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TELEPHONE: CENTRAL 6565 (10 LINES) *MANAGING EDITOR:* H. G. FOSTER, M.Sc., M.I.E.E. *TELEGRAMS:* LECTRONING, ESTRAND, LONDON

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CONTENTS

R.C.E.E.A.

THAT part of the British radio industry which is represented by the Radio Communication and Electronic Engineering Association may well congratulate itself on recent achievements and look forward to a very busy time ahead. In the words of the retiring chairman of the Association, Mr. F. S. Mockford, its business is largely "tailor-making" for customers, particularly those overseas, whose special needs have been so carefully studied that in fifty years Britain has kept the lead in radio not so much by selling equipment "off the shelf," but by making it to meet exact individual requirements. The United States, with a vast home market for standardised products, is in a rather different position; she may often have standard equipment which meets a customer's wishes, but the British manufacturer can meet a special requirement perhaps rather more easily. "If there is an electronic valve in it, Britain can make it," Mr. Mockford said.

It follows that the user of radio equipment—especially when he has a bias towards sterling—should continually be in the closest consultation with the industry, and there can be no better service, to the user and to the manufacturer alike, than that which the Association provides in its consultative and advisory capacity.

It would appear from instances cited by Mr. Mockford that to their own and the manufacturers' detriment, some of our own governmental authorities do not always use this service as much as they might.

Overseas, the industry appears to be able to give full satisfaction to the customer in the face of competition. Customs and Excise figures for the first nine months of 1949 showed that the exports of broadcast transmitters, communication equipment, marine and air navigational aids, test gear, measuring instruments and industrial electronics were at the rate of £3,250,000 a year—nearly double the 1947 figure—and this takes no account of indirect exports, such as installations in ships and aircraft, which, it is estimated, would raise the total by 50 per cent or more.

The growing applications of "business radio" equipment—short-wave mobile communications—both abroad and at home, where the Postmaster-General is becoming a little less reluctant to grant licences, are expected to make this an increasingly important part of the industry's work. There are also signs that electronic industrial equipment is likely to be in much greater demand.

The term of office of the new chairman, Mr. V. M. Roberts, opens with the tangible signs of a satisfactory year in the shape of orders for all types of equipment, the most spectacular probably being that for the television stations in Scotland and the South-West of England. This consists of two 12-kilowatt sound transmitters and two vision transmitters each with an output of 50 kilowatts, as compared with the 35 kilowatts of Sutton Coldfield, which at present is several times more powerful than any other television station in the world.

The first order from abroad—from the United States moreover—for a television transmitter has also been announced, and the industry may well expect that before the year is out, through its unrivalled "know-how" and workmanship, it will be making television transmitting equipment for several continents.

A.R.

The Exact Solution for Transient Distortion in Networks

This paper presents a rigorous and systematic method of distortion correction in electrical networks. The correction network is derived by inversion from a hypothetical simulating network which can be defined exactly and systematically from the waveform of distortion of the actual transmission system.

By D. C. ESPLEY, D.Eng., M.I.E.E.*

(Communication from the staff of The General Electric Company, Limited, Wembley, England)

IN the case of linear transmission systems it is known that freedom from distortion can be achieved only by the use of transfer characteristics of constant amplitude and linear phase shift with frequency. In the general case departures from the ideal can be corrected systematically by a combination of amplitude networks, which always contain a phase component, and phase networks which may or may not include an amplitude component. The necessary design information must contain two separate sets of data (amplitude and phase) and the complexity of the networks is dependent on the order, or rates of variation, of the separate distortions.

The transfer characteristic is defined completely by a display of the output waveform (time/voltage) resulting from the application of an infinitesimal pulse, or step waveform, of voltage to the input terminals of the system. In waveform systems such as television and telegraphy it is only this output time/voltage characteristic which defines quality of transmission. Hitherto, in the absence of a systematic method for transient distortion correction, Fourier or Laplace transforms would have been used to convert information into the steady state amplitude and phase forms to permit the use of classical network correction, or the system required complete measurement of these parameters. Considerable skill was required in many cases to resolve the steady-state distortions into a number of forms which could individually fit the correction curves of networks chosen from a large number of types. This additive process was carried on until the system, plus correcting networks, produced a satisfactory approach to the ideal characteristics.

For the purpose of the following method the distorting system can be represented simply by Fig. 1(a), in which V_o is the desired input signal and V_d is the distorted output voltage. The transfer characteristic is defined as a time function $f(t)$. It will be realised that in most actual systems any attempt to define $f(t)$ by, for example, a complete differential equation is likely to fail because of extreme complexity, and very simple cases are not worth the effort of computation. It is now proposed to define the system entirely in terms of input and output waveforms of the kind shown in Fig. 1(b), in

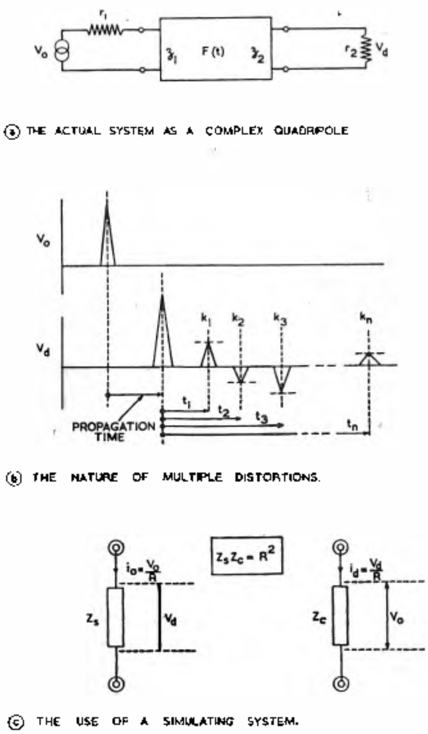

Fig. 1 (a), (b) and (c)

* Research Laboratories of The General Electric Company, Limited, Wembley, England.

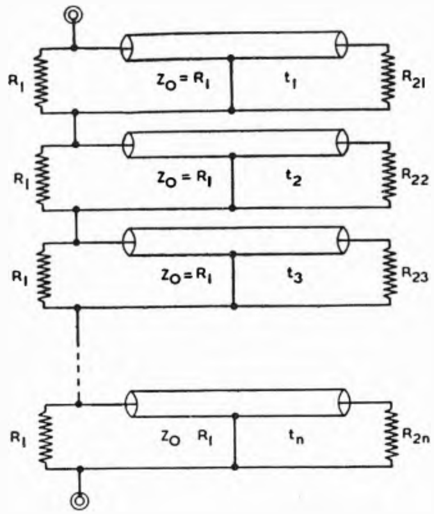

Fig. 2.

Simulating Networks (Z_s) SERIES Type (1) constant Z_0.

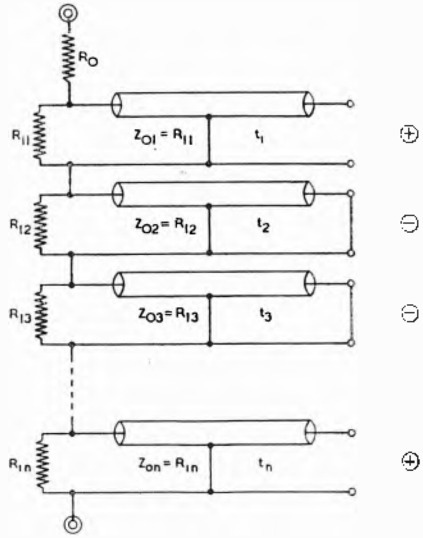

Fig. 3.

Simulating Networks (Z_s) SERIES Type (2) variable Z_0.

which V_o is shown diagrammatically as a pulse with an energy content appropriate to the expected frequency range of the transmission path. The output waveform V_d is shown, by way of example, as a desired signal appearing after the nominal propagation time and followed by a finite series of echoes defined by amplitude, time and sign.

The parameter k defines the ratio of a particular echo amplitude to the desired signal. Echoes of a form differing from the desired signal may be considered as a plurality of overlapping discrete echoes of arbitrary signs (a previous paper dealt with the simple case of a single discrete echo[1]). It is now possible to remove any single echo[2,3] or any combination completely or to a degree considered satisfactory for transmission. Fig. 1(b) now defines the distorting system, and no attention need be given to the circuit structure producing the distortion. However, this statement seems to give no clue to any systematic method for distortion correction, but the key has been found in terms of a special concept.

It is proposed[1] to consider the possibility of a hypothetical network, Z_s in Fig. 1(c), of such a kind that the passage of a desired signal current i_o of the waveform of V_o, will produce across the terminals an exact waveform of the system distorted voltage V_d. It can be shown that, if a second network Z_c is constructed, the passage of the distorted current i_d, of the waveform of V_d, will produce across the terminals a voltage of the undistorted form V_o if the relationship $Z_sZ_c = R^2$ holds. The parameter R is resistive and can have any value and Z_c is obviously the inverse of Z_s. The hypothetical impedance Z_s is not physically required, as it represents only a systematic form of the transfer impedance of the actual distorting system. The correcting network, or "time equaliser," requires to be fed by the distorted current of a form delivered by the actual system but, in the diagram example, the source impedance must be infinite. This limitation can be overcome and, at the end of this paper, it is shown how the complete correction can be achieved between sources and loads of finite resistances. The process of inversion is simple in certain cases, but is always possible in the redundant and non-redundant forms of practical interest.

Distortion Simulating Networks

If the desired signal current i_o is delivered to the simulating network Z_s from a source of infinite impedance, then Z_s can comprise a series combination of networks, each of which produces a single echo distortion selected individually from the array of Fig. 1(b). It is necessary to limit the separate networks to a single echo component as otherwise infinite trains appear in forms quite different from the determinate distortions of Fig. 1(b).

Series Type I.

The most direct, but not the most economical, form for Z_s is shown in Fig. 2, which is a series combination of n echo networks, each exactly terminated at the input end, all of the same characteristic impedance Z_o, of echo times t_1, t_2, t_3, - - - t_n and each terminated by a resistance so chosen that the single echoes are proportioned relatively in accordance with the known system distortion. It will be seen that if a current of a waveform of V_o is passed between the two terminals, then the output voltage waveform appearing across apparatus of infinite impedance, will comprise an initial pulse followed by a finite train of distortion echoes at times t_1 - - - t_n as shown in Fig. 1(b). No interaction current or echoes pass between one echo network and another as no other finite impedance is defined between these two terminals and no loop secondary currents can flow.

The terminating resistances R_{21}, etc., have values above or below Z_o to produce distortion echoes of positive or negative signs repectively. When all these terminating resistances are either zero or infinite in value the sum of the echo amplitudes, irrespective of sign, is equal to the desired signal. In all other cases the sum is less and in the limit reaches zero when all the terminating resistances are equal to Z_o. This form of simulating network and the corresponding correcting network are doubly redundant in terms of the total time delay in the system and the number of associated components. Of course, in the simulating networks the physical structure of the echo " lines " is irrelevant and the problem of construction applies only to the corresponding correcting networks.

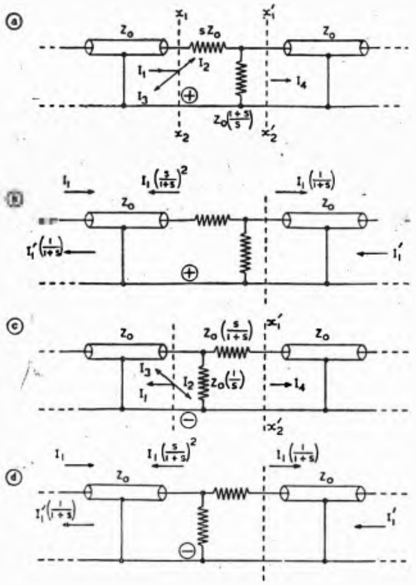

Fig. 4 (*left*). Simulating Networks (Z_S) Cascade Type (I) constant Z_0. The conditions for unilateral reflexions.

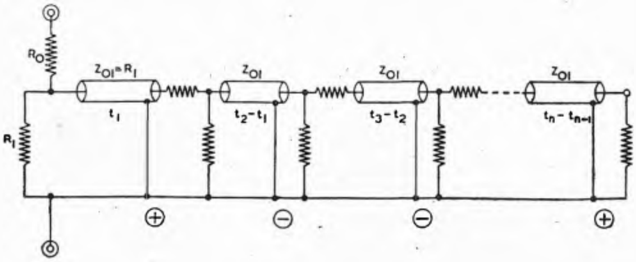

Fig. 5 (*right*). Simulating Networks (Z_S) Cascade Type (I) constant Z_0

Series Type II.

In this case, shown in Fig. 3, all the terminating resistances are either zero or infinite in value dependent on the sign of the required echo. The initial and echo pulses across the input terminals of each line are equal, but as the distortion echoes at the various times differ in value it becomes necessary, in the general case, to establish different characteristic impedances for the echo lines. This condition is not yet sufficient as the echo sum is equal to the initial desired signal, and to overcome this limitation there is a series-connected resistance R_0 across which is produced simply an initial pulse of desired signal form and which can be made large enough to reduce the ratio of all echo distortions to any desired degree. Simulating networks of this kind have only single redundancy as the number of components is a minimum, but the total time delay is the sum of the delays of all the distortion echoes which, in the limiting case, may approach the value nt_n which is n times the optimum value. It remains to determine the separate characteristic impedances Z_{01}, etc., in terms of the separate echo coefficients k_1, etc. If the initial pulse has an amplitude V_0 and the separate distortion echoes V_1, V_2, V_3, etc., then the characteristic impedances can be found in the following manner

$$k_1 = V_1/V_0 = \frac{Z_{01}}{2R_0 + Z_{01} + Z_{02} + ---- Z_{0n}}$$

$$k_2 = V_2/V_0 = \frac{Z_{02}}{2R_0 + Z_{01} + Z_{02} + ---- Z_{0n}}$$

- - - - - - - - - - - -

$$k_n = V_n/V_0 = \frac{Z_{0n}}{2R_0 + Z_{01} + Z_{02} + ---- Z_{0n}}$$

These equation can be solved for Z_{01} --- Z_{0n} to give

$$Z_{01} = \frac{2k_1R_0}{1-(k_1 + k_2 + ---- k_n)}$$

$$Z_{02} = \frac{2k_2R_0}{1-(k_1 + k_2 + ---- k_n)}$$

- - - - - - - - - - - -

$$Z_{0n} = \frac{2k_nR_0}{1-(k_1 + k_2 + ---- k_n)}$$

The common parameter R_0 can have any value as its effect can be controlled by the inversion resistance R so that the correcting network can be constructed in terms of suitable impedances.

