEVEL; THE WINDOWS BELOW SERVE THE LINE OF LABORATORIES.)

The laboratories are divided by removable partitions and the services to them are arranged so that each laboratory may consist of one or more units of 12 ft. 6 in. width. Flexibility of this kind is desirable to cater for changes in the class of work that may need to be done. At present the laboratories are being used for studies of the designs of thermionic valves and allied work.

The basement space has been allocated for various purposes such as storage, locker and rest rooms, ventilation plant, etc., and a 65 kVA diesel generating plant capable, in emergency, of maintaining the machine shop at a reduced load.

An 18 ft. concrete roadway separates the new workshop from the old one; giving access for goods vehicles to the tool and material stores.

It was originally intended that the centre portion of the old workshop building should be removed leaving the last few bays at each end. The west-end portion was to be used for garage accommodation for official vans and a drivers' waiting room, while the portion at the east end was to provide space for a new spray-painting shop, a wood store and thermionic valve life-testing equipment. Emergency demands for further laboratory space have, however, necessitated a change in plan and it has now been decided that the whole of the old building shall remain. Work on the modifications to the old workshop building is proceeding.

O. W. G.

Notes and Comments

Birthday Honours

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

Blackburn Telephone Area	Thornley, H. G.	Lately Executive Engineer	Member of the Order of the British Empire
Blackburn Telephone Area	Unsworth. P.	Technician Class I	British Empire Medal
Edinburgh Telephone Area	Bowles, G. A.	Technician Class I	British Empire Medal
Sheffield Telephone Area	Critchlow, V. G.	Area Engineer	Member of the Order of the British Empire
Tunbridge Wells Telephone Area	Powell, F. E. T.	Technical Officer	British Empire Medal

Improvements to the Journal

Readers may recall that some two years ago when the financial position of the Journal was far from satisfactory, arrangements were made to introduce various production economies and to increase the price of the Journal and the advertising rates. The result of this policy is that in spite of the expected small decline in circulation due to the price increase, the Journal is now again on a firm financial footing.

As promised at the time, such profit as accrues to the Journal is to be used for the benefit of readers, and accordingly a 64-page Journal will be published during the next 12 months. In addition, a further set of model answers, Mathematics for Telecommunications 1, will appear in the Supplement, so that with the exception of Grades 4 and 5 in this subject, the whole of the City and Guilds Telecommunication Engineering syllabus will be covered in future.

Because of the considerable increase in expenditure arising from the larger Journal and Supplement, it will be necessary to restrict the number of copies printed to a figure closely in line with the firm orders on hand, and very little margin can be allowed for the subsequent supply of back numbers. Readers are urged, therefore, to make sure of their copies by placing a regular order with the Local Agent or with the Publishers whose address is quoted on page 126.

I.P.O.E.E. Printed Papers

Many of the Printed Papers issued by the Institution are now out of print, and copies no longer required by members, particularly Nos. 183, 189, 190, 192, 194 and 195, would be gratefully received by the Librarian at Alder House.

Institution of Post Office Electrical Engineers

Essay Competition 1953/54—Results

A Prize of £5 5s. 0d. and an Institution Certificate have been awarded to the following competitor in respect of the essay named:—

G. Chalk, Technician I, Canterbury (H.C. Region). "Electric Lift Roping Systems. Their Maintenance and Renewal."

Prizes of £3 3s. 0d. each and Institution Certificates have been awarded to the following four competitors:—

E. H. Piper, Technical Officer, Bournemouth (S.W. Region). "The Introduction of the Rationalised M.K.S. System of Electrical Units to Technical Education."

W. P. Skinner, Technical Officer, LTR/SW Area. "A review of Lead-Acid Secondary Cell practice with some observations on possible developments."

R. N. Burt, Technical Officer, Bath (S.W. Region). "Problems of Staff Training in the Engineering Department."

G. Douglas, Technical Officer, Ladybank, Fife (Scotland). "New Equipment Practice used in 24 Circuit Carrier at intermediate stations."

Institution Certificates of Merit have been awarded to:—

O. G. Plumridge, Technician I, Salford (N.W. Region). "Subscribers Apparatus—Its Installation and Maintenance."

R. H. Thornton, Technical Officer, LTR/LD Area. "A Method of Reducing Carrier Leak from Cowan Type Modulators."

G. W. Bates, Technical Officer, E.-in-C.O. (Test Section). "Photometry and the London Test Section."

A. W. Morris, Senior Mechanic, Belfast (N. Ireland). "Automobile Electricity and the Modern Post Office Vehicle."

R. Grant, Technical Officer, Glasgow (Scotland). "The Proper Approach to our Subscribers and Public."

The Council of the Institution records its appreciation to Messrs. W. S. Procter, F. A. Hough and H. E. Francis, who kindly undertook to adjudicate upon the essays entered for the competition.

N.B.—Particulars of the next competition, entry for which closes on the 31st December, 1954, will be published later.

Review of Prize-Winning Essays—1953/54 Competition

The Council of the Institution is indebted to Mr. W. S. Procter, M.I.E.E., F.R.S.E., Chairman of the Judging Panel, for the following review of the five prize-winning essays:—

"It is encouraging to find that the essay judged to take first place this year was entered by a contributor who obtained the third prize last year. The title of the winning entry is 'Electric Lift Roping Systems—their Maintenance and Renewal', entered by G. Chalk of Canterbury. In this essay, which is very well written and illustrated by drawings, Mr. Chalk deals with the make-up of lift ropes and their maintenance as well as the general principles underlying the replacement of ropes on various types of lift. The skill and care necessary to be taken in terminating the ropes and various tests and checks to be made to ensure correct operation of the lift after re-roping are described very clearly.

Second in order of merit is an essay by E. H. Piper, of Bournemouth, entitled 'The Introduction of the Rationalised M.K.S. System of Electrical Units to Technical Education'. The subject chosen may perhaps be regarded as one of the more difficult to treat in essay form, but the author has tackled the subject enthusiastically with the object of clarifying those points relating to electrical units which might be confusing to the student of technical electricity.

The essay by W. P. Skinner, of Purley, 'A Review of Lead-Acid Secondary Cell practice with some observations on possible developments' merited third prize. This essay covers the maintenance of secondary cells very thoroughly. It focuses attention on those points which a careful maintenance officer will observe with the object of avoiding unnecessary costly replacement before the expiry of the designed life of cell plates.

Fourth in order of merit is an essay by R. N. Burt of Bath entitled 'Problems of Staff Training in the Engineering Department'. In this essay the author has examined the basis of departmental training with particular regard to the youths taking the two-year course. Various difficulties are enumerated in a very neatly written article.

G. Douglas, of Ladybank, Fife, obtained the fifth place in order of merit for his essay 'New Equipment Practice used in

24 Circuit Carrier at intermediate stations'. This is a clearly written description of the various features incorporated in the design of the equipment. Attention is drawn to the differences between the superseded and new equipment and also the essentials of maintenance." H. E. WILCOCKSON, *Secretary*.

Additions to the Library

Members are reminded that suggestions for suitable additions to the Library are always welcomed by the Librarian.

2176 *Careers Encyclopaedia*. G. H. Shaffe (Brit. 1952).
A work of reference concerning requirements, training and prospects in some 220 occupations.

2177 *Radio and Car Battery Handbook*. C. Fleming (Brit. 1947).
Contains all the practical information the automobile electrician and radio serviceman needs to know about accumulators, their charging from A.C. or D.C. mains, servicing and repair.

2178 *Plastics Progress*, 1953. Ed. P. Morgan (Brit. 1953).
Papers and discussions at the British Plastics Convention, 1953.

2179 *Statistics for Technologists*. C. G. Parodine and B. H. P. Rivett (Brit. 1953).
A text-book for the student, research worker or engineer who wishes to learn the principal statistical methods and the main lines of the theory behind them.

2180 *Electronic Measurements*. F. E. Terman and J. M. Pettitt (Amer. 1952).
A reference book for the practising engineer—covers fundamentals in numerous fields beyond conventional radio, including television, radar and a diversity of techniques of value where electronics are used in instrumentation.

2181 *Introduction to Circuit Theory*. E. A. Guilleman (Amer. 1953).
An introductory treatment of all the basic principles and concepts needed for complete understanding of advanced work in network analysis and synthesis.

2182 *Fundamentals of Electric Motion*. W. W. Harman (Amer. 1953).
Attempts to give a general understanding of electron tube analysis—largely mathematical in presentation, but no initial knowledge beyond the calculus is assumed.

2183 *Battery Chargers and Charging*. R. A. Harvey (Brit. 1953).
Describes the fundamental principles of battery charging and explains how these principles are used in various applications.

2184 *Automatic Digital Calculators*. A. D. and K. H. V. Booth (Brit. 1953).
A guide to the theory of these machines.

2185 *Optics*. W. H. A. Fincham (Brit. 1951).
For the elementary student with no previous knowledge of the subject. Includes also the work required by students of Light for the Intermediate examinations of the Universities.

2186 *Acoustics*. T. M. Yarwood (Brit. 1953).
Covers the ground from ordinary to scholarship level of the General Certificate of Education. Includes also some practical aspects (sound recording, etc.) of interest to first Year University students of engineering.

2187 *Britain's Post Office*. H. Robinson (Brit. 1953).
A history of development from the beginnings to the present day.

2188 *Developing the Negative Technique*. C. J. Jacobson (Brit. 1953).
An exhaustive survey of modern negative technique and a comprehensive collection of the formulae used in its practice.

2189 *Report on the Atom*. G. Dean (Amer. 1954).
An authoritative survey, by the recently retired Chairman of the U.S. Atomic Energy Commission, of atomic developments and of the present situation of atomic energy in all countries, including Russia. The prospects of using atomic power for peaceful purposes is also discussed.

2190 *Techniques of Technical Training*. H. R. Mills (Brit. 1953).
Suggests ways and means by which instructors, technical teachers, training officers and works supervisors and managers can improve the technical training of men in their charge.

2191 *Electrical Installation Rules and Tables*. W. S. Ibbetson (Brit. 1953).
A compendium of useful information for practical wiremen, electricians, engineers, contractors and architects.

2192 *Rotating Amplifiers*. Ed. E. D. Say (Brit. 1954).
A description of the amplidyne, metadyne, magnicon and magnavolt and their use in control systems.

2193 *The Electromagnetic Field and its Engineering Aspects*. G. W. Carter (Brit. 1954).
A thoroughgoing, non-mathematical treatment, aimed chiefly at explaining how electromagnetic apparatus behaves.

2194 *Electrical Testing for Practical Engineers*. G. W. Stubbings (Brit. 1949).
A handbook of reference for engineers engaged in the erection and maintenance of electrical installations, plant and machinery.

2195 *The Synchronous Induction Motor*. J. Griffin (Brit. 1954).
An overall review of present-day practice, with especial reference to the various developments which have taken place in the last 30 years.

2196 *Cathode Ray Tubes*. Ed. M. G. Say (Brit. 1954).
An authoritative account of present-day cathode ray tube theory and practice.

2197 *Ultra High Frequency Radio Engineering*. S. A. Knight (Brit. 1954).

2198 *Data and Circuits of Television Receiver Valves*. J. Jager (Dutch 1953).
Complete data and characteristic curves, usual applications of these valves, and some important aspects of modern receiver technique.

2199 *Mathematics Queen and Servant of Science*. E. T. Bell (Amer. 1952).
An account of the developments in pure and applied mathematics from the geometry of Euclid to the most recent ideas of mathematical physics.

2200 *Britain's Atomic Factories*. K. E. B. Jay (Brit. 1954).
The story of atomic energy production in Britain.

2201 *The Cyclotron*. W. B. Mann (Amer. 1953).
Mainly an account of the development of the first large-scale cyclotron, the 37-inch cyclotron at Berkeley.

2202 *Television Broadcasting*. H. Chinn (Amer. 1953).
Covers in detail the equipment, the facilities, and the techniques that are the immediate concern of personnel who are responsible for the operation of television broadcasting establishments.

W. D. FLORENCE, *Librarian*.

Book Review

"Automatic Voltage Regulators and Stabilisers." G. N. Patchett, Ph.D., A.M.I.E.E., M.I.R.E., A.M.Brit.I.R.E. Sir Isaac Pitman & Sons Ltd. 336 pp., 196 ill. 50s.

This is a very scholarly work of some 330 pages and 196 illustrations. The author adheres closely to his title and deals with the fundamental principles of regulators, electro-mechanical and all-electric (including electronic) regulators. The field is covered from the stabilised power supply to small radio equipments to the control of large generators.

Although the author says he has made the descriptions of existing types of regulators as general as possible he has managed to give a surprising amount of information on most of those in general use not only in this country but also on the Continent and in America.

The hunting of regulators with negligible response time is not treated in detail as the author points out that the regulator is a special case in the large and complex subject of servo-mechanisms. The references should satisfy the most ardent research worker as there are over 600 in the text, a bibliography of six pages and a complete author index.

The only matter that can be criticised is the reproduction of many of the photographic illustrations which do not do justice to the excellent diagrams and text.

A. E. P.

Regional Notes

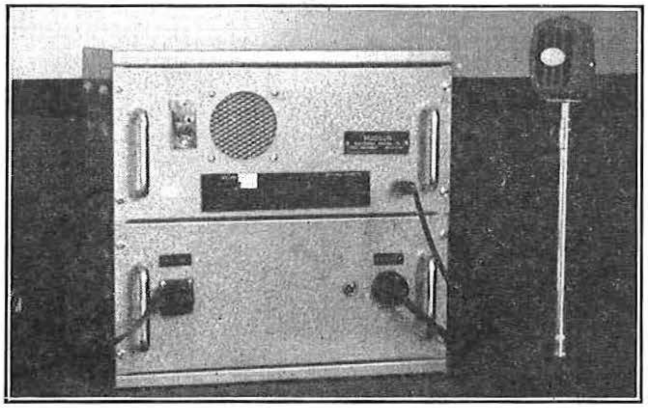
London Telecommunications Region

RADIO CONTROL OF OUTDOOR MAINTENANCE STAFF

An interesting Engineering Department experiment in the use of short-wave two-way radio communication for the control of staff employed on subscribers' apparatus and external plant maintenance in the Dartford area was started in April.

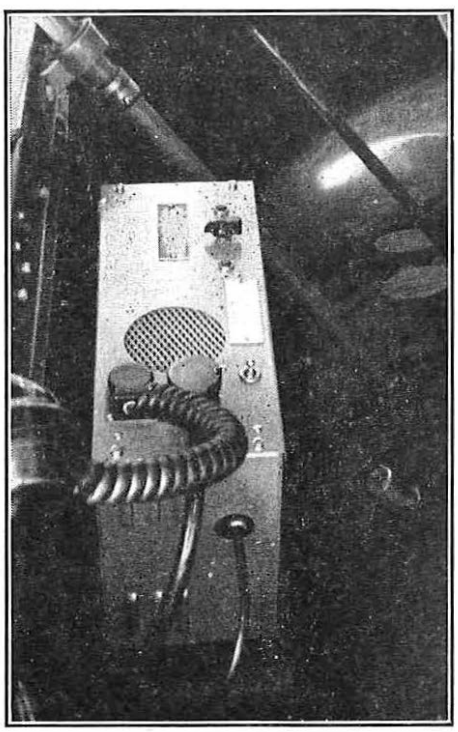
A main transmitter has been installed at Stonewood repeater station with remote control in Dartford test room three miles away. A total of 13 vehicles have been equipped with sets, ranging from the heavy overhead gang vehicle, a 2-ton G.U., down to the Morris Minors carrying single overhead linemen and subscribers' apparatus men.

The equipment is manufactured by Hudson Electronic Devices, Ltd., London. The fixed station comprises a 6-W amplitude-modulated crystal-controlled transmitter



The Fixed Station; the Upper Unit is the Transmitter and Receiver; the Lower Unit contains the Power Pack.

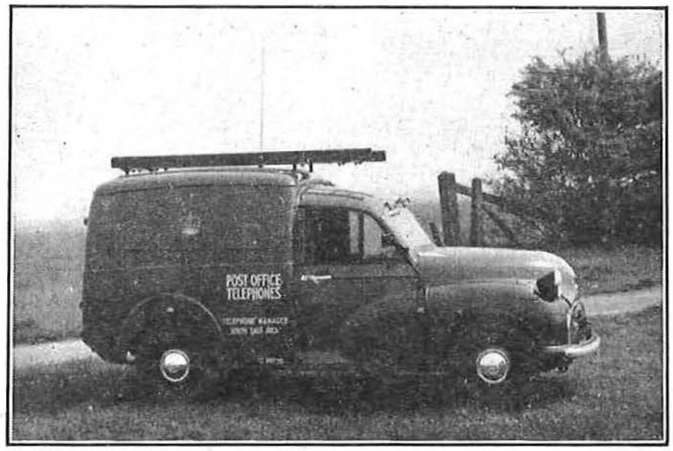
and double frequency changer receiver, also crystal controlled and fitted with a wide range of automatic volume control. The mobile stations are built to a similar specification but are only rated at 5W output. One frequency is used for fixed station to all mobile stations and another for all mobiles to the fixed station; thus mobile stations are unable to converse with each other direct.



Arrangement of Mobile Set in a Van.

In the modern Morris Minor vehicles, power is derived from the car battery. On other vehicles an auxiliary 12-V car battery is fitted to supply the heater current to the valves and to operate the small rotary converter for high-tension supply. The set is left switched on unless the man is going to be away from the vehicle for some time. This means a fairly heavy drain on the battery and this is changed and charged daily. The microphone for the mobile set is contained in a handset and facilities exist for using an extension lead from the set to the top of a pole or some such remote point.

In vehicles of the metal body type the body acts as a counterpoise to the dipole fitted on the roof; in other vehicles a sheet of perforated zinc is fastened inside the vehicle under the roof to complete the circuit.



Vehicle, showing Position of Aerial.

To obtain the maximum advantages of the scheme it is necessary to adopt a new approach to the whole question of fault distribution. The control needs to be able to relate the positions of faults and vehicles, so that unnecessary mileage is cut out and a fault-finder can be diverted to any point as required. To do this a 6 in. to the mile metal-backed map of the area has been mounted near the test desk and faults and vehicles are plotted on it by magnetic counters. By this means a clear picture of the situation throughout the 100 square miles of the area is continuously available.

Although the system is still in its very early stages, and it is not yet possible to say what benefits have accrued to subscribers' maintenance, there have been some unexpected applications of its usefulness already, such as the offer to relay urgent messages via the repair vehicle radio for a hospital which was isolated by a cable breakdown; co-operation with a police car to intercept a person making malicious calls from call offices; and obtaining the services of the Water Board staff when a water main was accidentally damaged.

The benefit to the staff themselves is also a big factor in favour of the arrangement—the ability to get speedy help either on a difficult job or in case of vehicle breakdown or accident, is greatly appreciated. As one man said—"I now feel isolated if my radio set is off the air."

W. H. O.

South-Western Region

STEEL PIPES ACROSS RIVER AVON

To carry out a recent external plant operation it was desired to lay nine steel pipes over one of the Avon bridges, but due to lack of cover and the bridge being an ancient monument precluding the use of attachments, this was not possible. It was decided, therefore, to lay the steel pipes below the river bed, downstream from the bridge.

Easements from adjacent property owners were obtained for the disturbance of the banks, and for the laying of several hundred yards of approach duct and manholes. The contract for the river crossing was placed on a lump-sum basis and the successful contractor indicated that dredging plant would be used. An unsuccessful contractor catered for the use of coffer dams.

The river banks rise 13 ft. above normal water level and are some 110 ft. apart. The River Board stipulated that the plant, including anchorage of concrete-filled bags, should rest at a fixed level above Liverpool datum which necessitated a trench in the river bed of at least 6 ft. depth below a normal level of water of 6 to 8 ft., with a current of 4 m.p.h. Depth of water and current increase considerably after heavy rainfalls.

An outboard motor boat was made available for staff traffic across the river. A raft and landing stage with rails and steps to the top of one bank was constructed.

The dredging plant consisted of two mobile diesel winches, one on each side of the river, and a drag bucket 6 ft. wide. The winches were 120 yds. apart due to difficulties of access.

A length of 65 yds. of nine standard P.O. steel pipes was laid out on the river bank in the direction of the proposed trench. The joints were lap welded and hessian protected. The land portions of the pipes were bent to provide the necessary rise to the manholes and the whole formation of "four over five" was clamped together at suitable spacing with mild steel flats and bolts.

Over the major part of the crossing where the river bed was of gravel and clay, dredging presented little difficulty. A hard crust extending for 20 ft. from the west side defied removal

DREDGING THE CHANNEL ACROSS RIVER AVON.

for 10 days, but ultimately gave way while alternative methods were being discussed. The desired level of trench was not obtained but the conditions were accepted by the River Board in view of the excavation difficulties, and since, in any case, the plant and anchorage would be well below the river bed. The final depth of cover was 4 ft. below the normal river bed.

Soundings revealed that the trench was not in a straight line between the cuttings in the bank. This was attributed to current effects on the empty or partially loaded bucket, coupled with the loss of control on the hawsers due to the wide spacing of the winches. As the trench was 6 ft. wide, however, and the plant much less than 3 ft., no difficulty was foreseen.

The formation of pipes, water-loaded to overcome buoyancy, was drawn across the river behind the bucket which was reversed. When some 30 yds. had been drawn across, the formation of pipes heeled over through 90°, undoubtedly due to the irregularity of the trench. The pipes were withdrawn, examined and tested, and were found to be undamaged. Finally they were drawn across buoyant, and when in position with regard to length were found to be carried 3 ft. downstream in the centre of the river, buoyancy supporting the pipes 3 ft. below water level.

Soundings revealed that the pipes were lying directly over the trench; water was pumped into them and the formation settled steadily to the trench bed. By means of a chute, concrete-filled bags were lowered to the top of the pipes for anchorage. The trench was then levelled off to the river bed by clay-filled bags; which were also used with steel stakes for making good the banks.

The operations occupied an average of six men for a period of six weeks.

The private property on the east side of the river is liable to flooding to a depth of 4 ft. Two manholes will be built with the roofs 5 ft. above ground level ramped off with soil and grass at 45° to the field level. Anchor irons in the outside wall will

PIPES LAID IN CHANNEL ACROSS AVON.

enable a boat to be tied during flood conditions so that access and working room will still be available.

SOUTHAMPTON NEW NON-DIRECTOR EXCHANGE

A very pleasant opening ceremony, performed by the Postmaster-General, marked the birth of this new exchange on Saturday, 3rd April, 1954. The Regional Director, Mr. L. G. Semple, C.B.E. and Mr. F. E. Ferneyhough, Telephone Manager, welcomed Earl De La Warr and the many distinguished guests. The Telephone Manager explained briefly the operations which would take place for the transfer of lines to the new building. The Postmaster-General operated the "cut-out" signal at 1 p.m. precisely. Disconnection of some 2,000 trunks and junctions and 3,800 subscribers was completed at the old exchange within five minutes of receipt of instructions to "cut out." During this period, a running commentary on the engineering work being carried out was made over the public address equipment to the guests who were assembled in the clerical room. The final cut-over was completed without a hitch at 1.7 p.m. and this was followed by a novel inaugural call. At 1.15 p.m. the Mayor of Southampton dialled "0" and was connected to the Captain of the "Queen Elizabeth" on the high seas. Reception was excellent and the call was broadcast for the benefit of the guests.

During the afternoon the Regional Director presided at a luncheon given in honour of the Postmaster-General and guests. In the after-lunch speeches some warm tributes were paid to the Post Office as a whole and the Engineering Department in particular.

The opening of the new exchange terminates the occupation of unsuitable temporary accommodation forced upon us by the unfortunate loss of our exchange by enemy action on the night of 30th November, 1940. The initial equipment capacity is for 8,600 subscribers with an ultimate of 10,000. Manual board equipment comprises 95 positions with 10 monitors, 14 directory enquiry and 10 test desk positions. The equipment was installed by Ericsson Telephones, Ltd., and the whole of the work occupied a year and eleven months. New facilities available to subscribers include the speaking clock and multi-metering up to four unit fees.

L. T. J.

A RELIC OF THE UNITED KINGDOM TELEGRAPH CO., LTD.

During recent prelimary survey work in connection with Gloucester West Zone development scheme, unexpected carriageway-type cable markers were discovered in St. Mary's Street, Gloucester. This is just outside the cathedral precincts and quite close to Bishop Hooper's monument. The conduit diagram for the locality did not show the existence of any conduit in the position indicated by the presence of the markers. Reference was also made to National Telephone Company prints of the area, but again the presence of conduit or cable was not indicated. Enquiry of some of the oldest members of the external staff did elicit the fact that an old iron pipe was routed from Commercial Road, alongside the external wall of Her Majesty's Prison, Quay Street, over Westgate Street, and along St. Mary's Street to a test pole near the South Wales railway line bordering Priory Road. Many years ago, the route of this existing pipe had been indicated by laying cable markers, but apparently the records had been lost. When, and by whom the pipe was laid is not known.

In order to clarify the position, an excavation was made near one of the markers and at a depth of 14 in. a cast iron pipe of $1\frac{1}{2}$ in. external diameter was exposed. This pipe was much smaller than had been expected and much speculation was evinced as to its origin. Further excavation revealed some raised lettering on the surface of the pipe. After scratch brushing, the lettering became decipherable as U.K.T. Co., Ltd.—Henleys Patented. The lettering was assumed to represent the United Kingdom Telegraph Co., Ltd. Unfortunately the iron pipe had rusted badly and it was found necessary to break the pipe in order to ascertain what it carried. This exposed a cable consisting of 12/40 lb. wires, each wire being covered with a thick layer of gutta percha insulation, the whole being wrapped in an outer covering of hessian protection impregnated with pitch or something of a similar nature. It was not found possible to draw the cable out of the pipe as the outer covering had become very firmly attached to the inner surface of the pipe.

The condition of the gutta percha insulation varied from conductor to conductor; but in most cases it was in a remarkably good condition and still possessed a high degree of elasticity. Continuous bending did not cause any noticeable loss of flexibility and to all external appearance the material was still quite satisfactory as an insulator.

The cast iron pipe is of unusual construction judged on present-day practice. It is made up in 6-ft. lengths, each length consisting of two longitudinal split sections so designed that one section could be made to slide over a recessed ledge on the other section. The sections are joined by a coupling.

Records held in the Gloucester City Library show that an office of the United Kingdom Telegraph Company existed in Commercial Road in the year 1867.

It is also recorded that in the year 1863 three telegraph offices existed in Commercial Road. They were:

(a) Gloucester and Sharpness Telegraph Company,
(b) Electric and International Telegraph Company, and
(c) British and Irish Magnetic Telegraph Company.

It is assumed that traffic connected with Gloucester Docks, an entrance to which exists in Commercial Road, may have been the reason for the telegraph offices.

The United Kingdom Telegraph Company is mentioned in E.I. Wayleaves, General B.0011 and B.0013, as existing in 1862.

W. J. T.

North-Eastern Region

BILLY GRAHAM RELAYS

In the four weeks between 23rd April and 21st May over 90 circuits for special relays from Harringay Arena were set up via Leeds/Burley Street repeater station. They arrived there on a Leeds-Manchester Occasional Programme circuit and a large proportion radiated to places at a considerable distance from Leeds, e.g., Aberdeen, Arbroath, Belfast, Falkirk, Glasgow, Edinburgh, Sunderland, Scarborough, Hull, Grimsby, Bradford, Sheffield, etc. A considerable amount of circuit provision work was involved but with the willing co-operation of all concerned all the relays were carried out successfully.

J. A. H.

JESMOND (NEWCASTLE) CONVERSION TO N.D./SATELLITE

When the Newcastle M.E. area was established in 1931 there remained a C.B.1 exchange, serving about 2,000 subscribers and surrounded by auto satellites and situated only a mile from the main exchange. The reason for the non-inclusion of this exchange area, Jesmond by name, was that although the equipment had been in service since 1908, it was in excellent condition and capable of at least a further five or six years' efficient service. Before conversion took place, however, various proposals and counter proposals for dispensing with the exchange area, by distributing the territory served amongst its neighbours, were considered and the consequent delays, together with the continued efficiency of the manual exchange resulted in its still being in service at the outbreak of the last war. Further consideration was temporarily suspended but eventually a decision was reached whereby the exchange area remained undisturbed and Jesmond became a satellite but lost its identity and assumed the name "Newcastle."

A single-storey building was erected, and in March, 1952, the installation of equipment (4,800 multiple) by Standard Telephones & Cables, Ltd., commenced. Shortly afterwards it was decided to add two floors to the building to accommodate a Trunk Control Centre and with these structural alterations proceeding, no mean effort was necessary to safeguard the installation. The abnormal amount of dust, ingress of water through the roof on two occasions, and the absence of a regular heating system, all due to the building operations, made conditions very trying and the forbearance of the contractors and Post Office staffs is worthy of mention.

During the progress of installation, the numbering range of the Newcastle Area came under review, and a mixed 5- and 6-digit scheme was decided upon. The Jesmond installation was regarded as not too far advanced to adopt a 6-digit scheme for that area; consequently, an amended design and layout to provide for 4th selectors was necessary.

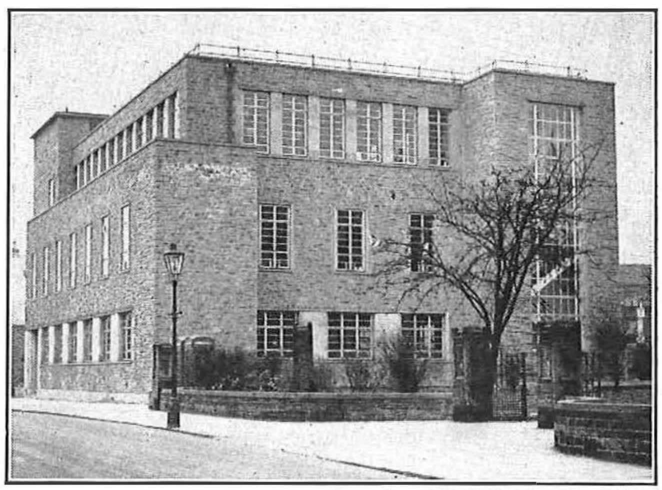
The conversion took place at midnight on Saturday, 24th April, approximately 3,300 subscribers' exchange lines and 270 junctions being affected.