Cascade Type I.

It has been proposed elsewhere to devise a multiple echo distortion system in terms of a long ladder network capable of producing echoes at different times by the manipulation of the various shunt elements of the structure. This is theoretically impossible as the separate echoes in their return path to the input terminals pass through the various discontinuities which have been located to produce other echoes. In these circumstances infinite trains of echoes, or reverberations, are excited between adjacent and other discontinuities. The arrangement is only of interest for those cases in which the various echo distortions have very small values so that the second, third and higher order reverberation terms become vanishingly small compared with the required first order echoes.

This difficulty is overcome completely by the use of special cascade simulating networks[6] designed to permit only unilateral reflexions at the echo points. Fig. 4 shows the principles involved in the production of unilateral discontinuities between delay lines of the same characteristic impedance. In Fig. 4(a) the network is arranged to produce a positive echo from the boundary x_1x_2 so that a current I_1 moving from the input end is subject to a discontinuity producing a positive reflexion current I_3 and a continuing current I_2. If the two resistances have the values shown, then a current appearing from the right-hand side suffers no reflexion at the boundary $x_1'x_2'$ and is transmitted, after attenuation, towards the input terminals.

The slope of the arrows for currents I_2 and I_3 is shown to indicate transmission of current into higher and lower impedances respectively. The assignable parameter s can have any value from zero to infinity and is chosen to determine the appropriate value of the return echo component. Fig. 4(b) shows the conditions resulting from the left to right transmission of a current I_1 giving an echo and a continuing current. Any current I_1' transmitted from right to left, and taking the form of one or more distortion echoes produced from further discontinuities, passes through the circuit shown and emerges with exactly the same waveform but with a reduced amplitude determined by the parameter S. Figs. 4(c) and 4(d) deal with the equally important case for a negative distortion echo, but it will be observed that the attenuations through the circuit in both directions are exactly the same as for the positive echo case.

The form of a complete simulating network of this type is shown in Fig. 5. This is simply a cascade arrangement of any number of the unilateral discontinuities of Fig. 4. It will be observed that the initial signal current i_0 flowing between the two terminals produces a "timeless" voltage component across R_0 and a finite array of echo distortion components across R_1. Exactly half of the current i_0 flows into the delay system and discrete distortion echoes are produced at each discontinuity from which they are transmitted, after attenuation at each discontinuity, back to the input termination R_1 where the perfect termination prevents return currents and hence higher order reflexions.

It is not strictly necessary to include the resistance R_0 as the two resistances at each discontinuity can be adjusted to give any desired reflexion coefficient, but it will be seen later that, when consideration is given to the inverse correcting networks, the appearance of R_0 at this stage provides a useful, and sometimes necessary, facility. Cascade networks of this kind are of great interest as they are entirely non-redundant with regard to the total time delay which, in sum, is no greater than the time displacement of the final echo distortion component. However, this Type I network is redundant in components, but it is only by the use of this structure that an arrangement can be achieved with constant characteristic impedance for the delay lines which, when expressed in terms of the actual delay lines in the correcting network, gives a great practical advantage.

The impedance into which I_2 flows is:—

$$z = Z_0\left[\frac{1 + 2S + 2S^2}{1 + 2S}\right]$$

which produces a reflexion coefficient at the x_1x_2 boundary of $(S/1 + S)^2$. The attenuation (voltage or current ratio) for both directions of transmission is $(1/1 + S)$. If the resistance networks are arranged in forms appropriate to the signs of the required echoes then the reflexion coefficients and attenuations are independent of the signs.

In a multiple echo simulating network the echo components, arriving at the input terminals, have suffered an overall attenuation due firstly to the progressive attenuations of the initial pulse and the cascade attenuations of the returning echo. If parameters S_1S_2 - - - - S_n have been assigned to the various discontinuities, then the currents in the delay lines are:—

$$I_1$$

$$I_1\left(\frac{1}{1+S_1}\right)$$

$$I_1\left(\frac{1}{(1+S_1)(1+S_2)}\right)$$

- - - - - - - - - - -

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$$I_1\left(\frac{1}{(1+S_1)(1+S_2)(1+S_3)\text{ - - - - }(1+S_n)}\right)$$

and the echo currents arriving back at the input terminals are:—

$$I_1\left(\frac{S_1}{1+S_1}\right)^2 = k_1I_1$$

$$I_1\left(\frac{1}{1+S_1}\right)^2\left(\frac{S_2}{1+S_2}\right)^2 = k_2I_1$$

$$I_1\left(\frac{1}{1+S_1}\right)^2\left(\frac{1}{1+S_2}\right)^2\left(\frac{S_3}{1+S_3}\right)^2 = k_3I_1$$

and the pth term is given by

$$I_1\frac{S_p^2}{(1+S_p)^2}\prod_{r=1}^{p-1}\left(\frac{1}{1+S_r}\right)^2 = k_pI_1$$

In a practical analysis the coefficients k_1k_2 - - - - k_n are given from the actual system distortion, and the parameters S_1S_2 - - - - S_n can be found progressively from the above equations, starting at the first which yields S_1, the second which yields S_2, and so on.

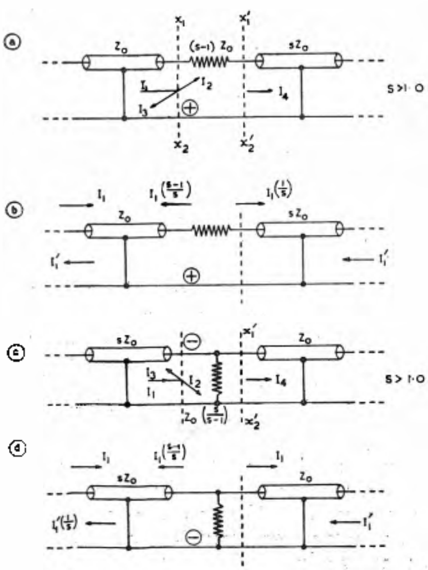

Fig. 6 (*left*). Simulating Networks (Z_S) Cascade Type (2) variable (Z_0). The conditions for unilateral reflexions

Cascade Type II.

The maximum simplicity of a unilateral discontinuity is achieved by the arrangements of Fig. 6, which covers the case of any assigned characteristic impedances for the delay lines. The symbols have the same significance as in Fig. 4.

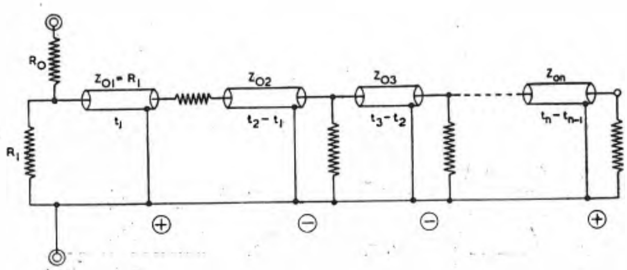

Fig. 7 (*right*). Simulating Networks (Z_S) Cascade Type (2) variable Z_0

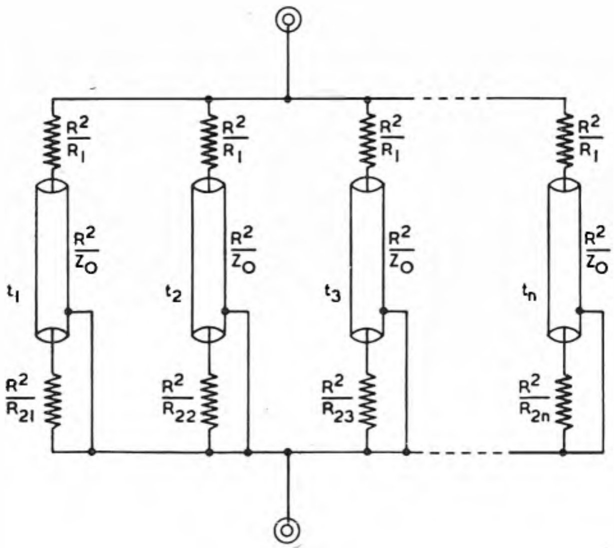

Fig. 8. Correcting Networks "Time Equalisers") Z_c Inverse of SERIES Type (1) Constant Z_0. $Z_cZ_s = R^2$

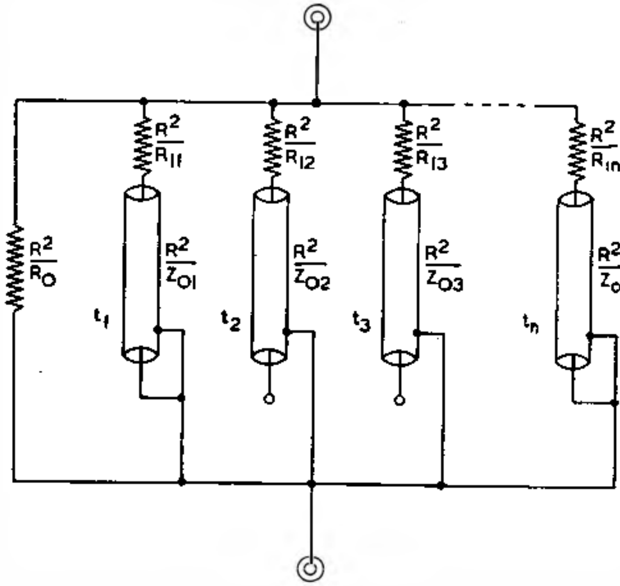

Fig. 9. Correcting Networks "Time Equalisers") Z_c Inverse of SERIES Type (2) Variable Z_0. $Z_cZ_s = R^2$

The corresponding simulating network is shown in Fig. 7 which is entirely non-redundant and represents the maximum economy which can be achieved with regard to total delay time and the number of associated components.

The impedance into which I_1 flows is $z = Z_0\,(2S-1)$ for positive reflexions and $z = Z_0\,(S/2S-1)$ for negative reflexions, both of which give reflexion coefficients of $(S-1/S)$. The attenuation (voltage or current ratio) for both directions of transmission is $1/S$ or unity as indicated in Fig. 6. The form of the resistance arrangement must be chosen in accordance with the required sign of reflexion.

It is not possible to define a single general form for the initial current amplitude in the various delay lines, but an illustration can be given for an echo system in which the echo signs are, for example,

(+) (+) (−) (+) (−) (−) . . .

I_1

$I_1\ (1/S_1)$

$I_1\ (1/S_1S_2)$

$I_1\ (1/S_1S_2)$

$I_1\ (1/S_1S_2S_4)$ and so on.

It will be observed that no forward attenuation takes place (on a current ratio basis) through a discontinuity of negative reflexion coefficient.

The echo currents at the input terminals are

$$I_1\left(\frac{S_1-1}{S_1}\right) = k_1I_1 \qquad S_1 = 1/1-k_1$$

$$\frac{I_1}{S_1}\left(\frac{S_2-1}{S_2}\right) = k_2I_1 \qquad S_2 = \frac{1-k_1}{1-k_1-k_2}$$

$$\frac{I_1}{S_1S_2}\left(\frac{S_3-1}{S_3}\right) = k_3I_1 \qquad S_3 = \frac{1-k_1-k_2}{1-k_1-k_2-k_3}$$

and the pth term is

$$I_1\left(\frac{S_p-1}{S_p}\right)\prod_{r=1}^{p-1} 1/S_r = k_pI_1 \qquad S_p = \frac{1-\Sigma_1^{p-1}k_r}{1-\Sigma_1^{p}k_r}$$

Distortion Correcting Networks ("Time Equalisers")

It is now possible to derive the four types of correcting networks which appear by inversion of the appropriate simulating impedances Z_s with respect to an assignable resistance R. These are the networks of various complexities which must be constructed in suitable forms and in a manner appropriate to the frequency range occupied by the signals. These networks Z_c satisfy the conditions for perfect correction defined simply in Fig. 1(c), but instead of requiring connexion to a simulting network they will actually be applied at a suitable point in the real distorting system. The distorted output current of the system is, in effect, to be passed between the two terminals of these correcting networks Z_c, to produce across the terminals a voltage exactly of the waveform of the original voltage V_0.

As drawn, these networks require the application of a voltage of the distorted form from a source of infinite impedance to provide a current of exactly the voltage form. In many practical cases, and particularly at low frequencies, it is often possible to approach this condition to a satisfactory degree, but the problem of connexion to sources and loads of finite impedance is dealt with later in this paper.

Series Type I.

The correcting network of Fig. 8 is exactly the inverse of the simulating network of Fig. 2, and it should be noted that aspects of redundancy apply equally to correcting networks and to the corresponding simulating networks.

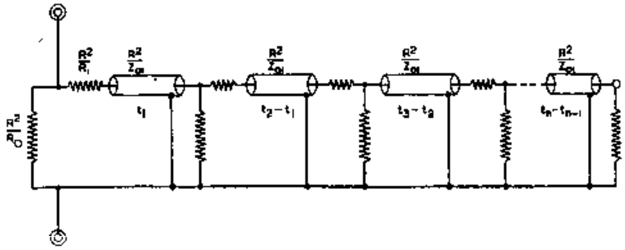

Fig. 10. Correcting Networks "Time Equalisers" Z_c Inverse of Cascade Type (1) Constant Z_0. $Z_cZ_s = R^2$

It has been stated above that a simulating network produces a finite array of distortion echoes when the network is excited by a single pulse current. It should be noted that the corresponding correcting network when excited by a single pulse produces infinite trains of pulses, or reverberations, of all orders and which persist for all time.

Series Type II.

The correcting network of this type is shown in Fig. 9 which is the exact inversion of the simulating network of Fig. 3. It is the more important of the series types if a variable Z_0 can be tolerated. Otherwise the network of Fig. 8 must be used and the absence of a shunt resistance can be overcome by introducing an appropriate R_0 in the Series Type I simulating network by manipulating the terminating resistances R_{21}, R_{22}, R_{23}, etc., to give higher terminal reflexion coefficients.