Concurrently with the transfer, the conversion of four other satellite exchanges from 5- to 6-digit numbering, and the introduction of multi-metering facilities at Newcastle Main and six satellite exchanges, took place. The whole operation was accomplished without a fault of any consequence —an achievement which reflects great credit on all the staff involved.

T. P. P.

SKIPTON EXCHANGE TRANSFER

At 12.30 p.m. on Wednesday, 7th April, 1954, the new non-director automanual exchange at Skipton, Yorkshire, was brought into service. With its opening, another of the few remaining magneto exchanges in the country has been replaced. The new exchange has a multiple of 1800 and is housed in a fine three-storey building of Northumberland stone. It is a pleasing modern addition to the architecture of this old Yorkshire market town.



By courtesy of Bradford Telegraph and Argus.

SKIPTON TELEPHONE EXCHANGE BUILDING.

The changeover followed standard engineering practice and was carried out smoothly, 1,045 subscriber's lines and 232 junctions being transferred to the new exchange. The automanual board was partly opened on Tuesday, 23rd March, 1954, when the routes to eight parented U.A.X.s and the outgoing portion of the routes to Bradford, Leeds and Keighley were transferred to the new exchange. Transfer circuits were provided between the old exchange and the new to enable both boards to function simultaneously until 7th April, 1954. In this interim period coin box installations were re-equipped with auto apparatus, all calls being obtained by dialling "0" until the full transfer.

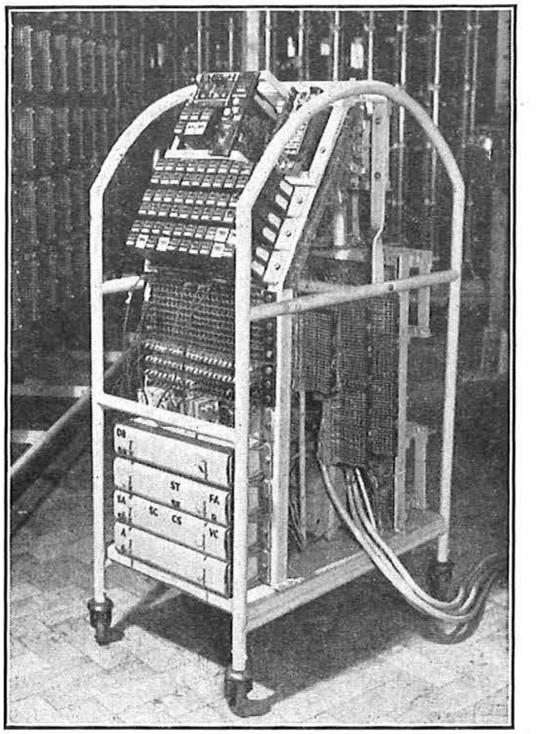
With the opening of the new exchange, Skipton became a Trunk Group Centre for 14 exchanges. At the same time the multi-metering facilities of many exchanges in the Yorkshire Dales were considerably extended and the "999" and speaking clock services were introduced.

L. J. D. B.

Scotland

TRANSPORTABLE TRAFFIC RECORDER

The Edinburgh Area contains a large number of scattered U.A.X.s and measurement of traffic has involved a considerable amount of travelling time. A transportable automatic traffic recorder has now been constructed locally, and this can be taken in a Morris Minor to a U.A.X. in advance of the



TRANSPORTABLE TRAFFIC RECORDER CONSTRUCTED BY EDINBURGH AREA.

first day of the record, connected to the equipment by flying leads and left unattended for the duration of the three-day record. It is, basically, a standard 2000-type traffic recorder fitted on a trolley (a modified Stand, Testing No. 23) and has a capacity of 600 recording points initially and 900 ultimately. This is a larger capacity than required at U.A.X.s but it is intended also to use the recorder for partial records at Siemens No. 16 non-director exchanges in Edinburgh where standard recorders are not available.

The 30-second and 30-minute timing pulses required are obtained from cold cathode discharge tube timing circuits built into the recorder, and driven from a small dry H.T. battery. A further feature which differs from the standard recorder is the provision of a circuit for switching meters at 30-minute intervals so that each hour's traffic is recorded on a separate meter. This necessitates a larger number of meters but allows the recorder to remain unattended for the whole of the three-day record.

Connection to the equipment is made by test clips and cordage on small groups, or by P.V.C. cable on larger groups.

W. G. C.

Midland Region

CIVIL DEFENCE COMMUNICATIONS STUDY AT LEICESTER

A Civil Defence communications study was held at the University College, Leicester, 29th-31st March, 1954. The study was initiated by the Home Office, Civil Defence Department, North Midland Region, and its object was to consider some of the communication problems which would arise following an air raid on a large city. Over 100 "students" attended, including representatives of the Home Office, Post Office, Local Government, Public Utilities and Hospital Management Boards. Detailed arrangements for the study were worked out by a Committee on which the Post Office, Midland Region, was represented.

The early part of the study was occupied by short talks on Civil Defence and the Fire, Police and Post Office communication systems illustrated by charts, slides and playlets. The syndicate technique was used for the consideration of specific problems. Practical demonstrations were given of radio, field telephone cable, and air raid warning systems and various items of Post Office plant, including the "999" demonstration set, were on display.

The success of the study was due in no small measure to the skilful co-ordination of the Home Office, Civil Defence Department, North Midland Region and the co-operation of all the various authorities who took part in it.

E. S. L.

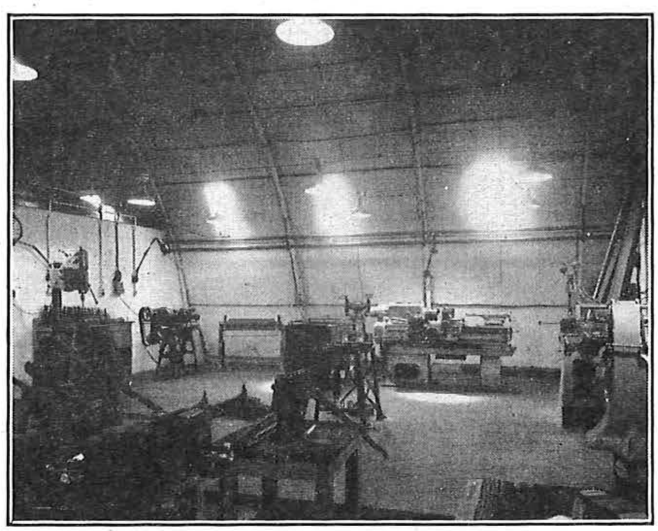
Home Counties Region

THE GUILDFORD AREA WORKSHOP

As a result of stores shortages, and the mounting cost of mechanical engineering work it was decided in 1947 to set up an Area Workshop in Guildford, covering the requirements of all Areas in the Home Counties Region. The venture proved very successful from its inception and, due to the rapid service given with low attendant costs, the volume and range of the work has increased steadily. Periodic expansion of the staff, range of machinery and premises has taken place in order to compete with this growth in demand.

From a modest beginning in a small room in the Guildford N.D. exchange, the workshop has finally expanded into a Romney hut sited within the boundary of the Guildford Engineering Concentration Scheme, where good road and rail communications are available. The situation is ideal in that good facilities exist for the delivery of raw materials, and the general working conditions are very pleasant. The premises are removed from any dwelling area.

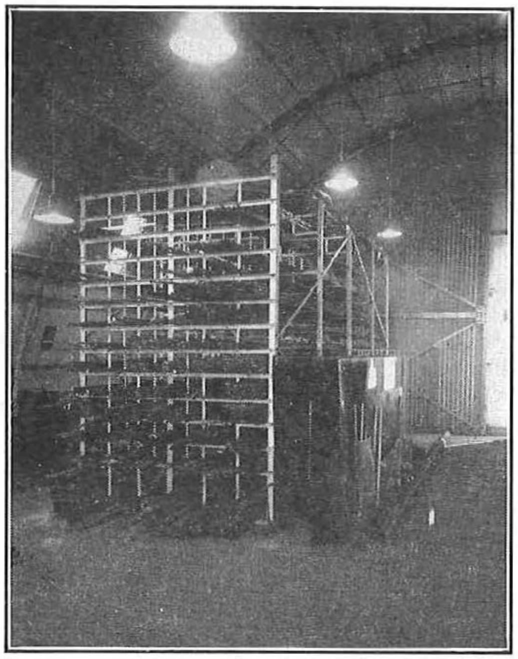
The present workshop consists of a main hall and small partitioned workshops for specialist work, the whole being



VIEW OF MAIN MACHINE HALL, GUILDFORD AREA WORKSHOP.

contained under one roof. The premises enjoy good natural lighting, have access ramps and are heated by high-pressure steam pipes. Electric lighting on the "catenary" system has been installed, resulting in an adequate artificial light density for every machine and bench.

The main hall contains the raw material storage racks, power hack saw, heavy guillotines and bending machines. These are arranged so as to allow "conveyor" or "band" methods of manufacture to be applied to the heavier items,



RAW MATERIAL RACK, GUILDFORD AREA WORKSHOP.

e.g., reinforcing material, anchor irons, etc. The material progresses from machine to machine with the minimum amount of handling, and the finished product emerges ready for packing at the distant end of the hall. Also located in the hall are the lathes, milling machine, drills, grinders, etc.

Turning and milling operations in most metals are possible. The large machine drill is equipped with a tapping box, enabling repetitive tapping operations, e.g. on meter racks, to be rapidly carried out. An 8-ton press with a set of universal bolsters enables punching operations to be carried out economically. Miscellaneous services such as high pressure hydraulic testing, coil winding, etc., are also housed in this department.

Access to the hall is through large sliding doors which permit vehicles to drive right up to the material racks for delivery, or, at the other end, to the stack of finished work.

Adjacent to the main hall the various smaller workshops are partitioned off, and specialist work may be performed without interference to the works in the hall. The facilities available are briefly described below.

(*a*) A welding shop containing heavy-current welding machines, both A.C. and D.C., together with a universal jig for the construction of cable racking. This jig can rapidly be set for any size, standard or non-standard, and by using all-welded technique rapid fabrication of racking results.

In addition to the construction of racking, many other jobs pass through the welders' hands; for economy reasons as much work as possible is done by prefabrication and subsequent welding. Oxy-acetylene welding is also available for non-ferrous work and the repair of castings.

(*b*) A blacksmithy furnished with a full-sized power-blown forge and a range of suitable tools enables most smithing operations to be undertaken. Non-standard racking bends, repairs to the heavier type of implements, etc., is work normally performed in the forge.

(*c*) A spraying shop equipped to deal with either cellulose or lead paints, enabling a good quality finish to be applied to the products of the workshop. The treatment and painting of racking, etc., is readily and rapidly carried out by spray methods. In addition to normal painting, various rust-proofing processes are available when required.

An air pressure-line is also taken into other parts of the building for cleaning and blowing-out purposes.

(*d*) A ringer repair shop equipped for the complete overhaul and repair of ringers, charging machines, electric pumps and battery chargers. Machines are stripped and any necessary mechanical repair work, e.g., new bearings, shaft trueing, commutator skim, etc. are carried out. On the electrical side, rewiring, rewinding, or reimpregnation may be undertaken as required.

Normal workshop progressive accounting methods are employed whereby the foreman mechanic has a card for each job where details of hours spent, materials used, etc., are recorded, thus enabling both a check on the work to be maintained and an accurate cost to be assessed when the operations are completed. The completed job details are filed in jackets under the appropriate serial number which serves to reduce clerical work should a repeat order be required. The final cost of a job is debited to the requisitioning Area.

Typical jobs turned out by the workshop include racking; skimming of commutators; duct seals; making and fitting motor bearings; aluminium chassis for electronic work, etc. A special adaptor, urgently required for the connection of a gas cylinder to a departmental pipe line, was made and delivered in four days. Experimental work is also carried out and some J.P.C. items incorporating tool design have had the prototypes made up in the workshop. Traffic analysers for satellite auto traffic were constructed and wired to E.-in-C. specification. Prototype electronic cable watchers have also been constructed.

Impulse machine overhauls and repairs are also carried out. A schedule of all impulse machines in the Region is held, and the machines are called in at regular intervals for overhaul. The histories of such machines are maintained at Guildford.

All spare parts for the "Transorma" letter-sorting machine were made in the workshop when they could not be obtained from any other source.

In conclusion, it has been demonstrated that the establishment of such a workshop, designed to satisfy the needs of Areas situated in the Home Counties Region, has proved of the greatest benefit and may be made to work efficiently, both from a financial and time-saving standpoint.

H. M. W.

Associate Section Notes

Birmingham Centre

Two interesting visits were made by members of this Centre during February and March, one being to the B.S.A. motor cycle plant and the other to Fisher & Ludlow's factory where metal pressings of many types are made ranging from car bodies to washing machine parts.

The final meeting of the 1953/54 session was addressed by the Chief Engineer of the City of Birmingham Water Department. He gave a most interesting and instructive talk illustrated with lantern slides, on the water supply system for this city. A visit was arranged for 27th May to see the reservoirs and dams of this system at the Elan Valley and the Claerwen Valley in Wales.

At the Annual General Meeting held on 27th April the following were elected to office for the 1954/55 session.—*Chairman:* E. W. Newnham; *Secretary:* K. G. S. Adams; *Asst. Secy. and Librarian:* W. G. Johnson; *Treasurer:* B. W. Headley; *Committee:* K. W. Gibbs, F. Edmonds, J. Farrand, R. O. Woodhouse, L. Oliver, A. E. Carpenter and S. Hayward.

It is hoped that the new programme will be arranged in time for the next notes and that it will prove once again to be popular among the members.

K. G. S. A.

Brighton Centre

The winter session opened with the film "Atomic Physics", a preview of which had been shown at the end of the previous session. Another film show followed, consisting of three films, "The Cathode Ray Tube", "A Power in the Land" and "Over and Under the Sea".

In December we received a visit from an old associate of the Brighton Telephone Area, Mr. C. H. Hartwell, who gave a very interesting talk on "The Development of the Telephone Business", copiously illustrated by slides.

January brought a lecture by an Associate Section member from Oxford, Mr. K. E. Felton, entitled "Television," which was much enjoyed by all present.

In February Mr. A. C. Young of the Senior Section gave us a talk on his visit to America in 1953 as a member of a productivity team. This talk was illustrated by slides, and proved to be of much interest.

In March one of our own members, Mr. R. G. Shepperd from Worthing, spoke to us on "Radio and Television Interference," a topical subject and one which was very well received by all those who attended.

We should also mention the visits to the B.B.C. by the Eastbourne section in November, and by Brighton in December. Unfortunately the party in each case was limited to eight members, so a draw was held, and those who were successful had an extremely interesting conducted tour around the B.B.C. building in Portland Place. Let us hope that the visit can be repeated in the next session, when some of the members who were unlucky in the draw may be able to participate.

The attendances at the meetings have been encouraging, the average being approximately 45 members. We are also pleased to be able to report the enrolment of between 40 and 50 members during the session.

We would like to thank the membership for their support, which has made worthwhile all our efforts in arranging the foregoing programme.

F. T. C.
K. E. G.

Chiltern Centre

Since our last notes, membership has increased quite substantially and attendance at meetings continues to be satisfactory.

The visit to Earls Court Signal School, though disappointing in some respects, was enjoyed by all. It was intriguing to note the hydraulic points and signals and mechanical interlocking in an otherwise electrical system!