Cascade Type I.

The correcting network of Fig. 10 is the inversion of the network of Fig. 5 and is perhaps the most useful of all correcting networks as it is non-redundant in time delay and has constant characteristic impedance throughout. The redundancy in components (junction resistances) is not important as they usually represent very small additions of space and cost.

Cascade Type II.

The correcting network of Fig. 11 is the inversion of the network of Fig. 7 and is completely non-redundant from all points of view. It differs from the network of Fig. 10 insofar as the manipulation of echo coefficients cannot be achieved without changes in characteristic impedances. This may not be of importance in connexion with a system in which echo distortions are not subject to variation. It is very difficult to contemplate delay lines of variable impedance and very few fixed values are available.

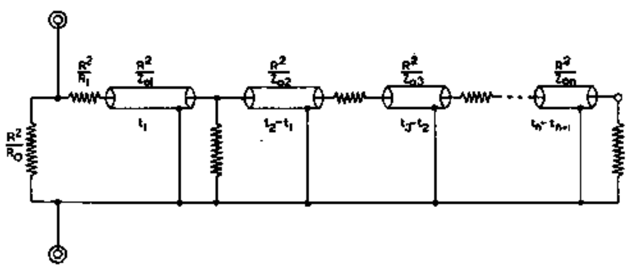

Fig. 11. Correcting Networks "Time Equalisers" Z_c Inverse of Cascade Type (2) Variable Z_0

Correction Networks between Finite Impedances.

It has been shown that the use of a "timeless" resistance R_0 in the simulating network gives a shunt resistance between the terminals of the correcting network. Fig. 12(a) shows this arrangement for Z_c, but no change in the value of Z_c is introduced by the connexion of two resistances R_a and R_b as in Fig. 12(b). The distorted current source of Fig. 12(b) can be transformed in known manner to the distorted voltage source of Fig. 12(c) in which R_a and R_b now represent the resistances of source and load respectively. This is perhaps the optimum form for a correcting network and it makes possible the use of the delay systems of such networks in association with lumped element filters, cables and waveguides of known impedances. If long but smooth transmission circuits are included between the actual source and load, then it is essential in

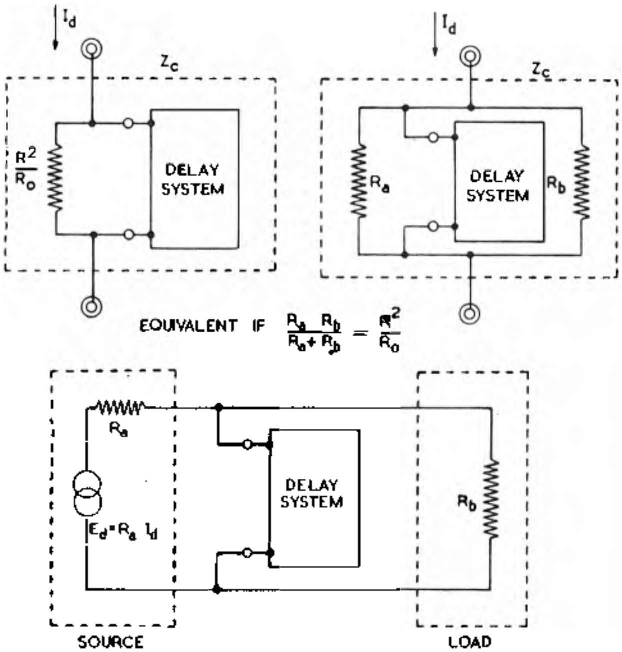

Fig. 12. The use of correcting networks between source and load of finite resistances

(a) *Top left* (b) *Top right* (c) *Below*

this arrangement that they should both be accurately terminated at their ends remote from the delay system and should have characteristic impedances R_a and R_b respectively in order to satisfy the equivalence to Fig. 12(a) as a safeguard against unwanted high order echoes.

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(This paper was given at the Congrès de Television held in Paris in 1948. It has appeared, in French, in the Proceedings of that Congress published by Editions Chiron, 40 Rue de Seine, Paris 6e.)

D

Electronic Instruments in Diagnostic Medicine —Part II

By H. A. HUGHES, B.Sc., A.R.C.S., A.Inst.P*

Electrical Stimulation

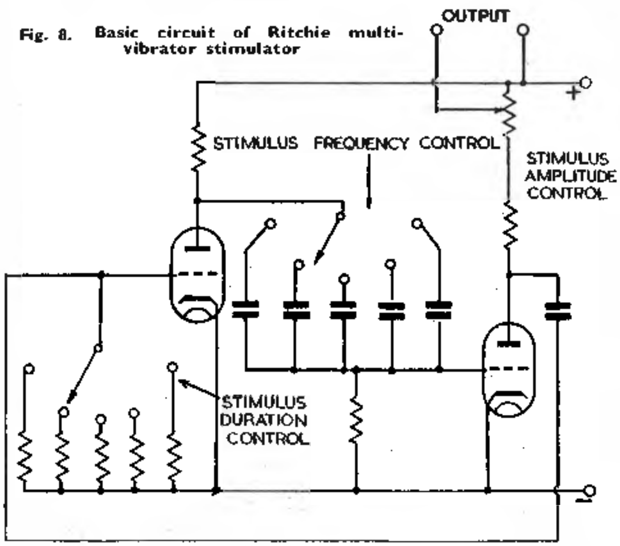
ELECTRICAL stimulation of the brain during surgical operation provides a valuable method of identifying the sites of certain brain disorders. Stimulation may be classified according to the type of current delivered as follows: (i) interrupted D.C.; (ii) capacitor discharge; (iii) sinusoidal wave; (iv) induction coil; (v) multi-vibrator output; (vi) thyratron discharge. The first two are not used clinically, and the output of an induction coil is variable in voltage, frequency and wave shape. The last two methods are both satisfactory as the output can be varied over a wide range of frequencies and wave shapes.

Ritchie[22] has described a multi-vibrator circuit using small power valves arranged so that one valve provides the stimuli, each being independently controlled by simple switching. The valves operate in one or another of two mutually exclusive conditions; one when the grid is highly negative and the anode current is cut off, and the other when the grid is at cathode potential, or slightly positive, with the anode current limited by load line and valve parameters. A basic circuit diagram is shown in Fig. 8, while a photograph of a commercial instrument—manufactured by Multitone Electric Company, is shown in Fig. 9. Brian Denny[23] developed a more elaborate apparatus which aimed at providing the means of determining the response to electrical stimulation of muscle and nerve (chronaxie measurement) and of applying electrical treatment of known character and dosage.

The thyratron is capable of handling more current than a vacuum valve because of the ability of the gas to ionise and thus become highly conductive. The voltage drop (10-15 V) across the valve is practically independent of the current through it. The anode voltage necessary for ionisation increases with the negative grid voltage. When the gas ionises, the valve continues to conduct as long as the anode voltage remains above the de-ionisation point, usually 10-15 V. A capacitor can be charged through a variable resistor (see Fig. 10 for basic circuit of a thyratron stimulator) until the ionisation voltage (about 150 V) is reached. The valve then fires and the capacitor is suddenly discharged through the transformer primary, producing a sharply peaked output in the secondary. When the de-ionisation point is reached the valve ceases to conduct, the capacitor recharges, and the cycle repeats. The reliability and versatility of such a device is obvious. The breakdown voltage is in quite constant relation to the grid voltage, so that the discharge of a capacitor in the grid circuit through a variable resistor provides an accurate method of electronic timing. The frequency may be changed without affecting the wave shape by varying the charging resistor. Wave shape may be modified by putting a capacitor across the output. A single impulse may be produced by applying a small positive voltage to the grid, reducing the ionisation voltage momentarily. A versatile electronic stimulator for research on nerve and muscle has been described by Nastuk and Borison,[24] which operates on the same principles.

* Physics Department, Medical School, Guy's Hospital, London.

Fig. 8. Basic circuit of Ritchie multi-vibrator stimulator



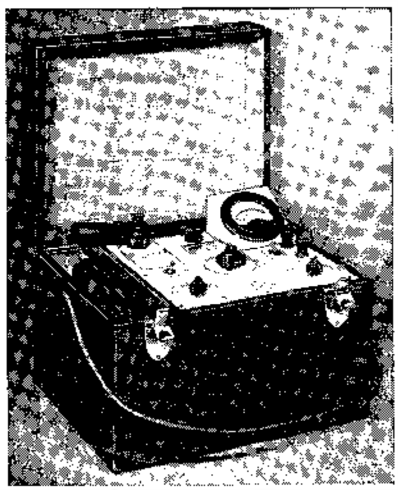


Fig. 9. Multitone Electric Co. multi-vibrator stimulator

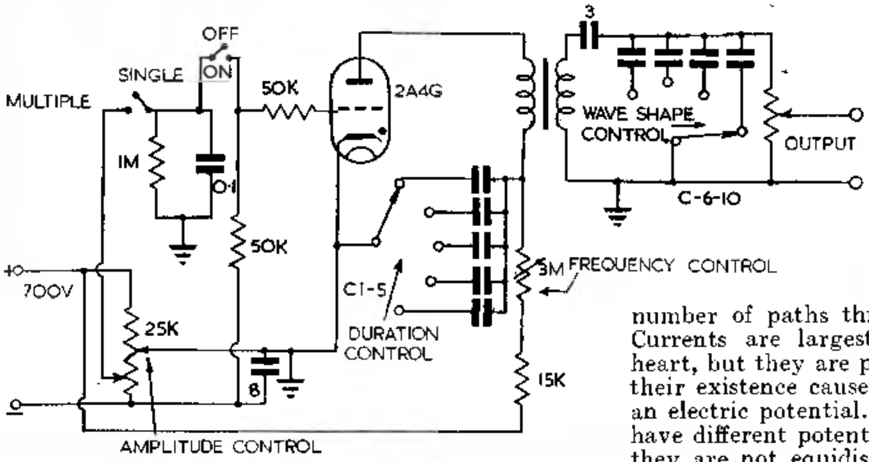


Fig. 10. Basic circuit of thyratron stimulator

Nerve and Muscle Action Potentials—Electromyography

Nerve fibre is a tissue in which some of the properties of living matter, especially conductivity and excitability, have become developed to an exceptional extent. If a nerve fibre is stimulated electrically, the rate of travel and magnitude are independent of the strength of the stimulus, and depend only on the state of the nerve at the point under consideration. In any particular fibre, stronger stimulation causes only an increase in the frequency of the potential waves. The record of potentials arising after stimulation consists of a complex series of transients, having a peak potential (from human subjects) of about 1.0 mV, with other signals about 50 μV, and duration of about 1 millisecond. (See Fig. 11, taken from the section on nerve excitation by Curtis and Cole in "Medical Physics," where a full bibliography is to be found). The action-potentials of muscle fibres are similar in shape to those of nerve fibre, but are larger and slower. Records of action-potentials from voluntary muscle can give useful information on the nature and position of certain pathological processes.

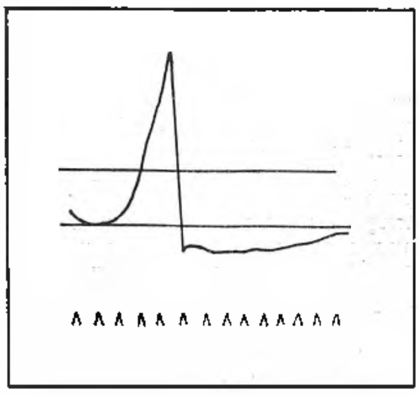
A technique commonly employed in E.M.G. work is to insert a concentric electrode made of a fine wire running through the centre of a hypodermic needle into the muscle. The barrel of the needle acts as a shield, and the wire picks up activity from a radius of about 1 mm. The electrical potentials may be amplified by standard E.E.G. amplifiers, and indeed most commercial apparatus may be modified for the measurement of any type of bio-electric potentials. A simple apparatus in use at Guy's Hospital has batteries throughout, and presents the record on a cathode-ray tube, and also feeds the output into a loud speaker. The detection of small differences in duration and frequency are more easily assessed by auditory than by visual methods.

Heart Potentials—Electrocardiography

In 1856, Kolliker and Muller showed that electrical phenomena occur during heart action by observing rhythmic contractions in a nerve-muscle preparation placed in contact with a beating heart. Subsequently it was proved that, due to the voltages arising in the heart, currents flow in an infinite number of paths through the tissues of the trunk. Currents are largest in the structure around the heart, but they are present throughout the torso and their existence causes all parts of the trunk to have an electric potential. Different points will generally have different potentials at the same instant because they are not equidistant from, or are not similarly located with respect to voltages present in the heart. The arm and legs, although directly continuous with the torso, do not serve as an integral part of the conducting medium, but behave as linear conductors. As the flow of currents into the trunk does not extend for any appreciable distance into the arms or legs, the electrical potential is the same for all points of a single extremity. A record of the potential between any two points is called an electrocardiogram. The electrical effects which occur during the action of the heart are closely related to auricular and ventricular systole (period of contraction of the heart). Three basic groups of waves appear in most tracings (see Fig. 12). The *P* wave is due to electrical activation of the auricle which immediately precedes auricular contraction; the *QRS* group is similarly related to ventricular contraction; the *T* wave is due to electrical recovery or repolarisation in the ventricular muscle. The frequency components range from about 1-1,000 c/s. It is obvious that in cases of a heart disease which interferes with the dilation and contraction of the heart, the waveform of the whole tracing may be altered in one or two ways: (i) the intervals between groups of waves may change, while the individual groups themselves may remain constant in waveform; (ii) the waveform of any group may be altered. Thus a study of the electrocardiogram is important in the diagnosis and management of patients with heart disease.

As in electroencephalography, all early work was

Fig. 11. Action potential from squid giant axon recorded between one electrode inside and another outside the axon. Upper horizontal line approximately represents zero potential difference across membrane; lower line, resting potential of 58 mV (outside positive). Action potential starts from resting potential and swings to 110 mV (outside negative). Time intervals are 3.2 μ sec. apart



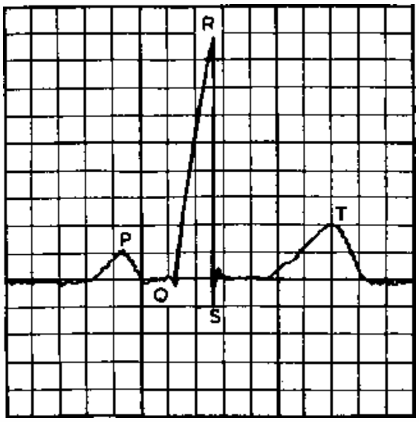


Fig. 12. Sketch of typical trace from Cossor model 1314 electro-cardiograph

done with a Lippmann capillary electrometer and later with the Einthoven string galvanometer. Many other types of electrocardiographs have been developed since the introduction of the original string galvanometer. Nearly all these instruments use some form of mirror galvanometer of comparatively low sensitivity in conjunction with an amplifier using thermionic valves.

An early circuit was used by Matthews[26] for recording electrocardiograms in which the amplifier was single-sided. Many other E.C.G. amplifiers used single-sided circuits, but in view of the considerations stated by Parr and Grey Walter[8] they may be considered obsolete. As stated in the previous section, standard E.E.G. apparatus can be used to record electrocardiograms. A photograph of the Cossor instrument is shown in Fig. 13. The amplifier has a balanced input stage, the bandwith is 0.1-100 c/s., and the maximum voltage gain 250,000.

A point regarding the time constants of E.C.G. amplifiers has been discussed by Dawson.[36] He showed that the reproduction of E.C.G. and E.E.G. waveforms can be seriously modified by the phase shift in several capacitor-coupled stages. A D.C. amplifier is not satisfactory because relatively large and slowly-changing muscle potentials would mask the desired record. The ideal amplifier should have the overall time-constant all in one coupling, other stages being direct-coupled.

Many workers who realised the unique properties of the cathode-ray tube adapted it to E.C.G. work. Among the first were Schmitz[27] and Matthews,[28] who used the C.R. tube merely as a recording device and not as an oscilloscope. Robertson and Bedford[29] devised an apparatus where the C.R. tube was employed as an oscilloscope, and had a long afterglow screen, which permitted direct visual observation of the electrocardiogram. Donovan[30] has described a phono-electrocardioscope which incorporate a double beam C.R. oscilloscope fitted with long afterglow screen, which permits simultaneous and constant viewing of a pair of phenomena such as the phonocardiogram and electrocardiogram.

Heart Sounds—Auscultation

Cardiac action also gives rise to mechanical vibrations of a composite nature which depend upon the heart itself and the paths along which the vibrations travel. There are relatively gross movements and a series of finer vibrations. The gross mechanical movement due to the apex beat of the heart appears to have no clinical importance. However, some of the finer vibrations reach an audible frequency, and the groups of waves and their form again prove an invaluable aid to the physician in his diagnosis of heart disease. Listening to sounds of the body for the purpose of diagnosis is known as auscultation. An instrument for cardiac auscultation whether it be a simple stethoscope or a more complicated valve amplifying type is nothing more than a hearing aid. To get maximum benefit from the use of such an aid, a knowledge of acoustics is desirable. In an excellent paper on the physical and physiological laws that govern auscultation, Rappaport and Sprague[31] enumerate the various factors involved in the problem. From their results they conclude that the human ear in auscultation has many faults. The acoustic stethoscope does not correct for the characteristics of the ear, and does not lend itself to any great radical improvements in design. For such improvements, electrical amplifying devices are necessary. An objective method which can be directly measured would seem to provide the answer. But physicians spend many years acquiring their auscultatory technique, and this cannot be discarded for some new method which may be difficult to correlate with previous experience. The solution arrived at by Donovan[30] is that the sensation of hearing should be correlated with an objective reality, viz., a graphic registration of heart sounds, or phonocardiogram. In order to time accurately the events of the cardiac cycle, an electrocardiogram occurring simultaneously should accompany a phonocardiogram, and his apparatus, the phonoelectrocardioscope, is designed on these principles.

The sounds of interest in auscultation are made up of frequencies below 1,000 c/s. The low frequency limit of heart sounds and murmur components is estimated to be 5-10 c/s., although 30-40 c/s. is the lower limit of audibility. In designing an amplifying stethoscope the following factors must be taken into consideration: (i) the apparatus must be capable of faithfully reproducing sounds of the above frequencies, (ii) it must be free from pick-up due to external electrical wiring, etc.; (iii) it must be free of inherent noise; (iv) the sound volume should be controllable; (v) it must incorporate devices which can overcome, whenever possible, the natural human ear defects which interfere with auscultation.

The heart sounds are picked up by a piezo-electric microphone. The fundamental frequency of the bimorph crystal incorporated is approximately 10 kc/s. This frequency is lowered to a few thousand c/s. when a diaphragm is coupled to the crystal, but this is still much higher than the upper frequency limits encountered in auscultatory work. A crystal element has freedom from parasitic noises, is sensitive, requires only electrostatic shielding, and there is no necessity for a coupling transformer.

The amplifier is resistance-capacitance coupled, and fitted with frequency-discriminating circuits which enable the investigator to accentuate or attenuate at will either high or low frequencies. The valves used are of the H.F. pentode type and give great amplification. A gain control is incorporated between the first and second valve. Two different types of frequency discriminating circuits control the frequency response of the amplifier. They depend for their action on the fact that the frequency response of the amplifier at the low frequency end of the amplifying band is directly dependent upon the magnitude of the coupling capacitors to the rest of the circuit, and the response at the high frequency end of the amplifying band in inversely dependent upon the magnitude of the shunt capacitance in relationship to the circuit resistances. In order to couple an electrical stethoscope to the amplifier without disturbing the operation of the C.R. oscillograph and at the same time provide a separate sound volume control, a tone-compensated gain control is used. This helps to correct for the deficiency in the human ear, in which the auditory sensation produced by complex sounds may be decidedly different in character as well as intensity when the stimulating level is increased or decreased.

Donovan's E.C.G. amplifier was single-sided and consequently he experienced trouble from mains interference. However, it proved satisfactory for recording sounds.

Pulse Waves—Sphygmography

Donovan's apparatus was also designed for the registration of the arterial and venous pulse waves, known as a sphygmogram, which may be necessary for a complete analysis of all events of the cardiac cycle. A piezo-electric attachment of the type described by Rappaport and Sprague[31] could be substituted for the patient in the electrocardiographic section of the apparatus to record the sphygmogram. This consists of the heart sound microphone mounted in an air-tight housing connected to the pick-up device over the point at which the pulse is to be measured. The microphone is shunted by an external capacitance to make the time-constant sufficiently long to record the low frequency pulse waves.

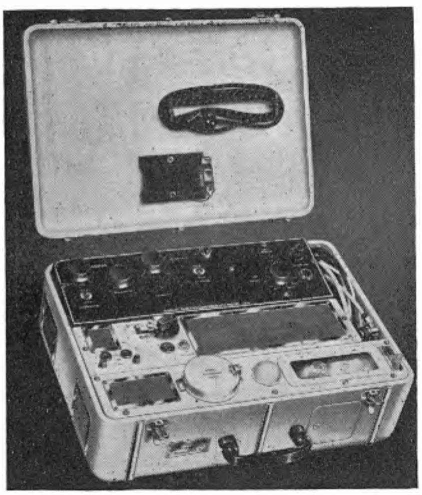


Fig. 13. Cossor electro-cardiograph, model 1314

Heart Rate—Cardiotachometry

In some physiological studies it is necessary to have a continuous record of the heart rate. An example is in the study of physiological events produced by sudden exposure of man to high acceleration in aviation medicine. Two methods of determining heart rate from electrocardiograms or sphygmograms are (i) to measure the number of beats occurring during a given time interval, or (ii) to measure the time interval between corresponding points of successive cardiac impulses. The first method gives only an average rate over a period of time and the second is laborious and time-consuming. An instrument has been developed by Sturm and Wood[32] which continuously records the heart rate by means of electronic measurement of the time intervals between successive heart beats. The instrument is activated by the *R* wave of the electrocardiogram, and is known as a cardiotachometer. The device includes an electronic circuit which deflects a galvanometer at a constant rate. The swing of the galvanometer is interrupted and returned to the zero position by the *R* wave of the electrocardiogram. Thus each galvanometer deflexion is proportional to the time interval between successive *R* waves and is inversely proportional to the heart rate.

The circuit diagram of the instrument is shown in Fig. 14. The inverted *R* wave is fed into a 6J5 valve with a parallel resonant circuit tuned to 15 c/s. in its anode circuit. This accentuates the 15 c/s. component of the electrocardiogram complex and discriminates against lower and higher frequencies such as occur in the *T* wave complex. The amplified *R* signal produces a positive increment of voltage on the grid of an 884 thyratron, normally biased so as to be non-conducting. When this valve becomes conducting it discharges a 0.1 μF capacitor connected to the anode, which extinguishes the 884. The discharge of the capacitor takes place quickly through a 1,000Ω resistor, and the voltage drop across this resistor is impressed through a capacitor on the grid of another 884 known as a "metering valve." Since the signal across the 1,000Ω resistor at each discharge is always the same in amplitude and duration, the second 884 receives a constant actuating potential regardless of the amplitude or duration of the *R* wave which originally initiates the phenomenon. The metering 884, also biased so as to be non-conducting in the quiescent state, has a 4 μF capacitor and a voltage divider of 7 megohms total resistance across it. The large time-constant of this circuit makes the charging of the 4 μF capacitor very slow, and in fact over the period of time involved between successive *R* impulses, the charging is also nearly linear. A 6H6 rectifier is connected from the anode of the metering 884 to the main voltage divider to limit the final voltage to which the 4 μF capacitor will charge. This avoids damage to the valve voltmeter which indicates the voltage across the voltage divider of the 4 μF capacitor. The valve voltmeter is a differential circuit type using a 6N7 double triode. This circuit also accommodates the galvanometer zero-setting voltage.

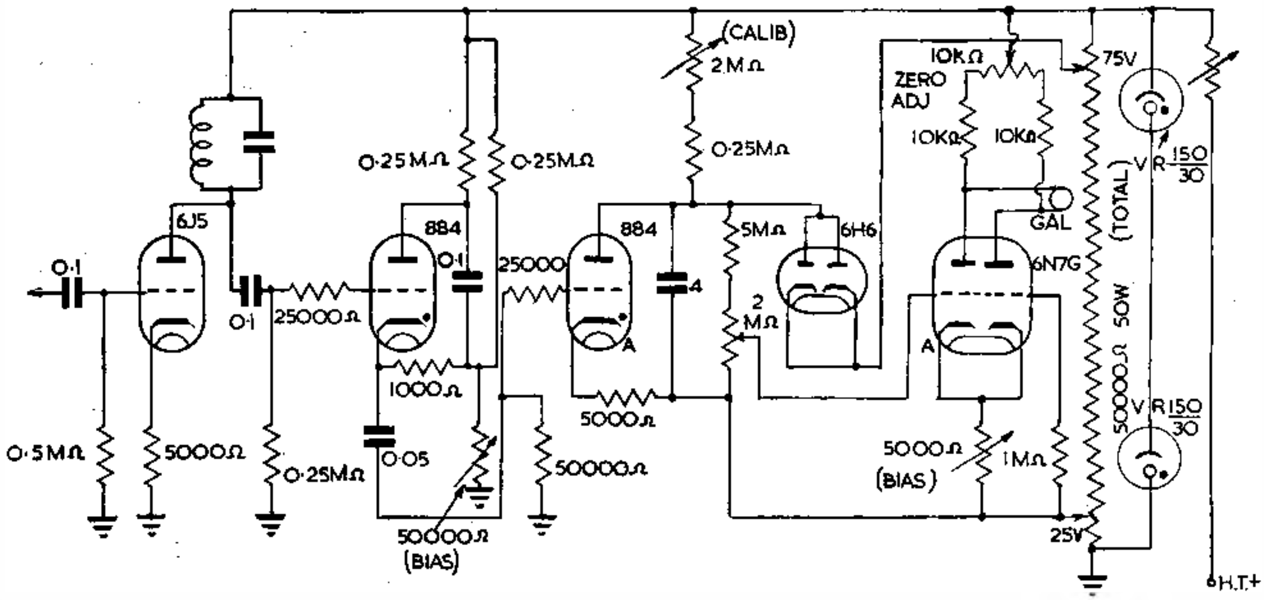


Fig. 14. Circuit diagram of cardiotachometer

Heart Volume Changes—Plethysmography

Rhythmical changes in electrical properties of the intact human subject have been noticed when alternating current of various frequencies was passed through the subject. Recent work by Nyboer[33] and others showed that the electrical impedance changes associated with each heart beat were the result of a pulsatile volume change in a given body segment. The method consists of passing a low voltage R.F. current through the body and detecting the modified R.F. potentials, the envelope form of which represents essentially a volume pulsation of the segment. The form of the impedance pulse or plethysmogram often is modified by disease and by artificial mechanical factors influencing the blood flow to a given segment of the body such as a digit, and hence the method is a useful diagnostic measure.

The procedure has distinct advantages over other plethysmographic methods for it can be applied anywhere on the body and has no known physical effect on the factors producing the pulse. Since the method is electrical, registration can be carried out with inertialess systems.

Blood Flow Velocity

A measure of the velocity of blood flow is useful in the examination of cardiac patients and of those with endocrine disturbances or pulmonary disorders which impair the flow of blood through the lungs. Various methods have been devised, most of which depend upon the measurement of time taken for some specific indicator inserted in the blood vessel to travel a certain distance. In many cases this involves opening the blood vessel concerned, a procedure which is generally undesirable.