Included in our 1953/54 programme were "Costs and Statistics," by Mr. A. H. C. Knox; visit to Hazells (local) factory, the main attraction being the huge "Goss" printing machine; and an interesting talk on "Iron and Steel" by Mr. J. Evans.

Arrangements for a visit to Siemens Bros. (Woolwich) were completed and we hope to report on the trip in the next issue.

H. J. T.

Darlington Centre

For the meeting on 16th February, 1954, our Area Engineer (Mr. F. W. Allan, A.M.I.E.E.) had chosen "The Area Engineer's Job" as the title for his subject. After an explanation of the organisation tree, Mr. Allan detailed the numerous activities of the Department, staff matters, working within budget allowance limits and co-operation with other Departments, etc., in the Area. Efficiency (with economy) was the aim. An interesting discussion followed the talk, and many points were clarified. A hearty vote of thanks was accorded Mr. Allan.

The illustrated talk on 16th March, 1954, "Thermal Insulation," by Mr. G. Walker (Chemical and Insulating Co., Ltd.), proved to be most educative. The speaker described the modern methods employed and the demands for the firm's products from a great variety of sources. Samples, which Mr. Walker had brought along, attracted much attention by the fact that their use is not common knowledge.

There was a good muster on 6th April, 1954, for Mr. L. M. Airey (Darlington Centre) and Mr. A. Walker from the Middlesbrough Centre, who spoke on "Amateur Radio" with "on-the-air" demonstration, having combined their knowledge and efforts to put on the show. Station G3GEJ was located in the lecture room temporarily. Mr. Airey explained the procedure to be followed to establish a station and the qualifications necessary to obtain a licence. The speakers, in turn, described the operation, the logging of stations, etc., and their own achievements of contacts, some of which were played back on a tape recorder. Amateur friends of the speakers in Darlington and at Whitby co-operated in the demonstration and greetings were exchanged.

The talks session has now been completed, but the Centre will not be dormant—outside visits are being planned and it behoves members not to forget the location of the Notice Board!

The Centre members are keenly disappointed that efforts to arrange a visit to *H.M.T.S. Monarch*, the cable ship, have not yet been successful.

The Annual General Meeting was held on 20th May, 1954.

C. N. H.

Dundee Centre

The Annual General Meeting of the Centre was held in Telephone House on Tuesday, 13th April, to complete a fairly successful session in which many interesting papers were read, and in which the visits have been greatly appreciated.

The new committee are now in the throes of arranging a programme for the coming session, in which they hope to hear papers on the following subjects:—

"The Storm in N.E. Scotland 1953," an outline of the cost and methods used to overcome the difficulties arising.

"Stores Control and Accounting," which will range from the issue of primary vouchers to the recording of such transactions in the Department's accounts, and will touch on clerical operations at intermediate stages and link them with engineering operations.

"The Atlantic Cable."

"From Facts to Figures," in which an explanation of the processes in getting from field operations to statistics and from the interpretation of statistics to the effect of this as applied to field operations with the object of improving quality of service.

"The Productivity Team Report."

"Growth of the Telephone," in which will be demonstrated the changes in subscribers' equipment over the past years.

"Time and The Post Office," a demonstration of the types of clocks used by the Post Office.

The visits from which a choice has to be made are:—Ferranti's Radio Equipment Works; An Observatory; An Experimental Jute Works; Beatties' Bakery; Bowar Long's Transformer Works; and a Sugar Beet Factory.

From these items it will be appreciated that the coming session offers a great opportunity of interesting entertainment for the winter evenings.

R. L. T.

Edinburgh Centre

At the March meeting of the Centre, Mr. J. J. Loughlin gave his paper, "Principles of Electronic Switching," and illustrated the main points of what was a most interesting topic by numerous slides and practical demonstrations.

There was a good attendance at the Annual General Meeting on the 13th of April, when it was noted that the membership of the Centre was still on the increase and that attendances at recent meetings had been more encouraging. The following members were elected for the new session:—

Chairman: J. H. S. Phillips; *Secretary/Treasurer:* J. R. Haggart; *Committee:* T. J. Potter, J. Kellard, J. G. Ferguson, W. F. Irvine.

After all the Centre business had been completed, the members adjourned to enjoy an excellent dinner and social evening.

Due to the interest in our magazine circulation a new list of periodicals available has been drawn up and circulated to the membership. As the committee is already at work preparing the programme for the coming session, any suggestions and offers of suitable papers will be welcomed.

This year it is hoped that the membership of the Centre will be doubled and that all members will lend active support to our activities so that more ambitious items can be undertaken in the future.

J. R. H.

Glasgow and Scotland West Centre

In February, we had Mr. Munro of the Regional Training School and two of his colleagues lecturing, with demonstrations, on "Training and Teaching Methods." This was followed in March, by Mr. W. G. Campbell, Post Office Headquarters, Edinburgh, on "Trunk Mechanisation." In April, a very successful bus run to the B.B.C. Westerglen station took place, and at the time of writing, there only remains the bus-tour

:o Loch Sloy Hydro-Electric Scheme and the three lochs to :ake place, to complete what has been acclaimed our most successful year yet.

The Annual General Meeting was held on the 23rd of April, and although the attendance was small, a considerable amount of business was completed.

The Committee received 17 suggestions for visits and a further 17 suggestions for talks, from which they have to produce the programme for 1954-55!

The following office bearers and committee members were elected:—

Chairman: J. L. Angus, B.Sc., A.M.I.E.E.; *Vice-Chairman:* R. T. Shanks; *Secretary:* J. Fleming; *Treasurer:* J. J. Brown; *Librarian:* R. Goldie; *Committee:* J. A. Brown, J. Ramsay, W. Leitch, T. Walker, W. Fotheringham, A. Wallace, W. Bolton, J. K. Moore, J. Deans, J. Morrison; *Auditors:* D. Carmichael and W. Craig. J. F.

Hastings Centre

The Session got off to a flying start with a visit in August to the extensive Gypsum Mine and processing works at Mountfield. Regrettably, danger of falling rock prevented the party from going "down under."

In November, Mr. W. A. Paul, of the Post Office Research Station, entertained the Centre with a very interesting illustrated talk on "Cinephotography in the Engineering Department."

Film shows were arranged for September and February, a varied programme being secured for both showings. "The Cornish Engine"; "Hands full of Power," a colour film showing the manufacture of Wolf's hand tools; and "Railway Electrification in Brazil," were the main films.

October, December and January were reserved for local associate members, the subjects covered being, "The Communications of Co-operation in Modern Industry," by W. W. Yeats; "Carrier Telephony," by J. H. Bloor; and "An Approach to T.V.," by H. Northwood.

The Annual General Meeting was held in March. The following were elected to form the committee: Messrs. K. Noakes, Holdstock, Little, Bloor, Loker and H. Northwood. The Committee now has two external members. Other officers continue unchanged.

To complete the winter's formal meetings a Senior Section member, H. Wales, gave a talk on "Coaxial Carrier Systems."

The session finished as it commenced with a visit, this time to the local power station. Thanks to the staff there, we spent an informative evening inspecting and asking questions about the equipment.

We would like to see more external staff as members—why not join before next winter? L. J. S. W.

Leicester Centre

The Annual General Meeting was held on 26th April, 1954, with the President, Mr. E. S. Loosemore, B.Sc., M.I.E.E., in the Chair. Mr. Loosemore was unanimously re-elected to serve for the 1954/55 session. Other offices were filled as follows:—*Chairman:* Mr. C. J. Wykes; *Vice-Chairman:* Mr. R. A. Medland; *Secretary:* Mr. T. E. Lord; *Assistant Secretary:* Mr. M. K. Wilkinson; *Treasurer:* Mr. J. A. Richardson; *Committee:* Messrs. A. F. Allsopp, A. S. Bradshaw, S. Bircham, L. C. Chappell and D. S. Ladkin; *Auditors:* Messrs. . R. Cambridge and R. A. Cave.

Both the Secretary and Treasurer gave encouraging reports. The effective membership is increasing steadily although the attendance at meetings varies considerably. With an excellent programme in prospect it is hoped that members will turn up in force at each meeting.

In reviewing events during the past winter session we have held some extremely interesting meetings. Outstanding among them was a talk, "Photography," with practical demonstrations, by E. Richardson, Leading Technical Officer. T. E. L.

London Centre

The disadvantages of having to arrange a lecture programme well in advance of the actual dateshave certainlybeen evident to the General Secretary this session. The last three lectures had to be altered at very short notice due to unforseen circumstances. Great credit is due to him for the way new lecturers were found and the lecture programme was able to continue without a break.

On 27th April, Mr. G. W. Bates a member of London Test Section presented his paper on "The Post-War Developments in the Testing of Dials, Automatic." The lecturer outlined the developments in the technique of dial testing both to laboratory standard and also for large quantities of dials. Hard valve and cold cathode tube counting methods were included and practical demonstrations given where possible. The demonstrations included the electronic dial tester, hard valve impulse counter and an electronic impulse generator.

At the time of writing, the final event of the 53/54 session was to be the A.G.M. on 28th May, at the I.E.E. Savoy Street, with Mr. F. I. Ray, the London Centre President, delivering his lecture entitled "This Telephone Business." E. W. B.

Middlesbrough Centre

A very pleasing ceremony took place in the Mayor's Parlour at West Hartlepool on Saturday, 1st May, when Mr. J. W. Dodds, Leading Technical Officer, a member of this Centre, received from Lord Lawson the British Empire Medal which had been awarded him by Her Majesty The Queen in the New Year Honours List. The Regional Director, Telephone Manager, and several of Mr. Dodds' colleagues were present. Distinction is added to the occasion by the fact that only eight members of the Engineering Department, including the Engineer-in-Chief, featured in the Honours List.

With the Annual General Meeting almost on hand this Centre can look back over yet another successful year. The advertised programme, which included visits to local technical and industrial organisations and also the customary regular lectures, was carried through without any hitches.

During the latter part of this year our enthusiasm has been somewhat damped by the sudden serious illness of our Chairman, Wilf Costello. It will be remembered that he was the recipient of a national prize for a written paper last year. His efforts to maintain and increase the centre activities have never flagged. We all sincerely hope that Wilf's recovery is speedy and lasting and that he will be back with us soon.

Many thanks to K. Hamilton for filling the vacant date on the programme. Although not a large audience, we found many interesting points in the paper "Modern Carrier Equipment" to converse on.

G. F.

Tunbridge Wells Centre

At the Annual General Meeting held on 12th April, 1954, the following officers were elected for the 1954/55 Session: *Chairman:* Mr. G. Kingswood; *Secretary:* Mr. E. L. English; *Treasurer:* Mr. F. W. Archer; *Auditors:* Messrs. K. Muggridge and S. H. Wilson; *Committee:* Messrs. R. Charman, R. G. Dancy, F. Glazier, R. A. Goswell, J. A. V. Sparrowe, K. H. Waddell and R. Winn.

During the past year our membership has increased, attendances at meetings have improved and a greater interest has been taken by staff in the Associate Section. Although the committee are at present arranging the 1954/55 programme, we have finally reached a period when members have offered papers without the usual appeals.

A library has been formed and arrangements have been made to purchase locally a number of technical journals for circulation to our members.

Our A.G.M. was one of the liveliest meetings we have held and it is hoped that the same spirit will prevail throughout the future of the Tunbridge Wells Centre.

E. L. E.

Staff Changes

Promotions

Regl. Engr. to Depy. C.R.E.

Name	Region	Date
Straw, J. G.	Scot. to L.T. Reg.	1.3.54

Snr. Exec. Engr. to Asst. Staff Engr.

Name	Region	Date
Clarke, E. F. S.	E.-in-C.O.	1.3.54
Welch, S.	E.-in-C.O.	23.2.54

Area Engr. to Regl. Engr.

Name	Region	Date
Blackburn, E.	N.W. Reg. to Scot.	15.3.54

Exec. Engr. to Snr. Exec. Engr.

Name	Region	Date
Hancock, L.	Mid. Reg.	25.2.54
Rees, T. J.	E.-in-C.O.	8.3.54
Coulson, J. N.	N.W. Reg.	1.4.54
Archbold, R. B.	E.-in-C.O.	15.3.54
Brice, P. J.	E.-in-C.O.	15.3.54
MacDiarmid, J. F.	E.-in-C.O.	15.3.54
Williams, J.	E.-in-C.O.	1.4.54
Harris, D. J.	E.-in-C.O.	5.4.54
Waters, H. S.	E.-in-C.O.	12.4.54
Day, J. V.	N.E. Reg.	10.5.54

Exec. Engr. (Open Competition)

Name	Region	Date
Fenton, K. C.	E.-in-C.O.	20.4.54
Earls, J. C.	Scot. to E.-in-C.O.	13.1.54

Executive Engineer (Limited Competition)

Name	Region	Date
Wheele, D. W. E.	E.-in-C.O.	8.3.54
Oatey, L. W.	E.-in-C.O.	8.3.54
Shaw, S.	E.-in-C.O.	6.3.54
Groves, H. J.	E.-in-C.O.	15.3.54
Nunn, R. G. W.	L.T. Reg.	22.3.54
Welsh, A. W.	E.-in-C.O.	23.3.54
Eckersley, G. B.	E.-in-C.O.	1.4.54
Lang, W. N.	E.-in-C.O.	22.3.54
Marsh, R. V. R.	N.W. Reg.	22.3.54
Lillie, S.	E.-in-C.O. to H.C. Reg.	5.4.54
Blanchard, C. H.	E.-in-C.O.	5.4.54
Step, E. C.	L.T. Reg. to E.-in-C.O.	20.4.54
Samuels, F. L. N.	E.-in-C.O.	20.4.54
Stewart, W. F. G.	Scot.	5.4.54
Drinkwater, R. W.	E.-in-C.O.	20.4.54
Swann, G. F.	E.-in-C.O.	20.4.54
Millar, J. B.	N.I. Reg. to E.-in-C.O.	10.5.54
Gilpin, F. A., D.S.C.	Mid. Reg.	29.3.54

Asst. Engr. to Exec. Engr.

Name	Region	Date
Randall, F. L.	E.-in-C.O.	27.2.54
Gaut, R. G.	E.-in-C.O.	27.2.54
Selwood, S. J.	E.-in-C.O.	27.2.54
Shelley, G. J.	E.-in-C.O.	27.2.54
Gibson, R. W.	E.-in-C.O.	27.2.54
Tite, L. G.	E.-in-C.O.	27.2.54
Standage, C. F.	E.-in-C.O.	27.2.54
Ruck, E. F.	E.-in-C.O.	27.2.54
Jennings, S. W.	H.C. Reg. to E.-in-C.O.	15.3.54
Oakford, E. R.	L.T. Reg. to E.-in-C.O.	10.3.54
Redhouse, A. R.	E.-in-C.O.	29.3.54
Cooper, R. P.	S.W. Reg. to E.-in-C.O.	5.4.54
Cunninghame, J. W. N. S.	W.B.C. to E.-in-C.O.	20.4.54
Fryatt, M. E.	H.C. Reg.	26.4.54
Roberts, A.	Mid. Reg.	14.5.54
Dennis, H.	Mid. Reg. to E.-in-C.O.	17.5.54
Allen, C. N.	E.-in-C.O.	20.4.54

Asst. Engr. (Limited Competition)

Name	Region	Date
Perkins, M. R.	L.T. Reg.	15.2.54
Comber, G.	E.-in-C.O.	7.4.54
Adair, J. C.	E.-in-C.O.	30.3.54
Toussaint, G. C. C.	E.-in-C.O.	24.4.54
Taylor, J. R.	E.-in-C.O.	24.4.54
Lane, J.	E.-in-C.O.	24.4.54
Evans, J.	E.-in-C.O.	24.4.54
London, A. G.	E.-in-C.O.	24.4.54
Cheeseman, D. S.	E.-in-C.O.	24.4.54
McLaren, A.	E.-in-C.O.	3.5.54
Richardson, F. S.	E.-in-C.O.	3.5.54
Knox, D. M.	H.C. Reg. to E.-in-C.O.	10.5.54
Verdon, A. T.	L.T. Reg.	3.5.54
Mason, D. J. H.	E.-in-C.O. to N.Ire. Reg.	10.5.54
Harrison, A. F.	E.-in-C.O.	3.5.54

Asst. Engr. (Limited Competition)—continued.