An electromagnetic flowmeter has been described by Kolin[34] which, it is claimed, has not this disadvantage and, in addition, it faithfully records rapid changes in blood flow occurring during each cardiac cycle, thus making it possible to record an instantaneous velocity pulse. The principle of operation depends upon the fact that a potential difference is created across an electrical conductor which is moving across the lines of force in a magnetic field. The P.D. is directly proportional to the speed of motion of the conductor, and independent of the nature of the conductor. The unopened blood vessel is placed within a uniform magnetic field with the axis of the vessel at right angles to the direction of the field. The portion of the vessel included between the poles of the magnet is enclosed in an insulating sleeve through which two non-polarisable electrodes are led, and placed in contact with the vessel wall at points diametrically opposite and in a line at right angles to both direction of field and long axis of vessel. To record absolute rate of flow as well as changes in flow a direct-coupled amplifier would normally be needed. Since difficulties due to instability arise with D.C. amplifiers, the input from the electrodes is fed into a 50 c/s. interruptor and thence into a resistance-capacitance coupled amplifier. Thus the amplifier output consists of a modulated 50 c/s. tracing, the lower peaks forming an approximately straight base line, and the upper peaks delineating the velocity pulse. The amplifier has an overall voltage gain of 1,000, there being two stages using 6SJ7 and 6C5 valves. The time constant of the coupling circuits is about two seconds, this being sufficiently long to ensure adequate response and a steady base line.

Photo-electric Cells

Photo-electric devices have been widely used in biochemical and pathological investigations. Colorimetric problems, in particular, have been aided by such devices. One such problem is the measurements of oxygen saturation of the blood, an important factor which varies with disease. The principle of operation of photo-electric "oxygen-in-blood" measurements is that in the red region of the spectrum, reduced haemoglobin (the oxygen "carrier" of the blood) absorbs a greater amount of light than oxyhaemoglobin (the actual compound of oxygen and haemoglobin), and thus a variation of red light absorption indicates a change in the ratio of oxygenated to reduced haemoglobin. Kramer[35] and Matthes[36] did the fundamental work in blood oximetry, and their technique was applied by Hartman and McClure[37] to continuous measurement of oxygen in blood flowing during the course of an operation on an anaesthetised patient by colorimetric measurements of red light passing through the first interdigital fold of the hand. The transmitted beam of light fell on a high vacuum photocell, the output of which was amplified to give the required indication.

Apart from the drift due to instability of the D.C. amplifier, the most serious limitation of the monochromatic method is drift due to variations in (i) tissue thickness, which affects the amount of light absorption by the tissue itself, (ii) the amount of blood in the optical path, (iii) total haemoglobin in the optical path, (iv) vasomotor changes caused by fluctuations in blood pressure, which would affect factor (ii). Other workers have recognised the disturbing effects of these "volume" variables and have attempted to correct for them. Squire[38] and Goldie[39] standardised their instruments by rendering the tissue bloodless, whereas Millikan[40] compared the fully flushed ear with an optical filter. A modification of the Millikan method has been described by Hartman.[41] A unit which can be attached to the ear contains two miniature photocells, a small lamp and two colour filters, red and green. Light transmitted through the pinna of the ear is measured in two spectral regions. The "red" cell photocurrent reflects changes in the oxygenation of the blood together with the "volume" variations mentioned above. The "green" cell photocurrent reflects only "volume" variables, because in this spectral region the absorption characteristics of oxyhaemoglobin and reduced haemoglobin are similar. The two photocurrents are connected in opposition, and the difference signal fed into a contact modulated amplifier of the type described by Liston Quinn, Sargeant and Scott.[42] In this type of amplifier the signal is broken up by an input breaker so that it is applied alternately between the two halves of an input transformer primary winding. The secondary winding of this transformer feeds into a tuned R-C coupled amplifier. The amplified signal is then rectified by an output breaker synchronised with the input breaker to produce a unidirectional output current. This synchronous rectification allows only those voltages of the same frequency as the input breaker to produce a D.C. output signal. The use of a normal alternating current amplifier avoids the drifts due to valve characteristic and supply voltage changes, always troublesome in D.C. amplifiers.

Photo-electric colorimeters can be used for turbidimetric determinations just as readily as for colorimetric procedures. The basis for the calibration of these methods, which depend on the development of a uniform turbity rather than a colour, is a solution of standard turbidity. There are many applications of this method, in particular, Joslyn[43] and McMahan[44] have used it for penicillin assay.

Conclusions

Electronics in diagnostic medicine covers such a vast field that in this article only some of the more interesting and important applications have been dealt with.

The application of radioactive isotopes in diagnostic problems has already been mentioned in a previous paper by the author,[1] and it has been thought unnecessary to deal again with the measurement of their radiations. Similar problems of instrumentation encountered in the use of X-rays in diagnosis, are also common to measurements of therapeutic dosage, again mentioned in the same paper.

Although it would seem that technical advances in circuitry and thermionics have been of immense benefit to instrumentation in medicine, there is in fact a long time lag between the discovery of any particular technique and its incorporation into an instrument of use to the medical profession. The physiologist, or whoever may be interested, is rarely in a position to dictate a line of research, usually because of commercial considerations. This often means that they themselves must carry out their own electronic development, a state of affairs which is unsatisfactory to say the least. If electronic engineers were acquainted with those problems confronting the medical profession which require their specialised knowledge, perhaps more of them would be attracted to the service of medicine. Facilities for their work would most certainly be made available, for the medical profession is aware of the value of their prospective contribution.

I am indebted to Mr. A. Nightingale for his helpful criticism of this paper. I also wish to express my appreciation to those firms who have provided photographs of instruments which are shown in the article.

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Geiger-Müller Tubes in Industrial Radiography

By O. J. RUSSELL, B.Sc.(Hons.), A.Inst.P.

THE Geiger-Müller tube, largely as a result of the great development of applied Nuclear Physics, has become a standard commercial product, available as a stable dependable device in a wide variety of specialised types.[1] As a result, the research and industrial applications of the peculiar advantages of the G.M. tube is rapidly advancing in many branches of investigation. While isotope tracer applications are widely recognised and appreciated, there are certain other applications which are of direct industrial importance. Industrial radiology is one particular field where G.M. tube techniques offer special advantages.

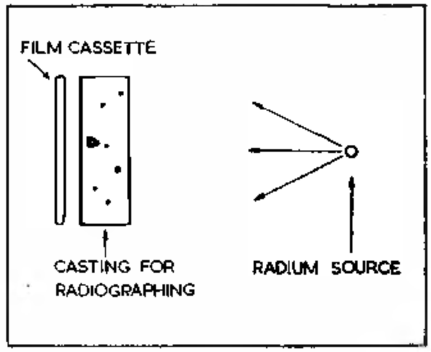


Fig. 1a. Typical set-up for conventional Gamma radiograph. The source-to-film distance is necessarily large, in order to obtain well-defined radiographs. This results in a long exposure time.

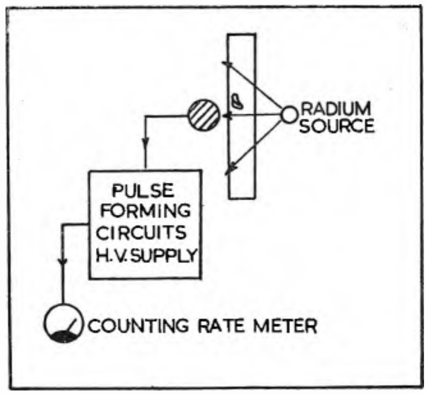


Fig. 1b. Set-up for G.-M. tube inspection. The closeness of the source enables a further gain of sensitivity due to the higher radiation intensity, quite apart from the superior sensitivity of the G.-M. tube.

Industrial Radiology

The great sensitivity of the G.M. tube as a detector of radiation, even down to a single high-energy quantum, enables conventional photographic methods of radiography to be replaced advantageously by techniques employing G.M. tubes. It should be clearly realised that the G.M. tube does not render photographic methods obsolete. For some applications it has a very clear advantage over photographic methods, so that it is likely altogether to supplant them. In other radiological fields photographic methods are supreme, while there is a considerable range of applications for which photography and the G.M. tube are of roughly equal value. However, even in cases where photographic methods are employed, it is possible to use the G.M. tube as a helpful adjunct, enabling more reliable radiographs of closely standardised contrast and density to be obtained.

G.M. Tube Exposure Meter

One particular difficulty in the radiography of large castings, whether by X-rays or by Gamma-rays from radium or other radioactive sources, is the adjustment of the exposure time. Where such radiography is a regular routine, exposure tables based upon the parameters of metal thickness, metal composition and type, kilovoltage and X-ray tube current, or radium source strength and distance, are used. These procedures are largely empirical, and generally inconvenient. In the case of radon sources, an irritating complication is the decay of strength of the source, so that the source strength is often uncertain, while in any case its effective value must be calculated from its initial value at the time of preparation from the radium source. The initial value itself may only be an estimation, as a source may be prepared before the parent radium has attained effective equilibrium with its own decay products. This difficulty, peculiar to the use of short-lived radio-elements, will also be experienced when compact gamma-ray sources of pile fission products are used in radiography (Fig. 1a).

The G.M. tube thus finds an ideal application in providing the basis of an exposure meter giving a definite indication of the required exposure time for a perfect radiograph. Once calibrated, such a device enables the required exposure time to be evaluated from a single reading, and the exposure can be made in the confident expectation of a standard density radiograph, thus facilitating comparisons between members of a series of radiographs taken at different times. The intensity of radiation passing through a sample to be radiographed may be detected by a G.M. tube. The pulse output of the tube can be made to operate a meter, by means of an averaging circuit. The meter reading can then be converted to the exposure time by means of a calibration chart. Such types of averaging meters, giving a reading of the average rate of pulses, are in effect specialised frequency meters, as in the case of radiation measurement the pulses are distributed at random about the mean value. They are described in the literature as "rate-of-count" meters or "integrators" (Fig. 1b).

The G.M. tube exposure meter has several clear advantages in the field of industrial radiography. The tube being in the position to be occupied by the photographic plate renders the system independent of the geometry of the set-up. Furthermore, as the intensity of the transmitted X-rays is the quantity determined, the reading is quite independent of the material to be radiographed, and the calibration chart suffices for all types of sample. The "exposure tables" based upon considerations of the absorption of incident X-rays, as normally employed, must be drawn up for every different class of material to be employed. One factor rendering the G.M. tube "exposure meter" especially sensitive should not be overlooked. The photographic plate response is logarithmic, whereas the response of the G.M. tube is linear. A small percentage change of intensity will thus cause a proportionate change in the G.M. operated "ratemeter" indication. However, the change in density of the developed film will be proportional to the change in the logarithm of the intensity, and this will be much smaller than the intensity. The G.M. charge tube exposure meter is thus more sensitive to small changes than the photographic emulsion, so that exposures can be estimated more closely than is necessary to ensure a standard negative density. The calibration of the G.M. exposure meter depends to some extent upon the X-ray tube voltage, but above 150 kV the calibration is very largely independent of the kilovoltage. The facility with which exposures may be computed enables multiple exposures readily to be made upon castings of variable cross-section, as the exposure required at any particular area can be quickly determined.

Radiation Leakage Monitoring

The G.M. tube exposure meter can be usefully employed in the measurement of the scattered radiation from radiographic installations, and to ensure that workers in the vicinity are not subjected to above-tolerance dosages of radiation. Ionisation chambers, largely employed in the past for monitoring stray radiation intensities, suffer from the disadvantage of requiring a considerable time to be expended in making a single reading. The tolerance level for daily exposure, may be taken as 10^{-6} Roentgens per second. A G.M. tube will readily register intensities of the order of micro-Roentgens per hour, so that a large area can be readily explored for excessive leakage fields. To avoid unnecessary exposure, it is quite feasible to operate the equipment at a low level, if this is a known fraction of the normal running level, so that there is no danger to the operator making the measurements. The G.M. tube can be conveniently mounted upon a probe, so that small areas and nearly inaccessible cavities may be tested. The G.M. tube response varies with the quality of the radiation in a different manner from the response of an ionisation chamber. Troost[2] employed a shield surrounding the G.M. tube, so as to duplicate closely the response of an ionisation chamber. A shield using a thickness of 1 mm. of tin and 1 mm. of brass was found suitable for X-rays from 120 kilovolt energy up to 300 kilovolts.

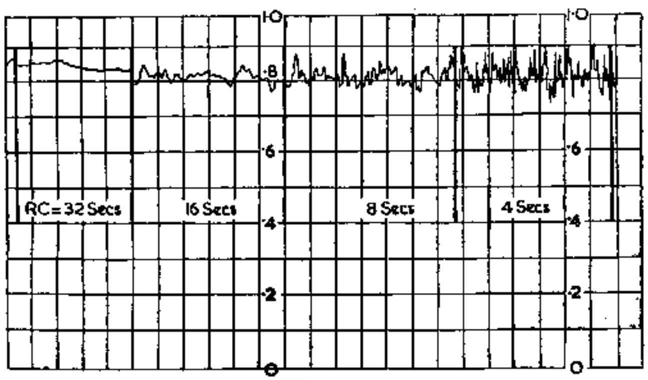
Inspection Considerations in Radiography

The fundamental difference between the G.M. tube and the photographic plate in radiographic applications, is that the G.M. tube can only explore a small element of area at a time, while the photographic plate records the intensity variations over an extended area. The photographic plate can record fine detail, while the G.M. tube may be limited to a rather coarse "element" of area. The G.M. tube must be arranged to "scan" an extended area element by element if the variations throughout are to be determined. Only if the G.M. tube can scan the whole area in a shorter time than a photographic exposure is there a saving in time.

In radiographing an extended area, we must consider that the G.M. tube is recording the high energy particles or quanta passing through a small element of that area. The particles or quanta are emitted at random, so that the number recorded will also fluctuate in accordance with the statistics of random events. If a large number of particles are counted, there is a probability that the number deviates from the true mean value. If N particles pass through the area in a given time, we may say that there is a Probable Error (P.E.) given by P.E. = $0.6745\sqrt{N}$, that this number deviates from the true mean rate of particles to be expected during this time. This sets a fundamental limit to the precision of measurement. If the intensity of radiation is fixed, and hence the rate of passage of high energy quanta or particles, then we can only increase the precision of measurement by recording for a longer time. This limitation applies to any device sensitive enough to respond to small numbers of quanta, and applies to direct counting methods and to "counting rate" meters alike. A counting rate meter circuit may be made so sensitive that a single quantum causes a large needle deflexion. This is useless if so few quanta are arriving that the needle is in a state of violent movement. It is necessary to provide the counting rate meter with a time constant such that a reasonably steady needle deflexion is obtained. Where very low intensities are concerned a direct counting method may have to be developed, as the time constant required may be so great as to be impracticable. The counting rate meter also requires time to adjust itself to a new counting rate, and in general a time of some three or four times the time constant must be allowed before the dial reading has approached the new value to a sufficient accuracy. In the case of a counting rate meter in which the needle is fluctuating, the mean position may be judged closely by observing the needle movement for some time. This again corresponds to taking a count over an extended period, in this case over several time constants.