Name	Region	Date
Spurgin, D. S.	L.T. Reg. to E.-in-C.O.	17.5.54
Morgan, E. P.	W.B.C.	24.5.54
Jennings, P. H.	Mid. Reg. to N.I. Reg.	24.5.54
Westcott, R. J.	S.W. Reg. to E.-in-C.O.	17.5.54
Brown, N. W.	E.-in-C.O.	17.5.54
Veneear, A. F.	E.-in-C.O. to L.T. Reg.	12.2.54
Osborne, E. J.	E.-in-C.O.	24.5.54
Black, A. R.	H.C. Reg. to N.W. Reg.	3.5.54
Mansfield, W. V. L.	L.T. Reg.	10.5.54
Davies, J. W. L.	W.B.C.	24.5.54
Fagg, D. E.	L.T. Reg.	24.5.54
Simcox, M. S.	Mid. Reg.	24.5.54
Shorland, F. J.	S.W. Reg.	24.5.54
Clement, D. M.	Mid. Reg.	24.5.54
Fountain, L. J.	E.T.E.	24.5.54
Taylor, R. G.	H.R. Reg. to Mid. Reg.	24.5.54
Hussey, E. D. F.	E.-in-C.O.	31.5.54
Bradshaw, G. T.	E.-in-C.O.	31.5.54
Luff, W.	N.E. Reg. to E.-in-C.O.	31.5.54

Inspector to Asst. Engr.

Name	Region	Date
Hardy, A. McH.	N.E. Reg	17.12.53
Hines, J. E.	L.T. Reg.	1.1.54
Constable, F. A.	L.T. Reg.	29.1.54
Owens, J.	W.B.C.	7.1.54
Hunt, G. V.	N.E. Reg. to E.-in-C.O.	1.5.54

Tech. Offr. to Asst. Engr.

Name	Region	Date
Erskine, J. F.	E.T.E.	15.2.54
Miller, G. H.	L.T. Reg. to E.-in-C.O.	8.3.54
Beardmore, A. R.	Mid. Reg. to E.-in-C.O.	16.4.54
Askew, E. A.	N.E. Reg. to E.-in-C.O.	6.3.54
Edge, P. C.	W.B.C. to E.-in-C.O.	16.4.54
Holder, J. H.	N.E. Reg to E.-in-C.O.	6.3.54
Whittingham, J. R.	W.B.C. to E.-in-C.O.	16.4.54
Fisher, J.	N.E. Reg to E.-in-C.O.	6.3.54
Mackintosh, J. J. D.	Scot.	10.3.54
Simpson, E. C.	N.E. Reg. to E.-in-C.O.	13.3.54
Tulloch, J. R.	Scot.	13.3.54
Stokes, A. E.	Mid. Reg. to E.-in-C.O.	13.3.54
Ferris, A. F.	S.W. Reg.	30.11.53
Merrick, W. A. W.	Mid. Reg.	14.5.54
Carroll, J. E.	L.T. Reg.	18.11.53
Rush, R. T. G.	L.T. Reg.	4.8.53
Lemon, P. J.	L.T. Reg.	7.5.53
Britton, A. W.	L.T. Reg.	19.8.53
Watkins, F. E.	L.T. Reg.	29.6.53
Cursley, J. J.	Mid. Reg.	16.2.54
Heppinstall, R. V.	N.E. Reg.	22.3.54
Thompson, D.	N.E. Reg.	18.2.53
Smith, H. R.	N.E. Reg.	21.3.54
McDowell, J. H.	N.Ire. Reg.	1.2.54
Dagley, R. C.	H.C. Reg.	28.1.54
Lamming, D. D.	H.C. Reg.	1.10.53

Tech. Offr. to Inspector

Name	Region	Date
Briggs, W. S.	N.W. Reg.	19.3.54

Tech. I. to Inspector

Name	Region	Date
Gardner, S. C.	L.T. Reg.	19.11.53
Murdoch, C. T.	L.T. Reg.	20.11.53
Piper, E.	L.T. Reg.	7.12.53
Gill, R. C.	L.T. Reg.	26.10.53
Eagles, H. S. H.	L.T. Reg.	2.12.53
Alderslade, R.	L.T. Reg.	7.12.53
Lawrence, W. S.	L.T. Reg.	18.11.53
Bolding, F. D.	L.T. Reg.	19.1.54
Robinson, W. S.	L.T. Reg.	1.1.54
Green, E. R.	L.T. Reg.	9.1.54
Reece, R. A.	L.T. Reg.	14.12.53
Catchpole, H.	L.T. Reg.	29.1.54
Pagan, A. B.	L.T. Reg.	28.1.54
Pattison, J. W. E.	N.E. Reg.	30.4.53
Atkinson, J. H.	N.E. Reg.	6.4.54
Hollingworth, G. K.	N.E. Reg.	27.2.54
Preston, J. J. P.	W.B.C.	10.3.54
Hodgson, S. H.	N.W. Reg.	23.3.54
McAlinder, D.	N.W. Reg.	30.3.54
Aitken, J. A.	Scot.	9.1.54
Palmer, P. W. A.	Scot.	27.3.54
Tytherleigh, W. A.	Mid. Reg.	29.3.54

Transfers

Name	Region	Date
Snr. Exec. Engr.		
Rattue, P. J.	E.-in-C.O. to H.C. Reg.	5.4.54
Exec. Engr.		
Home, J. K.	S.W. Reg. to E.-in-C.O.	8.3.54
Dickenson, C. R.	S.W. Reg. to Colonial Service	8.9.50
Johnson, E. S.	E.-in-C.O. to Mid. Reg.	20.4.54
White, C. F.	E.-in-C.O. to H.C. Reg.	26.4.54
Sims, A. E. J.	E.T.E. to L.T. Reg.	1.5.54
Boggis, R. J.	E.-in-C.O. to E.T.E.	1.5.54
Berresford, B. H.	E.-in-C.O. to Mid. Reg.	3.5.54
Dalton, A. W.	N.W. Reg. to E.-in-C.O.	26.4.54
Asst. Engr.		
Busby, K. D.	E.-in-C.O. to L.T. Reg.	10.3.54
Asst. Engr.—continued.		
Brooks, H. P.	L.T. Reg. to E.-in-C.O.	10.3.54
Savage, E. P.	E.T.E. to Min. of Transport	24.1.54
Ritchie, J. E.	L.T. Reg. to E.-in-C.O.	20.4.54
Flanagan, F. B.	E.-in-C.O. to W.B.C.	2.5.54
Browne, S.	E.-in-C.O. to Colonial Service	1.11.50
Long, J. H.	L.T. Reg. to E.-in-C.O.	10.5.54
Drake, C. P.	E.-in-C.O. to Min. of Supply	10.5.54
Snr. Exptl. Offr.		
Edwards, W. T.	BM Test Section to Dept. Atomic Energy	1.3.54
M.T.O. II		
Gibson, J.	E.-in-C.O. to Scot.	1.5.54

Retirements

Name	Region	Date
Area Engr.		
Owen, W.	N.W. Reg.	31.3.54
Markey, J. M., M.B.E.	N.E. Reg.	14.4.54
Exec. Engr.		
Thornley, H. G.	N.W. Reg.	14.1.54
Wood, J., M.B.E.	E.-in-C.O.	21.3.54
Bentley, F. E.	E.-in-C.O.	31.3.54
Thomson, A.	Scot.	2.4.54
Flood, Dr. J. E.	E.-in-C.O. (*Resigned*)	30.6.54
Blott, F.	L.T. Reg.	30.4.54
Asst. Engr.		
Williamson, A. A.	L.T. Reg.	9.3.54
Stuart, J. F.	L.T. Reg.	6.1.54
Traylor, W. L.	L.T. Reg.	31.3.54
Clark, L. L.	L.T. Reg.	26.3.54
Crane, L. H.	N.W. Reg.	31.3.54
Keen, F. L.	Mid. Reg.	31.3.54
Hawkins, W. J.	L.T. Reg.	26.2.54
Woodward, R. F. C.	L.T. Reg.	15.3.54
Mason, A.	N.W. Reg.	2.4.54
Danby, G. A.	W.B.C.	19.2.54
Pratt, F. A. N.	W.B.C.	14.2.54
Asst. Engr.—continued.		
McCarthy, G. W.	E.-in-C.O.	26.4.54
Wilshire, A. V.	E.T.E.	22.6.54
Goodman, B. C.	E.T.E.	31.5.54
Hillier, A.	N.W. Reg.	30.3.54
Dooley, T.	N.Ire. Reg.	30.6.54
Tedford, S. J.	N.Ire. Reg.	19.7.54
Barnes, F. L.	L.T. Reg.	29.5.54
Kitteridge, H.	H.C. Reg.	6.2.54
Summarsell, R.	H.C. Reg. (*Resigned*)	31.3.54
Woods, R. N.	E.-in-C.O.	24.5.54
Inspector		
Simons, E. F.	L.T. Reg.	27.2.54
Beetham, T.	N.W. Reg.	31.3.54
Little, S.	N.E. Reg.	5.4.54
King, J. W.	L.T. Reg.	9.4.54
Lyth, F.	Mid. Reg. (*Resigned*)	7.5.54
Morrison, N.	Scot.	31.5.54
Regl. M.T.O.		
Chapman, E.	N.W. Reg.	25.4.54
Allen, J. E.	Scot.	30.4.54

Deaths

Name	Region	Date
Exec. Engr.		
Padgham, F. V.	H.C. Reg.	5.4.54
Bell, G. W.	L.T. Reg.	14.4.54
Drysdale, T. W.	Scot.	14.5.54
Asst. Engr.		
Weller, A. E.	Mid. Reg.	27.2.54
Wright, G. W. P.	N.E. Reg.	7.3.54
Affleck, C. S.	L.T. Reg.	4.4.54
Asst. Engr.—continued.		
Rutherford, T.	S.W. Reg.	1.5.54
Allbon, G. E.	H.C. Reg.	15.5.54
Inspector		
Wilson, T.	Scot.	26.2.54
Bannerman, C. S.	Scot.	11.3.54
Williams, M.	S.W. Reg.	20.3.54
Dallman, A. S.	L.T. Reg.	25.4.54
Cherry, E. A.	L.T. Reg.	29.4.54

Correction.

The details regarding Alford, S. B., in the April 1954 issue were incorrect and should have indicated promotion from Leading Draftsman (E.-in-C.O.) to Senior Draftsman (Factories Department).

Book Reviews

"Relays for Electronic & Industrial Control". R. C. Walker, B.Sc., A.M.I.Mech.E., A.M.I.E.E. Chapman & Hall 300 pp. 187 ill. 42s.

In its ten chapters this book covers the fundamentals of relay design together with the principles of use in many industrial and telecommunication applications.

Theories governing design of relays are explained in a sufficiently general manner that their application to the many types of relay described can be readily understood. The important problem of arc quenching at contacts is well covered and methods of reducing contact erosion in various light and heavy current applications are explained. Numerous circuit elements describing the use of relays to give required effects permit a fundamental understanding of switching techniques.

To the potential switching circuit engineer the book provides a useful introduction to the art, and to the engineer in a less specialised field the information regarding the potentialities of relays for control purposes could be of great use.

L. F. S.

"Plastics Progress, 1953" (Papers and Discussions at the British Plastics Convention). Edited by Phillip Morgan, M.A. Iliffe & Sons, Ltd. 439 pp. 50s.

This book records the papers and discussions at the second British Plastics Convention, held in London in 1953. On the dust cover it says: "This book is an up-to-date report on several important branches of plastics technology." That is one way of describing it; the reviewer would prefer to say that it is a fascinating volume describing many exciting developments in the plastics field.

The reviewer was particularly interested in the 1951 volume, because it described the fruition of much work he had seen in (the work's) infancy. The 1953 Plastics Progress is interesting for just the opposite reason; it is full of information on entirely new projects and fully deserves being termed exciting.

With the exception of the section on Selling to the Public, there is not a paper in the whole book which is not of direct interest to communications engineers and scientists, particularly to those whose work is mainly research and development. The emphasis is markedly on the side of structural developments which are probably commercially attractive, and the development of such things as thin dielectrics for capacitors receives no mention. Considering the quantities involved, this is understandable and in any case we cannot have everything in one volume; perhaps we may hope for some discussion of this in the next.

The production is good and the price, by modern standards, is not high. The book is one the professional cannot afford to be without, but is unlikely to reach many people who could both profit from and enjoy reading it.

I.P.O.E.E. Library No. 2178. C. E. R.

SHORTER NOTICES

"The Insulation of Electrical Equipment." Edited by Willis Jackson, D.Sc., D.Phil., M.I.E.E., F.R.S. Messrs. Chapman & Hall. 340 pp. 42s.

Contains the series of lectures arranged by Professor Willis Jackson in 1952, on the general principles of insulation and the current practices in industry, each chapter being the work of an authority on the subject concerned.

"Electrical Accidents and their Causes, 1951." Published by H.M.S.O. for Factory Department, Ministry of Labour and National Service. 76 pp. 3s.

A detailed analysis of electrical accidents during 1951 in the fields of electricity supply, industrial application and electronic engineering. An appendix lists certificates issued to manufacturers by H.M. Chief Inspector of Factories in respect of electrical apparatus for use in certain specified atmospheres.

"National Physical Laboratory Report for the Year 1953." Published by H.M.S.O. for Department of Scientific and Industrial Research. 73 pp. 3s.

The 1953 report on the work of the N.P.L. covering each division of the organisation, viz., Light, Electricity, Aerodynamics, Mathematics, Metallurgy, Metrology, Physics, Ships, Electronics and Test House.