Counting rate meter circuits employ the time constant of a resistor and capacitor combination to store

Fig. 2. Recording of gamma-ray emission from a constant intensity source.



a number of impulses. The capacitor voltage thus indicates the mean rate of impulses received. The impulses decay exponentially, so that in effect the "counts" are weighted exponentially with time. The "time constant" of the meter circuit may be regarded as the time of counting, and the precision will be similar to that obtained by a direct count over the same period of time.

A recording meter may be operated from a counting rate meter circuit. The specimen record (Fig. 2) was made by a recording attachment operating from an Alltools standard G.M. equipment, the combination being designed for X-ray diffraction and similar applications where a permanent record is desirable. The recording is of a constant intensity radioactive source emitting gamma-rays. The meter circuit has a time constant adjustable in steps from four seconds up to 32 seconds, and the sections of recording illustrate how the fluctuations of the instantaneous reading from the mean position decrease with longer time constants. A plot of the maximum peak to peak fluctuation in each section against the reciprocal of the time constant gives a straight line, which is to be expected on statistical grounds (Fig. 3).

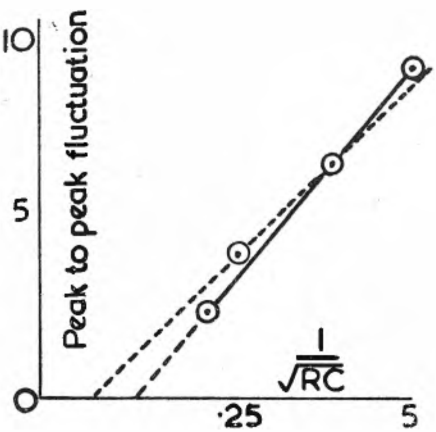


Fig. 3.

Peak fluctuations from recording, plotted against reciprocal of the square root of the time constant

The fact that the line does not appear to extrapolate through the origin, that is to zero fluctuation with an infinite time constant, is to be attributed to the drag of the inked recording needle on the paper chart. Needle drag is, in fact, of some importance in reducing the residual fluctuations when long time constants are employed. It will also be noticed that even when short time constants are used, the mean position can be accurately estimated from a short length of recording provided it extends over several time constants. This is equivalent to direct counting for a similar period. A chart speed of 12 in. per hour was employed, so that each section of the record extends for several time constants.

Practical Considerations in Radiographic Methods

Only photographic methods need be considered as an alternative to the G.M. tube. Ionisation chambers may be disregarded, as if the requisite sensitivity is obtainable the response is so sluggish that the time requirements are impracticably long. Even the use of high pressure chambers does not materially affect the situation, while the use of large chambers prevents the examination of small defects. The G.M. tube is the only "point to point" device that can rival the extended area recording of the film or plate.

In gamma radiography the G.M. tube must cover an area of about one square centimetre, due to screening difficulties. This provides a basis for a quantitative assessment of the G.M. tube against photographic methods.[3] With a 100 mg. radium source, and a steel plate 7.5 cm. thick, the optimum source-to-film distance is 40 cm., according to the paper quoted, and the exposure time would be three hours. A defect of approximately 2.5 mm. diameter would be detected, or a deficit slightly less deep than this would be detected if it was somewhat wider. Friedman, Kaiser and Christensen,[3] in considering a G.M. tube scanning a steel plate, assume that the radium source distance can be conveniently reduced to 12.5 cm. Assuming that a 1 gram radium source emits 7×10^{10} quanta per second, then with a normal linear absorption coefficient of 0.35 for steel, and a 100 mg. radium source, 2.5×10^{5} quanta per sq. cm. will emerge from the steel sample. The G.M. tube, if it has an efficiency of 1 per cent, will record 2.5×10^{3} quanta per second, if its sensitive area is 1 sq. cm., and in 0.3 seconds recording the probable error will be 2.5 per cent. However, a change in thickness of the steel of 2.5 per cent will produce a 5.3 per cent variation in radiation intensity, which is readily detectable.

In the radiographic case of 40 cm. source-to-film distance, geometrical considerations limit the area radiographed to about 270 sq. cm. A G.M. tube taking 0.3 seconds to record the intensity over each square centimetre would scan the entire area in 90 seconds, as against the three hours required for photographic recording. For thicker sections of steel, the G.M. tube is even more advantageous. A 15 cm. thick steel plate with a 100 mg. radium source at 45 cm. needs a photographic exposure of 40 hours, and the minimum defect that is detectable is about 4 per cent of the total thickness, and this is comparable with the area covered by the G.M. tube. With moderate sections, the photographic plate can detect defects of about 0.25 sq. cm., while the G.M. tube is limited to 1 sq. cm. For the detection of fine tears, cracks, small blow holes and shrinkage cavities photographic methods are preferable, while the G.M. tube is superior for detecting wall thickness changes, corrosion areas, large cavities and general porosities. As minor defects are of less importance in thick section material, and this is when the time required for a photographic radiography becomes excessive, it is here that the G.M. tube is of special value.

X-Radiography. Thin Sections

For X-radiography, the conditions are somewhat different, as the intensity available is greater than in gamma radiography, and it is also possible to reduce the effective area of the G.M. tube by means of thin lead screens, so that small defects may be picked up.

One interesting use is the measurement of the thickness of thin foils and sheets, where soft X-rays give a high sensitivity to small thickness variations. Troost[2] was able to measure by G.M. tube methods foils of lead, brass, copper and steel of .005 in. thickness to an accuracy of 1 per cent in a time of one-tenth of a second. This can provide a means of continuously monitoring the thickness of strips and sheet during manufacturing processes. Higher sensitivity still can be achieved by the use of a suitable

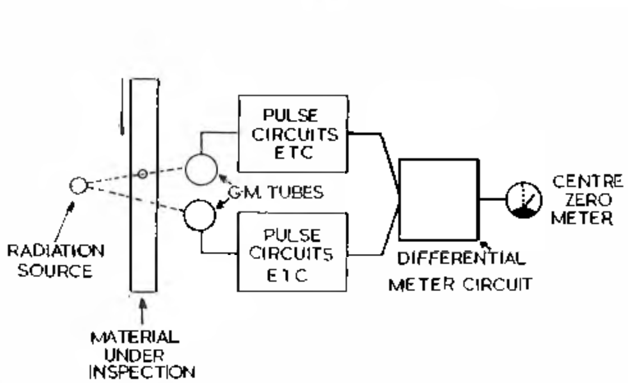


Fig. 4. Differential counter set-up for material inspection. Impulses from the two symmetrically disposed G.M. tubes are applied in opposition to a counting circuit with a null indicating meter

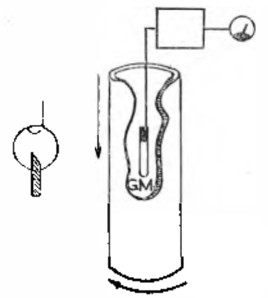


Fig. 5a. G.M. Tube inserted inside narrow cylinder to permit use of X-Ray equipment for inspection. For continuous inspection the cylinder may be simultaneously rotated and traversed past the G.M. tube, thus giving a spiral scan.

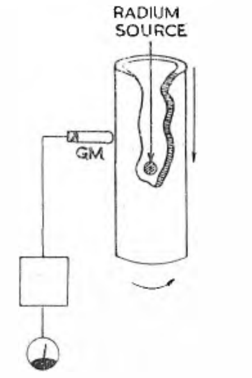


Fig. 5b. Radium source placed in narrow cylinder or tube for Gamma ray scanning. Particularly valuable for very narrow pipes and tubes

beta-ray emitting isotope as the radiation source.[4] Beta rays are convenient, in that they can be readily collimated to a narrow beam, and stray radiation may be completely stopped by very moderate shielding. Radiation hazards to personnel are thus eliminated, while the ready absorption of the rays gives a very high sensitivity to small thickness changes. Radio-strontium has been found a useful isotope for metal thickness determinations, while isotopic radiations may be selected to give adequate sensitivity for a wide variety of plastics and other products. The thickness of paper can be monitored during production, as a typical example.

Differential Scanning System

One arrangement of particular value for scanning techniques is the differential detection system illustrated in Fig. 4. Two G.M. tubes intercept the radiation passing through two closely spaced areas of the sample. Their outputs are connected in opposition to a null indicating meter circuit. With a homogeneous material in position, the two outputs should be equal, and the meter indicates balance. A defect passing one G.M. tube disturbs the radiation intensity, so that an unbalance is indicated. If the defect passes each G.M. tube in turn, a definite needle indication, first in one direction and then in the other, will be recorded. As two random inputs are combined, the totalled counts are in effect doubled, and although the indicating needle will fluctuate about the mean position, the passage of a defect is signalled by two definite indications, one in each direction about the zero. The certainty of detecting flaws is thus increased.

Specialised Scanning Methods

Using X-rays, it is difficult to use photographic methods for inspecting the wall thickness of pipes, gas cylinders, pressure vessels, etc. A G.M. tube can be readily introduced into quite narrow cylindrical bores, so as to register the transmitted X-ray intensity (Fig. 5a). This gives an accurate measure of thickness variations, and the presence of defects. By rotating the cylinder or pipes, in conjunction with an axial traverse, a spiral scan may be effected, so that the entire cylinder surface can be inspected. Wall thickness of 5 cm. can be checked to an accuracy of 0.5 per cent, using 200-300 kV X-rays. With a G.M. tube effective aperture of $\frac{3}{4}$ in., the time required for each element of area is 0.1 sec. If a radium source is used, or a compact gamma-ray source of pile fission products, the source may be inside the tube, and the G.M. tube outside, so that very narrow pipes may be inspected (Fig. 5b).

In the case of castings of irregular shape, it is possible to use a compact gamma-ray source as a probe. A G.M. tube can be placed at a succession of convenient positions, and the gamma-ray source moved to detect irregularities at strategic points. This can be used in cases where photographic methods are clearly inapplicable.

The use of a recording rate meter of the type previously considered enables an automatic recording to be made of the intensity, and hence thickness, variations at any point. The permanent record is of greater value than a photographic radiograph, as the recording gives a direct quantitative measure of radiation intensity.

Back Scatter Method

Back scatter methods are particularly valuable, in that it is possible to detect thickness variations in sheets, such as boiler plates, when only one side is accessible. The G.M. tube is shielded from direct radiation from the radium or other gamma-ray source, as in the arrangement of Fig. 6. The scattered radiation from the steel sheet is detected by the G.M. tube, and in back scatter arrangements the intensity increases with the thickness of the sheet. However, the increase becomes very slight for thick sheets, although the method is very useful up to about 2 cm. thickness. Back scatter methods are also of value in determining liquid levels in opaque tubes, the investigation of filled containers, of coated materials, etc., and can be employed with X-rays as well as gamma-ray sources.

A Fuel Pipe Problem

An interesting use of G.M. tubes in an inspection problem was devised in Alltools laboratory. In the bending of pipes, it is usual to fill the pipe with various compositions to prevent wall collapse during

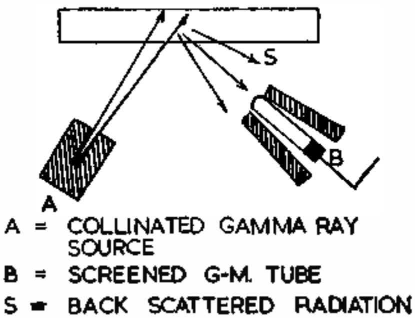


Fig. 6. Back scatter set-up

bending. Where such pipes may be used for fuel feed purposes, it is essential that all of the plugging material be removed from the pipes, so that a disastrous blocking of a narrow jet or orifice does not occur in service. By incorporating a harmless amount of radioactive tracer in the plugging compound, it is a matter of moments to detect with a G.M. tube if any trace of the plugging compound has been left in the tube. As only a "yes-no" type of indication is required, a very simple indicating device may be used.

X-Ray Diffraction Applications

The most significant advances in the use of G.M. tube techniques are likely to result from X-ray diffraction applications. Fig. 7 illustrates a G.M. tube specially developed for this work. The tube has a slit window covered by a micro-thin film, and is intended to be mounted on an X-ray spectrometer table. The high sensitivity of the G.M. tube enables very weak lines that are photographically invisible to be resolved from the background, as long counts up to an hour or so may be made. In more conventional diffraction applications, rapid line intensity readings may be obtained directly, as well as a quick location of line positions. If a recording attachment is used, a complete diffraction pattern can be mapped out on the chart, as the deflexions are directly proportional to X-ray intensity. The background intensity is also recorded if a continuous traverse is made, so that exact intensities can be read off the recording. This is of value in both routine and research applications, as the time is shorter than for photographic methods. It is possible to conserve X-ray tube life in many cases, by operating at greatly reduced currents. The recording circuit can be readily arranged to produce fiducial marks for identifying line positions, by means of contacts arranged at selected angles on the spectrometer. On the record previously discussed, the fiducial marking circuit has been used to separate the sections of the record.

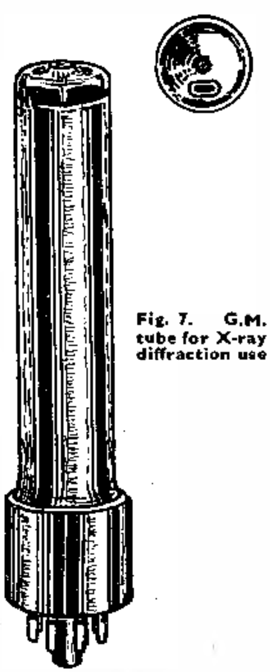


Fig. 7. G.M. tube for X-ray diffraction use

The estimates of the gain in speed possible with G.M. tube methods vary somewhat. One recent estimate is that the photographic methods require about 100 times as many quanta for comparable accuracy.[5] The advantage of increased speed is not wholly in the saving of time, but lies in the feasibility of hitherto impracticable investigations. Rapid changes of physical state in a heated sample or small changes in stressed samples can be readily investigated. The higher sensitivity enables smaller crystals to be investigated, a matter of extreme importance in the investigation of new synthetic products, and particularly in the bio-chemical and biological field where only small quantities of isolates may be available. The plotting of pole diagrams is also greatly facilitated, as intensity readings are obtained directly.