Communications

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

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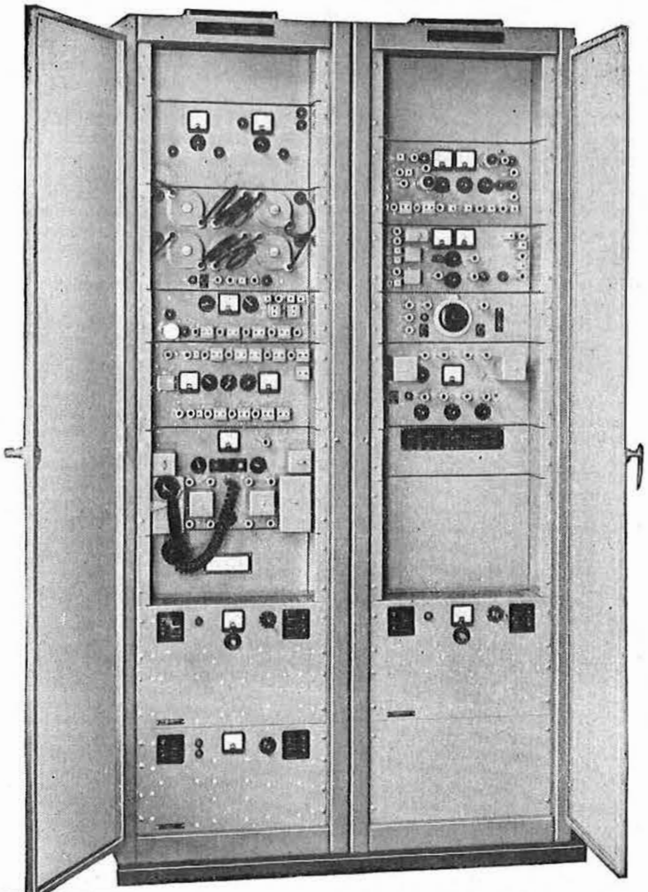

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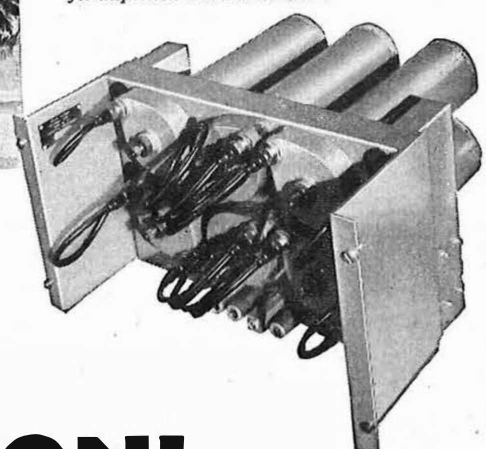

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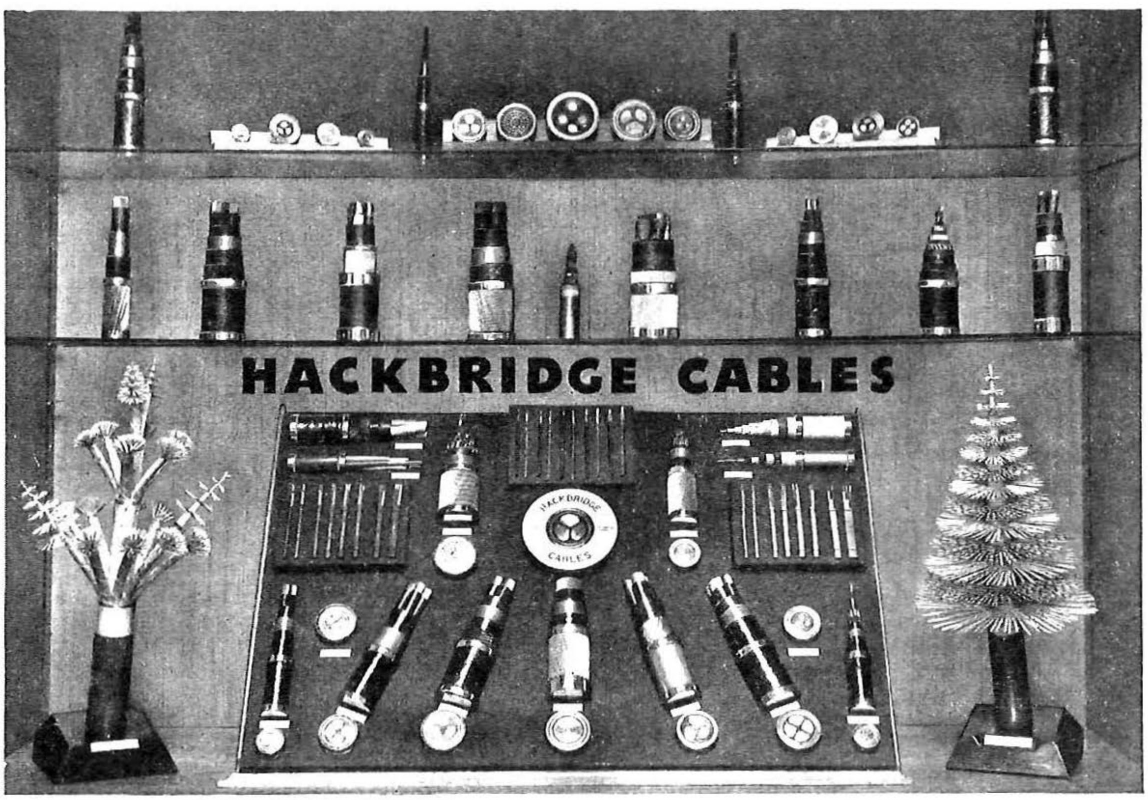

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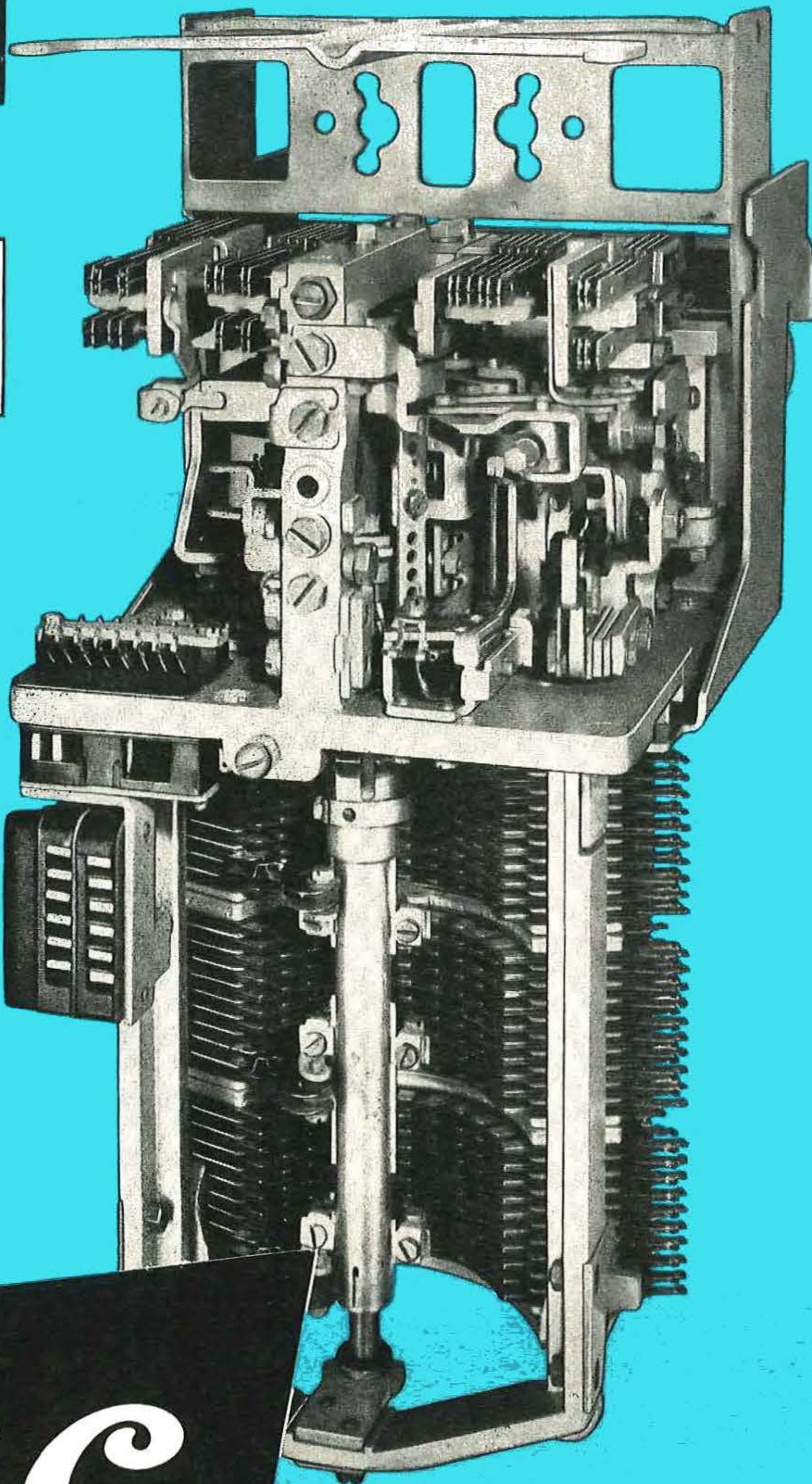

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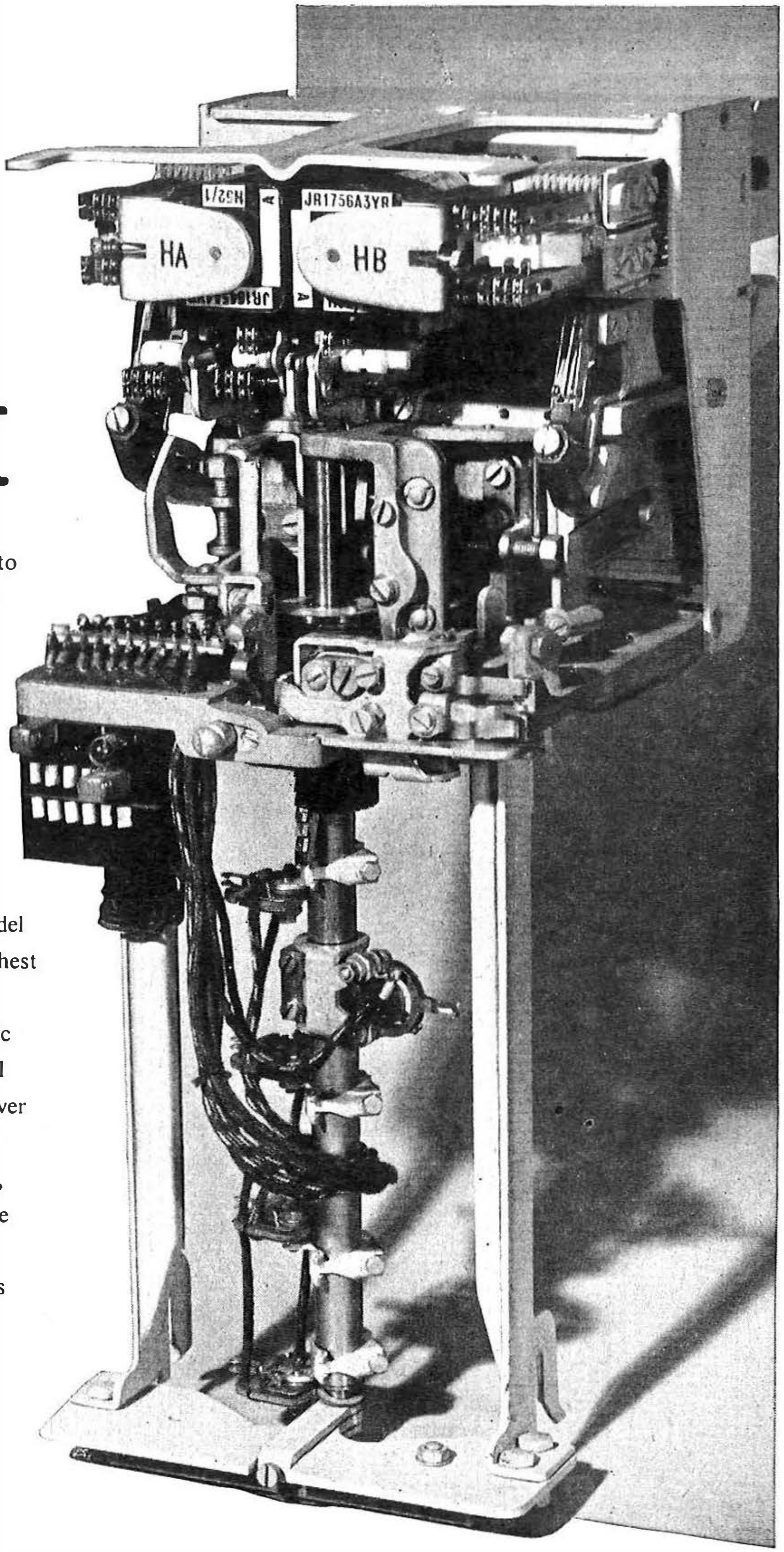

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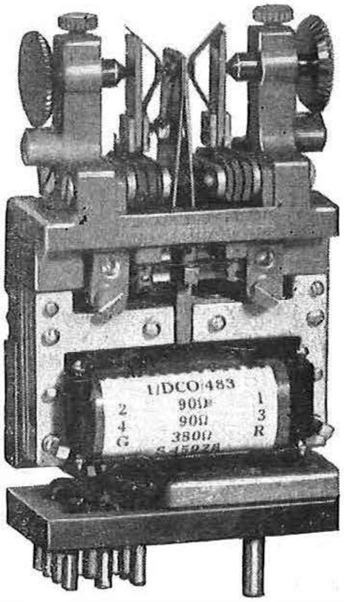

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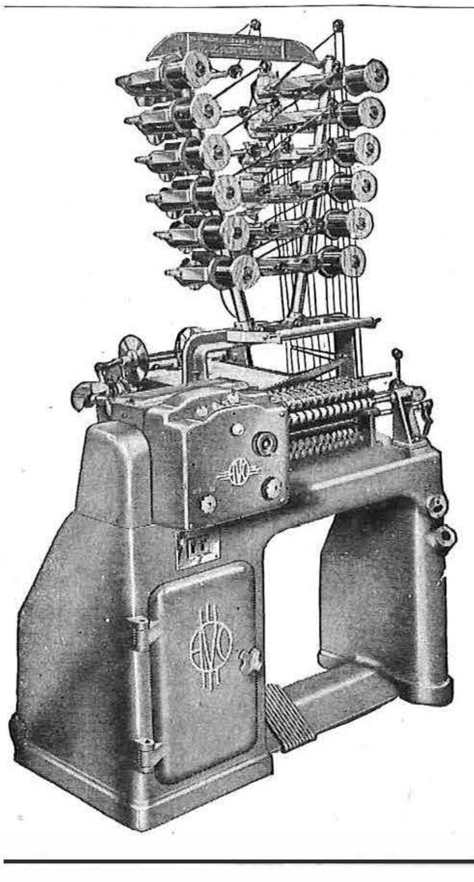

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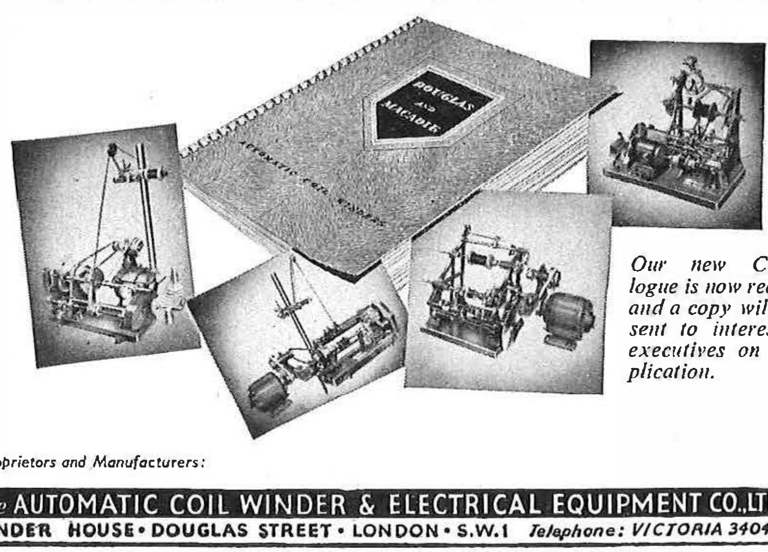