The above brief survey covers many of the applications of G.M. tube techniques to radiographic problems. It is, of course, obvious that in the field of medical radiology similar uses have been made of G.M. tube methods. The very new fields of neutron diffraction, and neutron radiography offer similar scope for neutron sensitive detecting tubes, and interesting developments are likely. It is hoped that the value to research and industrial workers has been adequately presented. In conclusion, thanks are expressed to the directors of Alltools, Limited, for permission to publish the above article, and to the Director of Research for helpful advice and criticism in the course of preparing the manuscript for publication.

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New Uses for Magnetic Fluids

ONE engineering application proposed in the Bureau's preliminary investigation of new uses for magnetic fluids is the magnetic fluid dash pot. If a magnetic fluid is used, the rate of motion of the plunger can be readily controlled by magnetically varying the viscosity of the fluid. If a coil of wire is placed around the dash pot, the viscosity of the magnetic fluid will be a function of the current in the coil. Employing this idea in the design of shock absorbers for automobiles and trucks would provide an adjustable riding quality to meet various loading and roadway conditions. The rate of response of the magnetic fluid is high enough to provide virtually instantaneous changes in viscosity, thereby making possible a shock absorber with automatic compensation. The fluid also offers interesting possibilities for use in hydraulic systems. If a hydraulic system is filled with a magnetic fluid, valving becomes extremely simple: by winding a coil of wire around a fluid-carrying pipe and controlling the amount of current through the coil, the flow of fluid past that point can be closely regulated.

—N.B.S. Technical Bulletin, 3, 74, 1949.

Make a Photocell

The photo-electric properties of a single selenium rectifier plate can be used to make a light-sensitive meter.

SELF-GENERATING photocells are rather expensive for the amateur electronic experimenter. For this reason, they seldom are bought for the prime purpose of amateur experimentation. However, few amateurs know that a good photocell of this type can be home-made very easily. A simple light-sensitive element for a home-made cell, requiring no chemical processing by the builder, is a plate taken from one of the small selenium rectifiers widely used at present in transformerless radio power supplies. The 150 milliampere size rectifier has plates each a little larger than 1 sq. in. in area. When electrical contact is made to each of the two faces of one of these plates, and the selenium-coated face is illuminated, a small but useful voltage will be set up. The plain metal face will be positive and the selenium-coated face negative. This voltage will actuate a sensitive meter-type D.C. relay directly, or it may be applied to the grid input circuit of a valve to operate a heavier relay. It will also deflect a D.C. microammeter directly.

A complete, rugged photocell is obtained by mounting the rectifier plate securely in a protective housing and providing output terminals. The finished cell may be used in a variety of experiments or may be installed permanently in electronic equipment.

Construction of the cell is shown in Fig. 1. The light-sensitive rectifier plate is fastened to the inside back of the jar top with its selenium-coated face exposed to receive incoming light rays. Contact to the selenium surface is made by means of a solder lug bent downward to rest firmly upon the coated surface of the plate. The lug is held in place by a screw which passes through the large clearance hole in the centre of the rectifier plate and through an aligned hole in the back of the jar top. An outside nut secures this screw, preventing contact between it and the sides of the clearance hole in the rectifier plate. Under this nut is a second solder lug for connexion of the selenium-coated surface to the external circuit. The bakelite washer separating the screw end of the inside lug from the selenium surface is necessary since the selenium coating on most rectifier plates does not extend unbroken to the edges of the central hole. Without the washer the lug would touch the uncoated portion of the metal plate and short-circuit. Connexion is made to the uncoated rear face of the rectifier plate by means of a narrow, flat strip of brass or phosphor bronze attached to the banana plug.

Building Instructions

1. Secure a 100- or 150-mA selenium rectifier. This unit must be an unpainted model. (Several commercial rectifiers are completely dipped in paint which conceals the light-sensitive selenium surface from light rays, and these models are unsatisfactory for photocell use. The paint probably can be removed with paint remover or lacquer thinner, but the author hesitates to recommend a paint-stripped unit, since he has not tested one.) Remove the plates from the rectifier and select one.

2. Be careful not to scratch or cut the selenium-coated surface of the rectifier plate. Using fine emery cloth or sandpaper, clean the uncoated rear face of the plate so as to ensure good electrical contact.

3. Secure a 2-in. diameter black plastic jar top. Drill a hole through its centre and an identical hole through its rim. The first hole is for the plate-holding back screw; the second one for the banana plug.

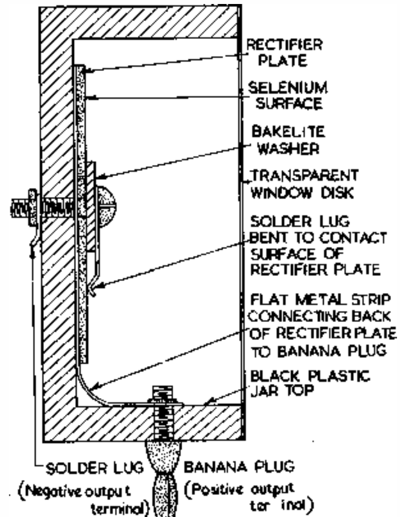


Fig. 1. How to mount the selenium disk in its protective case. The coated surface of the disk, must of course, face the window

4. Cut a flat strip of thin brass or phosphor bronze about $\frac{3}{4}$ in. long and $\frac{1}{4}$ in. wide. Drill a hole near one end of this strip and make a right-angle bend in the last $\frac{3}{4}$ in. at the drilled end. Place the strip inside the jar top, with the screw of the banana plug passing through its clearance hole. Fasten the strip and plug with a nut. Bend the free portion of the strip slightly upward so as to make contact with the rectifier disk when the latter is placed into position.

5. Bend a solder lug into the shape of a wiper contact, pass a screw through its hole, and pass the screw through a $\frac{1}{2}$-in. diameter bakelite washer.

6. Place a rectifier disk into the jar top with its selenium-coated surface outward, and press it down against the metal contact strip previously installed. Then pass the screw holding the lug and washer through the large clearance hole in the rectifier disk and through the hole in the back of the jar top, holding all the parts stationary to keep the screw in the exact centre of the hole and out of contact with the rectifier disk. Tighten the entire assembly by means of a nut on the outside of the jar top. Be careful that the inner lug does not bite through the selenium coating.

7. Place a solder lug on top of the outside back nut and add a second nut to secure this lug.

8. Cut a 2-in. diameter disk of transparent, colourless celluloid or other thin plastic and mount this disk over the open side of the photocell by means of adhesive cement.

Performance of the Unit

After the photocell has been completed, connect it to a D.C. microammeter, or D.C. valve voltmeter. When light is directed upon the surface of the rectifier plate within the cell, the meter will be deflected upward.

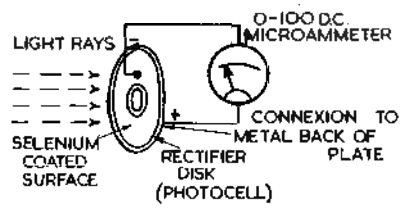
There will, of course, be some variation in results obtained by different experimenters. However, the following data obtained by the author is indicative of a performance to be expected: A 60-watt lamp (without lens or reflector) placed about 3 ft. from the cell gives a photocell output of 10 millivolts across a 1,000-ohm load. In broad daylight (high noon in sunny California), with the cell pointed away from the sun, 0.2 mA is obtained with the cell connected to a 0-1 D.C. milliammeter (meter internal resistance = 100 ohms). Feeding the cell into a Sylvania Type 221 Polymeter (input resistance = 17 megohms), the deflexion is 0.2 volt away from the sun and 0.3 volt when the cell is pointed toward the sun. Higher outputs may be obtained, when employing light bulbs, by using a stronger lamp than the 60-watt unit mentioned in the foregoing, and also by concentrating the rays with a lens or reflector.

For higher outputs, several rectifier plates converted into photocells may be fastened close together on a plate of metal or insulating material and connected in parallel. A four-cell unit of this type constructed by the author gave the following performance: (1) In strong daylight, but pointing the cell away from the direction of the sun, 0.95 mA deflexion was obtained in a 0-1 D.C. milliammeter; (2) illuminated by a 60-watt lamp at a distance of 3 ft., 110 millivolts output was obtained across a load resistance of approximately 1,000 ohms.

A Simple Light Meter

One of the simple applications of the home-made photocell is the light (or exposure) meter which is so useful to photographers. Fig. 2 is the light meter circuit.

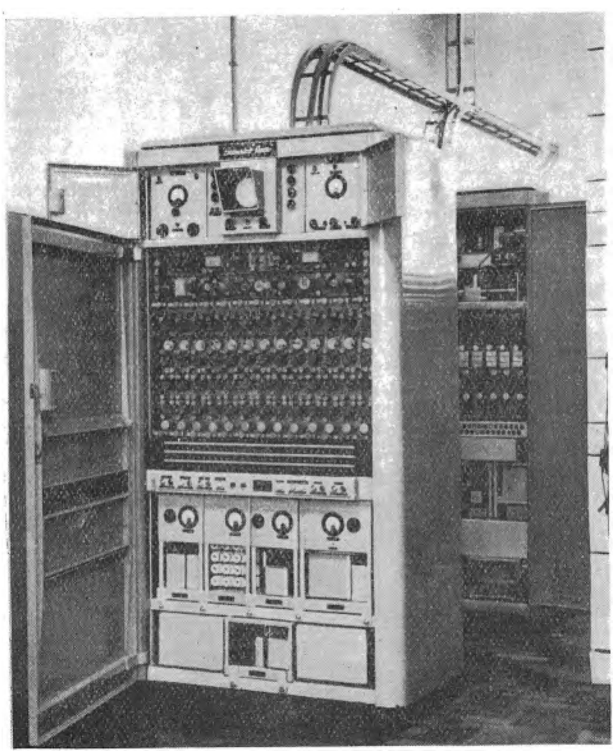
Fig. 2. Connexions for the exposure meter



The instrument is built into a $4\frac{1}{8}$-in. by 2-in. by $1\frac{5}{8}$-in. box with a $1\frac{1}{8}$-in. diameter hole cut for the light cell. After completion, the instrument may be calibrated against a factory-made exposure meter.

—*Radio & Television News, January*, 1950.

New Radio Link in South Africa



Standard Telephones and Cables, Limited, have recently completed for the South African Post Office an interesting installation to extend communications between Port Elizabeth and Uitenhage. The existing telephone communications of eight lines between these centres proved totally inadequate for the rapidly expanding industrial town of Uitenhage, causing delays of several hours. In view of the difficult terrain and the time factor, it was decided that a U.H.F. Radio Link should be installed and the "Standard" type Time Sharing Multiplex system was selected.

The Port Elizabeth terminal is installed in the carrier terminal station at Neal Street and is connected to the central Exchange by a multi-pair telephone cable.

The Uitenhage terminal is installed on a hill outside the town and connexion to the Exchange is by $1\frac{1}{4}$ miles of multi-pair telephone cable. This terminal is normally unattended. Alarms, indicating a failure of any part of the equipment, or unauthorised entry into the building, are immediately signalled to the Exchange.

The directive aerial systems at each terminal are half-wave dipoles in corner-type reflectors. These are mounted on lattice towers 125 ft. high and are connected to the equipment by 150-ft. co-axial feeders. The air line distance between aerials is $14\frac{1}{2}$ miles and the route is over a range of low hills. The system, dealing with up to 300 calls per hour, is now completely handled by the South African Post Office Authorities.

Resistance and Weight of Copper Wire

A Data Sheet for the calculation of the resistance and weight of wire in transformer and inductance windings

By N. H. CROWHURST

IN power transformers the winding resistance determines the heat dissipated in each winding at full load current. For economic power transformer design the watts dissipated in each winding and in the core should be proportioned so that the temperature rise on load is as uniform as possible, or does not exceed the permissible value at any point in the transformer. Also, winding resistance must be known in order to calculate the regulation of each winding of the transformer and of the transformer as a whole.

For iron cored inductance coils the Q of the coil is dependent upon the winding resistance and upon the loss due to hysteresis and eddy currents in the core. In iron cored chokes the D.C. potential drop across the choke is dependent upon its resistance value, while in energising coils for relays or loudspeaker fields the winding resistance must be accurately specified.

In the case of audio frequency transformers, winding resistance is equally important as it determines the series component of the insertion loss of the transformer, the shunt component being determined by the iron losses.

In simple two-winding transformers the economic choice of wire gauge for each winding is such that the series loss referred to each winding is equal, that is the D.C. resistance of each winding is the same fraction of the load impedance referred to that winding.

In the case of audio frequency transformers where there is a D.C. component in the primary, the design requires consideration of the primary of the transformer as a choke, while the transformer action is considered separately. Due to the requirement of minimum D.C. drop across the primary winding, it may be desirable to make the resistance of the primary referred to its operating impedance lower than that of the secondary by making the primary winding occupy a greater proportion of the available winding space.

Where push-pull transformers are operated in Class A there is no resultant D.C. magnetisation, so that D.C. drop across the primary winding due to the steady component of anode current in each of the pair of valves is usually small enough to be unimportant in the design of the transformer; it being possible, if the anode voltage requires to be adjusted to a precise value, to use a slightly higher supply voltage to offset the small drop. Generally for Class A working the maximum transfer of audio frequency energy from primary to secondary will be obtained by designing the transformer as a simple two-winding transformer having equal cross-sections of primary and secondary.

For Class B operation of audio frequency transformers only one-half of the primary winding is active in the transfer of energy from primary to secondary during each half-cycle of audio frequency wave form. It has been shown that under these conditions the minimum series losses for a given turns/impedance relationship will be obtained when each half-primary occupies 30 per cent of the available space, while the secondary occupies 40 per cent with the relative winding resistances in inverse ratio to these area proportions.