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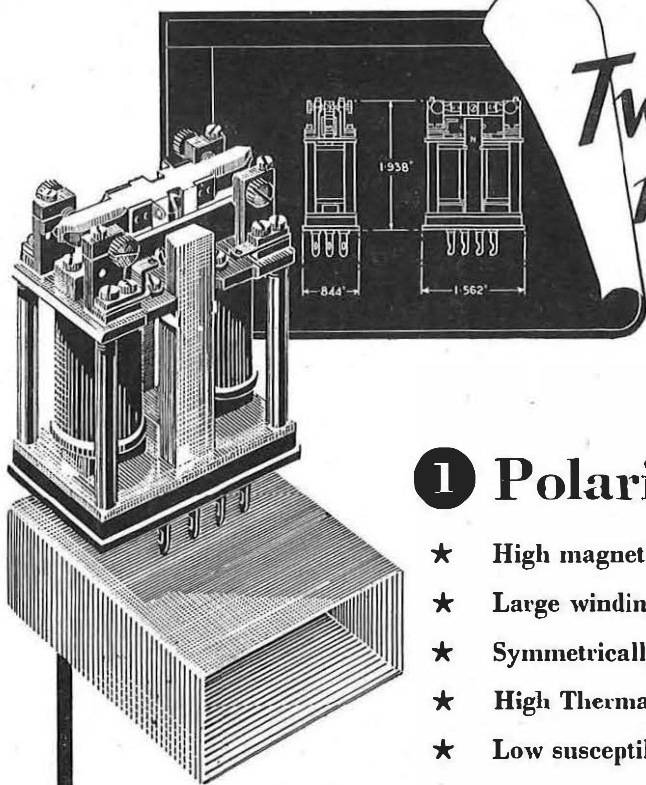
1·938"
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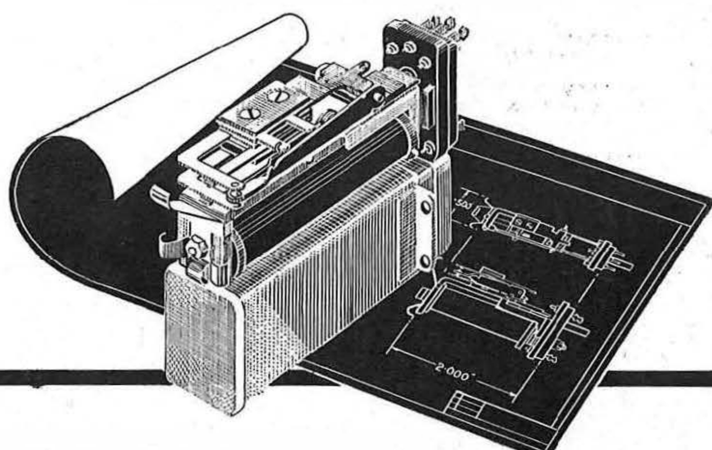
1·562"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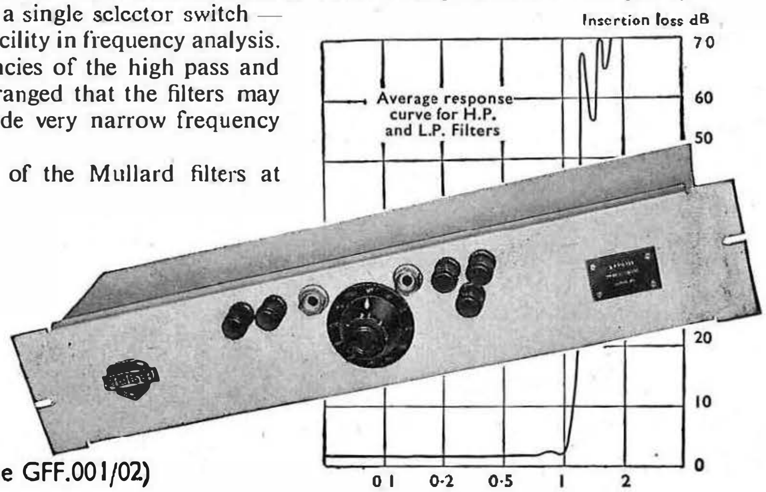

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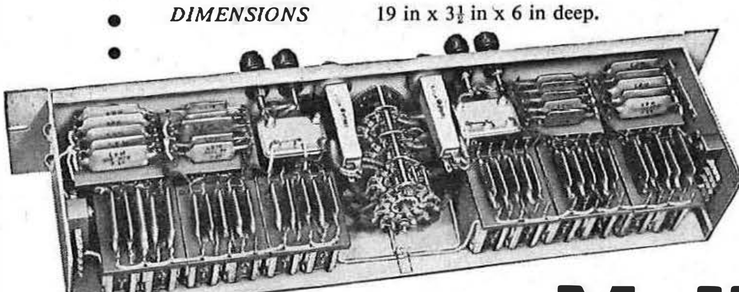
IMPEDANCES	Input and output 600 ohms, balanced or unbalanced
STOPBAND ATTENUATION	At 0.8 x fc — 50 dB At 0.6 x fc — 60 dB
PASSBAND ATTENUATION	3dB ± 1 dB from 1.1 x fc to 20 or 25 kc/s depending on cut-off frequency (fc)
DIMENSIONS	19 in x 3½ in x 6 in deep.

Low-Pass Filters (Type GFF.001/01)

CUT-OFF FREQUENCIES (fc)	400, 600, 900, 1350, 2025, 3040, 4500, 6830, 10250, 15400 c/s selected by 10-way switch
IMPEDANCES	Input and output 600 ohms, balanced or unbalanced
STOPBAND ATTENUATION	At 1.25 x fc — 50 dB At 1.35 x fc — 60 dB
PASSBAND ATTENUATION	2dB ± 1dB from 50 c/s to 0.9 x fc
DIMENSIONS	19 in x 3½ in x 6 in deep



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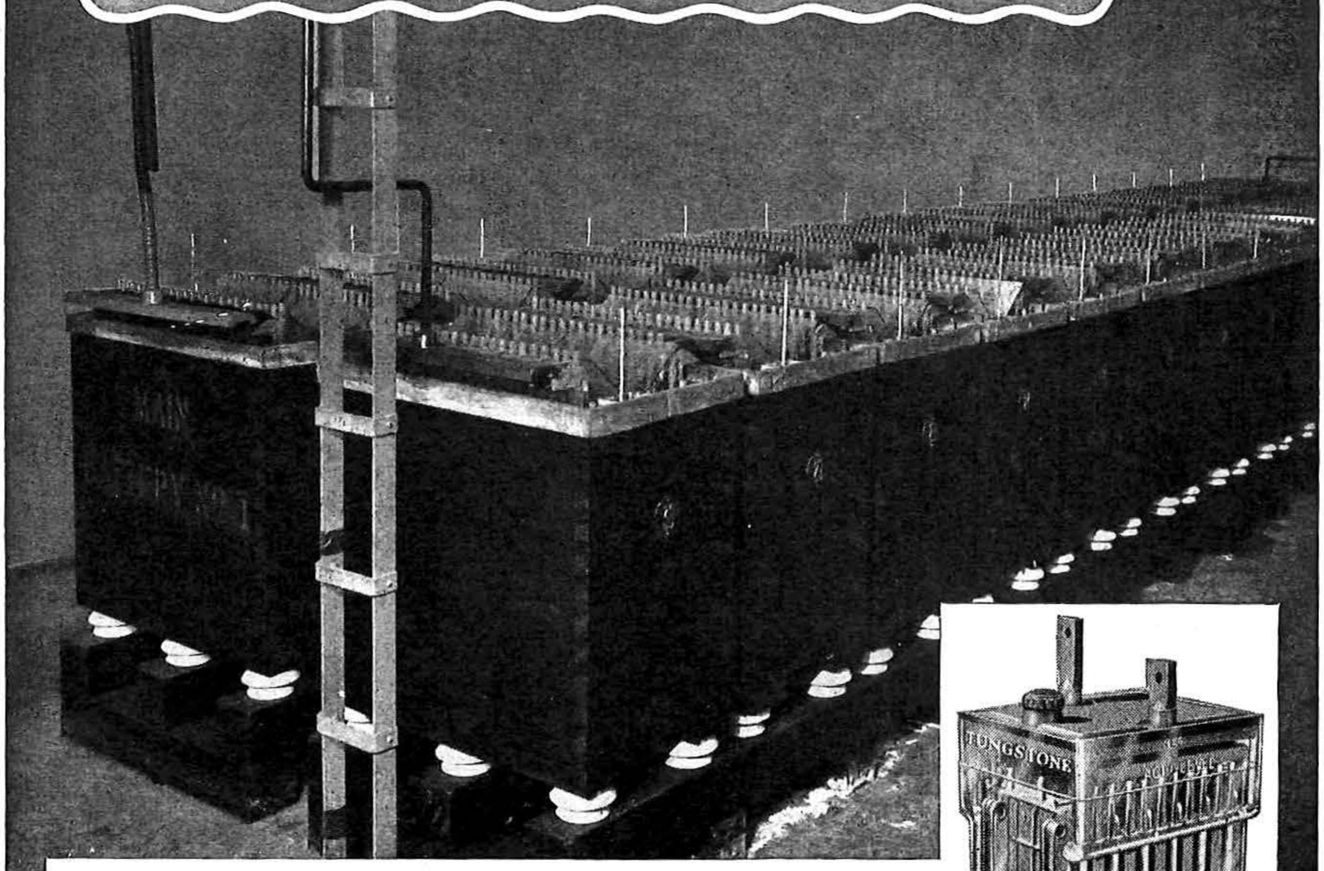

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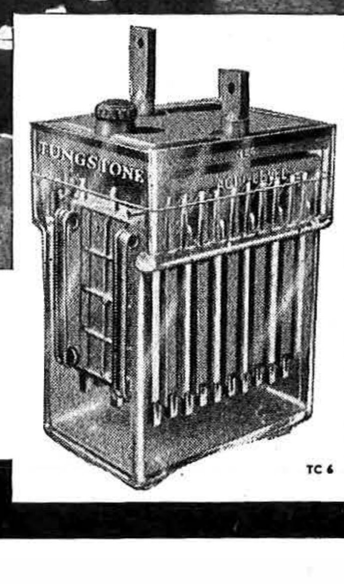
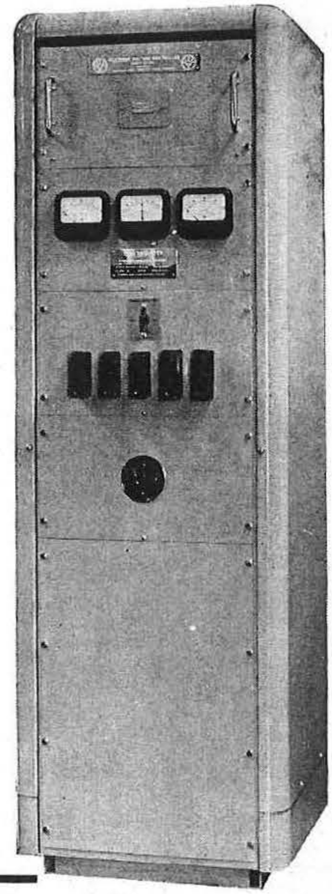


TC 6

F

THE TRANSBOOSTER



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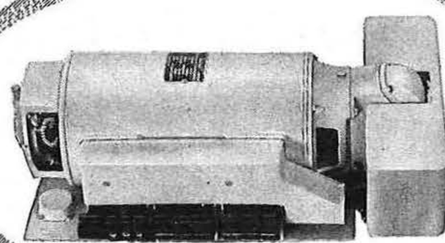
The latest Walter Jones Ringing, tone and pulse machine gives more output in less space. Made in battery operated and polyphase mains operated models. Output: 80 watts of ringing current, 400 c.p.s. 400/33 c.p.s. and dialling tones. Tones are of adjustable level. It has capacity for sixteen interrupters of simple or multiple spring piles. It is suitable for rack mounting with vibration insulation between machine and rack. Tone and ringing alternators have permanent magnet fields and require no exciting current, chokes or controls. Mains operated machines have no brushes nor windings on the rotating member and are free from radio interference.



WITH THE NEW WALTER JONES RINGING TONE & PULSE MACHINE

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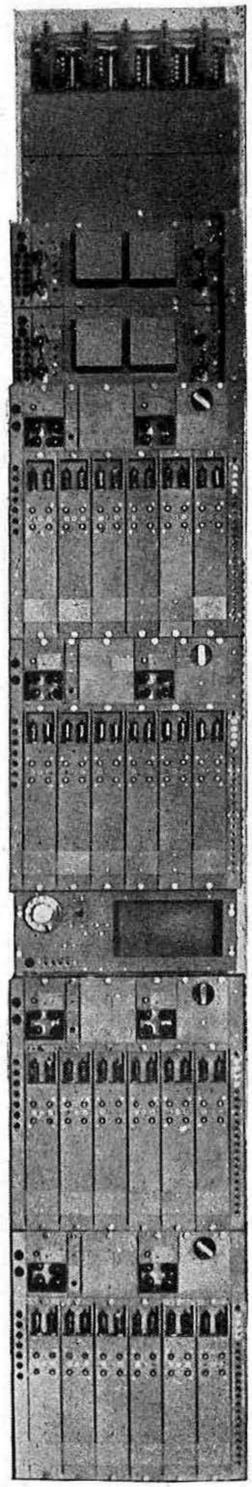
SKILLMAN

Twelve Channel Groups

COMPLETE WITH DIALLING EQUIPMENT



for use on

CARRIER TYPE CABLES

12, 24 or 48 Channel Groups are available conforming, in all respects to C.C.I.F. recommendations.

COAXIAL CABLES

60 Channel Super Groups are available to C.C.I.F. recommendations.

RADIO LINKS

Up to 120 Channels can be provided on existing links or in conjunction with new Murphy developments (see opposite).

✳ Each channel reaches the switching equipment as a voice circuit plus the equivalent of two extra copper wires from end to end for signalling.
The advantages of this from standardisation and organisational points of view are becoming widely recognised and, in making any economic studies, the complete elimination of the large groups of relays, required for pulse signalling systems, should not be overlooked.

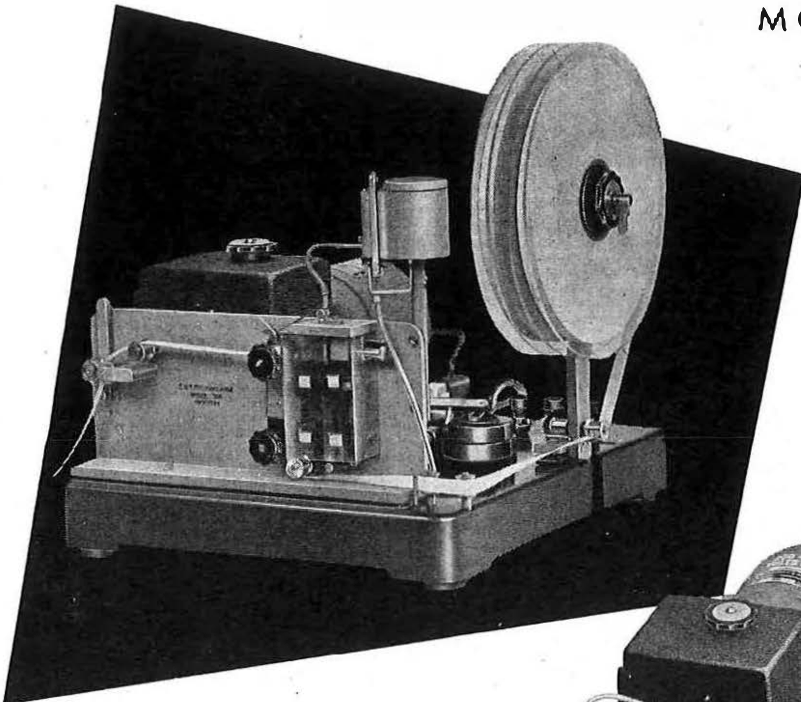
✳ Can be combined with T.O.M.E.

The illustration shows 24 channel ends, complete with signalling gear, 2-wire V.F. terminations, amplifiers, etc., all mounting on one side of a rack; 48 channels will mount on a double-sided rack.

G.N.T.

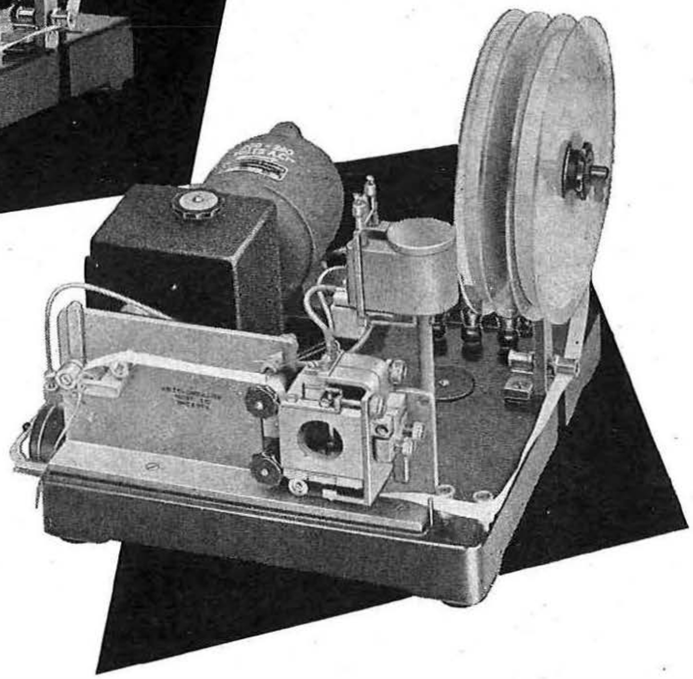
UNDULATORS

MODELS 309 & 310



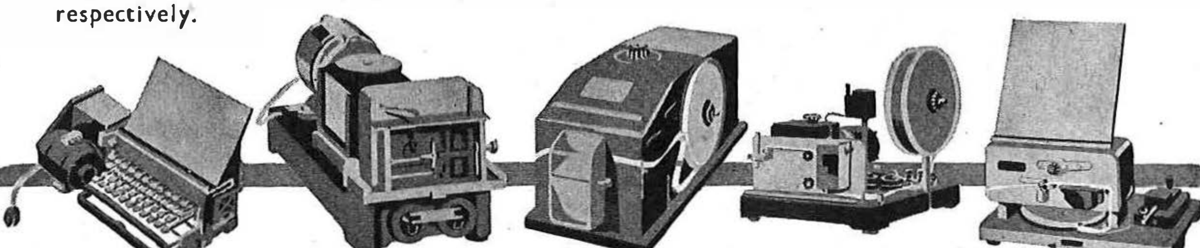
Model 309 with single recording part.

Model 310 with two recording parts.



Both models can record signals up to 300 w.p.m.
Supplied with A.C. or D.C. motors, as required.

Also manufactured with built-in amplifiers under catalogue numbers 311 and 312 for single and double recording, respectively.



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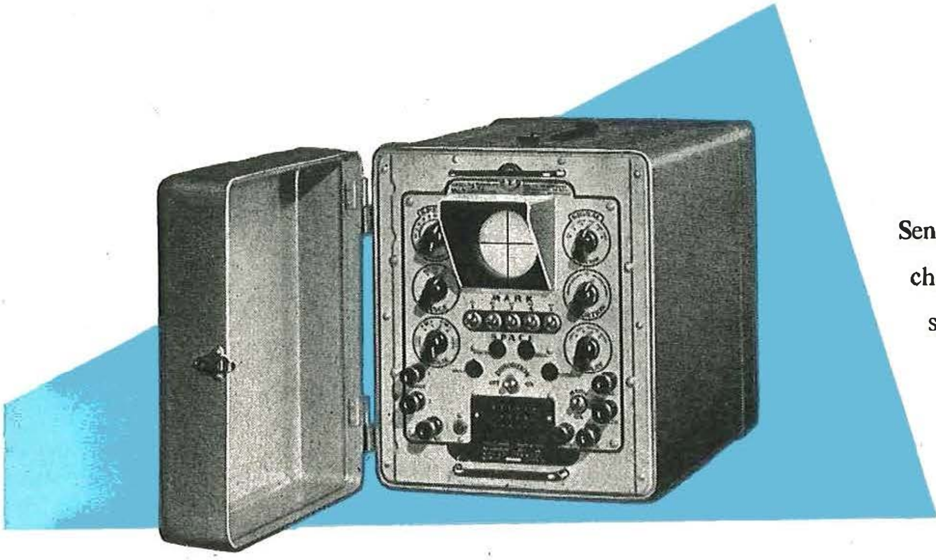
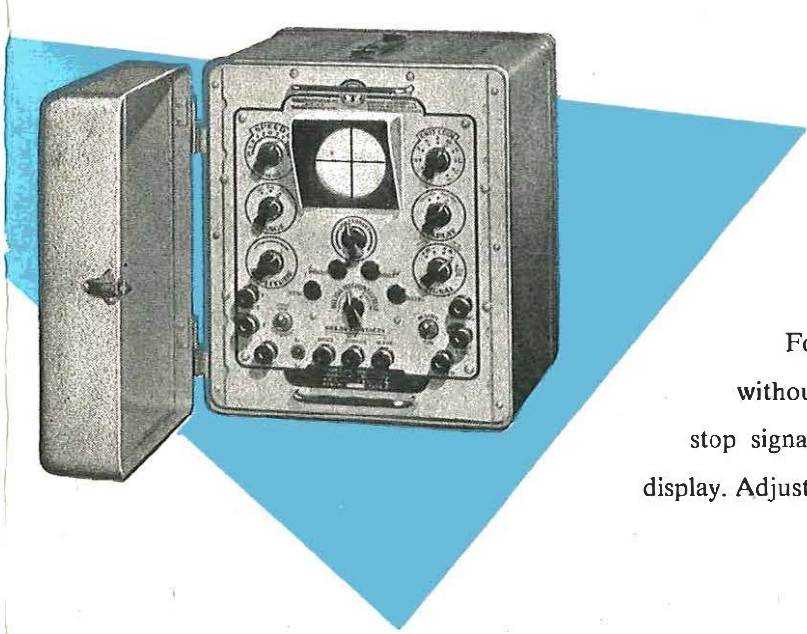


T.D.M.S. 5.

Sends an automatic test message or characters or reversals at any desired speed and/or percentage of distortion. The CRO has a circular time base for distortion measurements or relay adjustment.



T.D.M.S. 6.

For distortion measurements on working circuits without interrupting service. Each element of a start-stop signal appears separately on the spiral time base display. Adjustable speeds from 20-160 bauds.

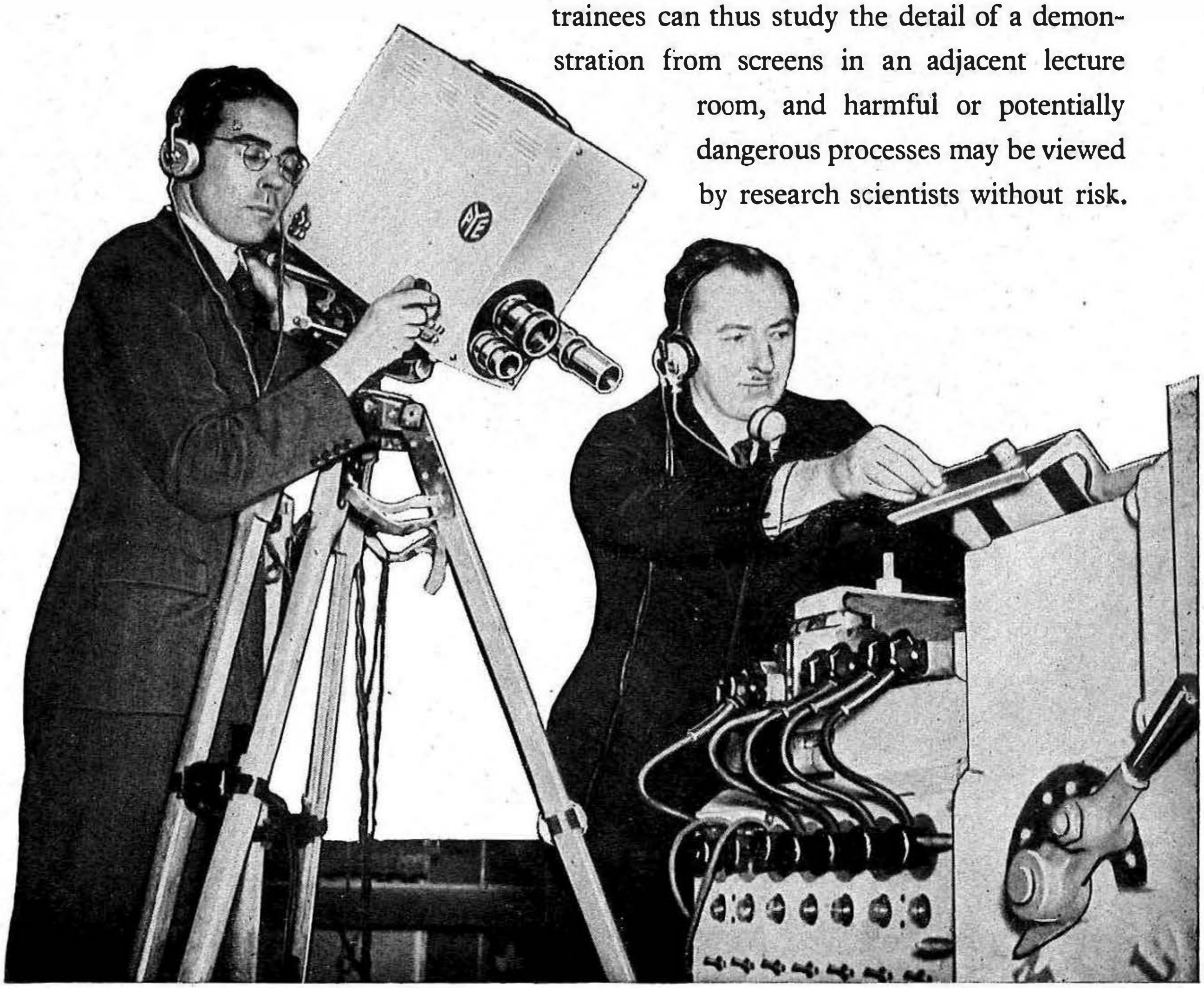
td.

2. Cablegrams: Strowgerex London.

A.T. 14501-AAZ 107

Industrial Television

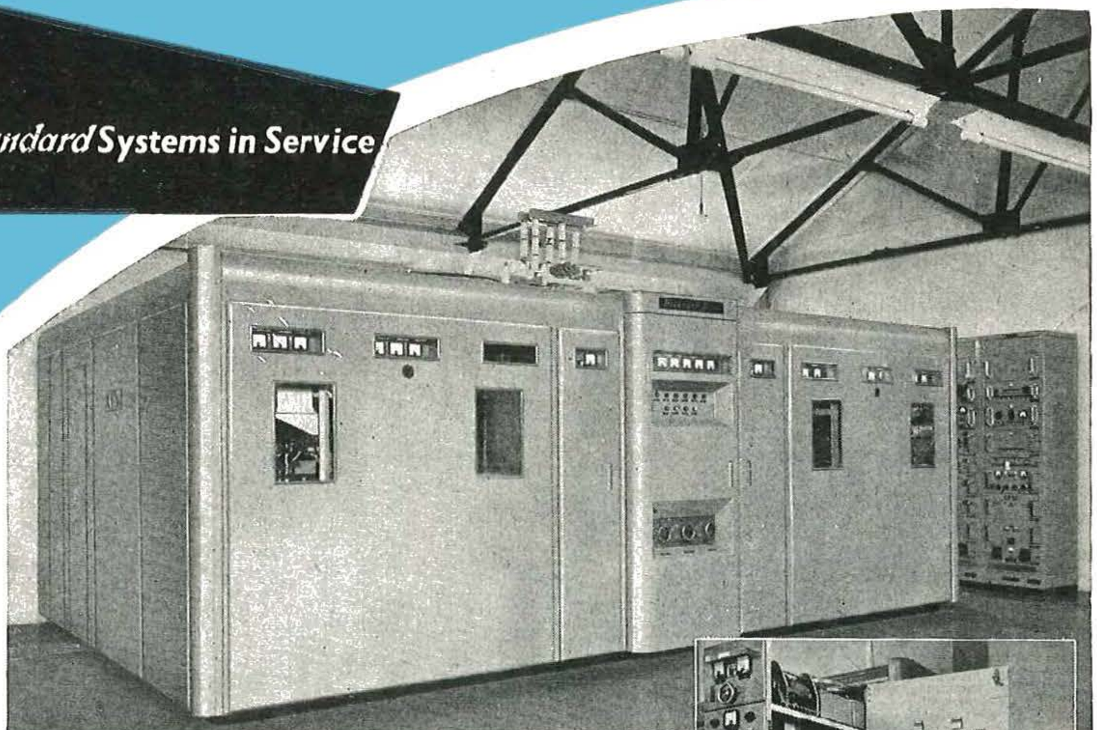
Intensive research into every aspect of television has enabled Pye to lead in all these fields and similar foresight has now resulted in the introduction of a special camera for industrial use. The new camera is small and will transmit an extremely bright picture without special lighting. Large numbers of trainees can thus study the detail of a demonstration from screens in an adjacent lecture room, and harmful or potentially dangerous processes may be viewed by research scientists without risk.



CENTRE OF SCIENTIFIC RESEARCH

Communication

Standard Systems in Service



A recent example of ***Standard's*** activity in the field of radio engineering is the DS.13—40 Kilowatt single side-band radio telephone transmitter designed and manufactured by the Company for the New Zealand P. T. & T. Administration. Made available for carrying H.M. the Queen's Christmas message to Britain and the Commonwealth this transmitter is installed at Himatangi 75 miles north of Wellington. The service with the U.K. constitutes the longest radio telephone link in the world.

A member of the New Zealand P. T. & T. staff making adjustments during installation.

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