Transformers for multi-ratio working and tapped inductances often require special consideration of series losses. By tapering the wire gauge of various sections of an iron cored inductance so that the series resistance bears a constant ratio to the inductance value, an iron cored decade inductance will be produced having an overall Q only 20-25 per cent below the maximum Q obtainable for a single fixed value inductance on the same core at the same operating frequency. For multi-ratio transformers it will be appreciated that series loss can be minimised by utilising as much as possible of the available winding area on all ratios. 2:1 steps in ratio can best be achieved by series-paralleling methods. Steps less than 2:1 require the use of tappings, but by arranging the transformer winding resistances in such a way that the series losses are of equal percentage on all tappings, it is possible to produce a multi-ratio transformer within the range of 2:1 variation in ratio having an insertion loss not more than 5-10 per cent greater than a fixed ratio transformer of the same size.

Auto-transformers either for mains or audio frequency use can most simply be designed on the basis of using equal proportions of the available winding area for series and shunt sections; otherwise expressed, the series and shunt sections are considered as separate windings in a two-winding transformer.

The chart is based upon the standard B.S.S. specification for copper wire gauges and therefore the results calculated will only be accurate in practice if the wire used is exactly true to its nominal standard throughout its entire length. Some grades of wire are subject to a variation in diameter of plus or minus 10 per cent. This means that the calculated resistance values and weight will be subject to a corresponding variation of plus or minus 20 per cent. This fact should be borne in mind when drawing up winding specifications, both from the viewpoint of specifying winding resistances, and the possibility of getting the required number of turns into the available space.

Instructions for Using the Chart

(a) Given number of turns, length of mean turn and wire gauge to find resistance and weight of wire.

The number of turns is referred along the vertical

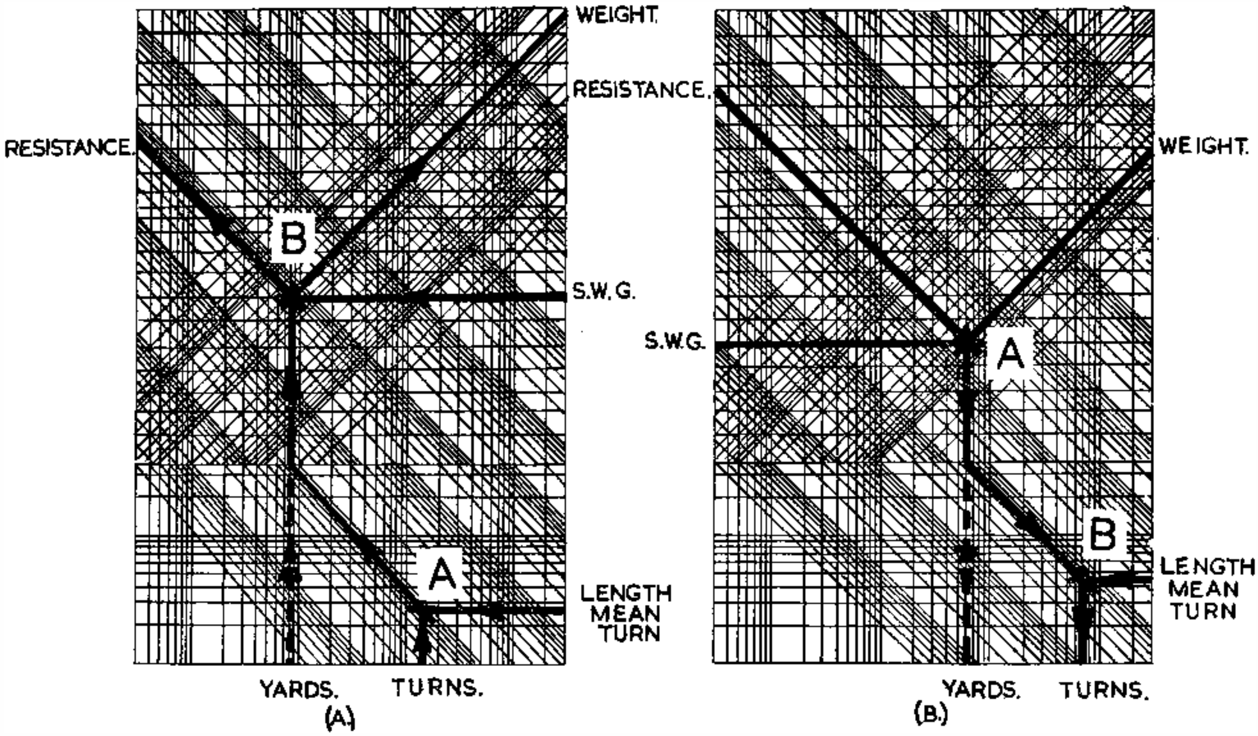


Fig. 1. Use of the Data Sheet: at (A) to find the resistance and weight of a given length of wire and at (B) to find the resistance of wire needed to fill a specified bobbin

lines from the bottom of the chart to intersect with the length of mean turn along the horizontal lines from the scale at the right-hand side of the chart at *A*. From here refer up the sloping lines to the 36-in. reference line at the top of the bottom portion of the chart and thence up the vertical lines to intersect with the horizontal reference line corresponding to the wire gauge. From this, reference along the sloping lines to the left-hand side of the chart will give the resistance of the winding, while reference along the sloping lines to the right-hand side of the chart will give the weight of wire.

If wire gauges other than those listed down the side of the chart against the reference lines are required, the appropriate horizontal plane on the chart can be determined if either the sectional area of the wire used, or its resistance per thousand yards, is known, from the reference scales alongside the wire gauge scales. (The intermediate lines between the even wire gauges marked represent the recognised odd wire gauges.)

(b) To find the resistance and weight of a given length of wire of specified wire gauge.

Simply refer direct from the bottom of the chart in yards to intersect with the horizontal wire gauge line at *B* as represented in Fig. 1(A) by the dotted line.

(c) To find the resistance of a winding composed of resistance wire given turns and length mean turn, or yards, and resistance per thousand yards of the wire gauge used.

From the reference scales at the right of the chart the appropriate horizontal plane is selected and reference across to intersect with the length in yards at *B* will give the resistance on the left-hand side of the chart as for copper wire, but in this case the weight of wire will not apply.

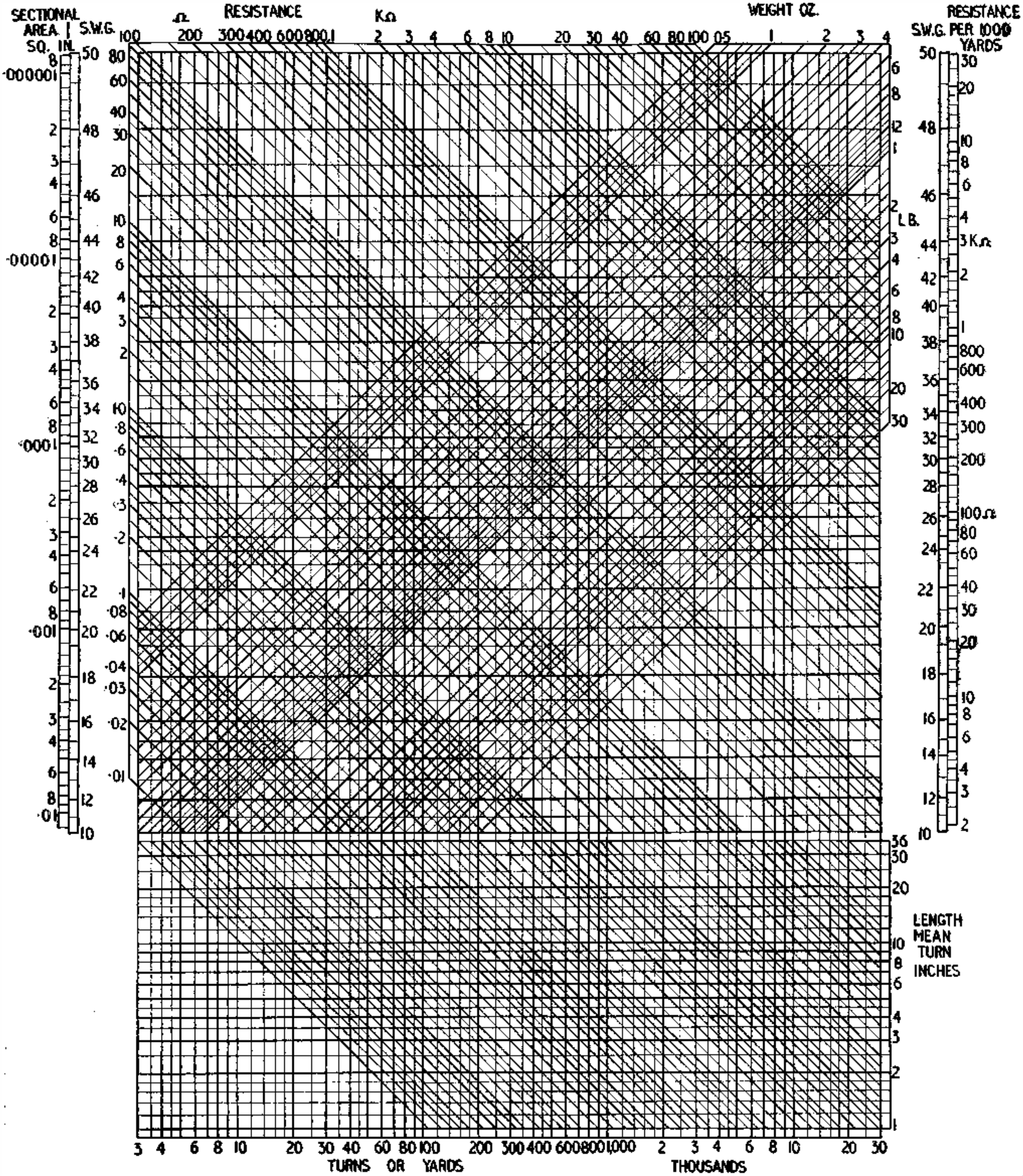
(d) To find the resistance of wire of given gauge and turns required to fill a specific bobbin.

It is assumed that the weight of wire to fill the bobbin has been determined from some other winding specification relating to the same bobbin allowing the necessary space factor for insulation. Direct reference from the weight scale to the wire gauge scale at *A*, Fig. 1(B), will enable the resistance to be read off along the sloping lines at the left-hand side of the chart, while reference downwards and along the sloping lines at the bottom of the chart to intersect with the length mean turn reference at *B* will give the number of turns at the bottom.

(e) To find the wire gauge and turns required to produce a given resistance filling a specific bobbin.

In this case the intersection between a given resistance and the weight of wire required to fill the bobbin will determine the wire gauge to be used. If the intersection does not fall conveniently on an exact wire gauge the next standard gauge above should be used, when the required resistance will be obtained by not quite filling the bobbin. Reference will then be taken from the intersection between the

(*Continued on page* 104)



Data Sheet for the resistance and weight of copper wire. Fig. 1 (opposite) illustrates its use

Resistance and Weight of Copper Wire — continued from p. 102

required resistance and wire gauge to determine the length and number of turns of wire required, while the weight scale will provide an indication as to the degree to which the available winding space is filled.

Examples

(1) 1,000 turns of wire, of mean turn length 5 in., and wire gauge 22, will have a resistance of $5\frac{1}{2}$ ohms and a weight of 1 lb.

(2) 1,000 yards of wire gauge 30 will have a resistance of 200 ohms and a weight of about $1\frac{3}{8}$ lb.

(3) 400 turns of length mean turn 8 in., and resistance per thousand yards 200 ohms, will have a resistance of 18 ohms.

(4) A bobbin takes 8 oz. of wire to fill it. If filled with copper wire of 32 gauge the resistance will be 120 ohms, the length 460 yards; and if the mean turn length is 4 in., about 4,100 turns will be required.

(5) It requires 12 oz. of wire to fill completely a given bobbin and the required resistance is 200 ohms. From the chart it will be seen that 32 gauge wire is too heavy. If 33 gauge can be used, then about $9\frac{1}{2}$ oz. of wire with 660 yards length will be required. If the odd gauge is not available, then about 550 yards of 34 gauge weighing about 7 oz. will be required.

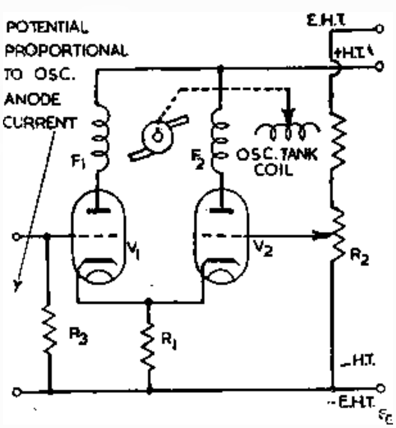
Automatic Control of R.F. Heaters

RECENT developments in the application of radio frequency heating to production processes in industry have proved the great practical value of this method of heating. The growing demand for R.F. heaters to deal with an ever-increasing range of methods and materials has resulted in the development of generators of progressively increased output power rating. In order to reduce the operating costs to a minimum, it is desirable to run each equipment at full output power. In these conditions, the auxiliary power requirement, e.g., valve filaments, fans, etc., are small compared with the R.F. power output, and the efficiency

$$\frac{\text{Total Power Input}}{\text{R.F. Power Output}}$$

is a maximum.

With dielectric heaters, it is found that the electrical characteristics of the load change during the heating cycle, and this results in a variation of the input power. This change of characteristics results from a variation of the moisture content of the load with temperature, and/or variation of loss factor with temperature.



With induction heaters, the application of power to a ferrous material results first in a decrease of impedance of the loaded work coil and then, as the Curie point is reached, a rapid increase is observed. In the case of non-ferrous loads only a slight change is noted.

The changes in the condition of the material being processed, except in the case of the induction heating of non-ferrous materials, results in the impedance of the load not remaining matched to the impedance of the generator. This causes a rise or fall in the output of energy into the load, and hence of the efficiency of the system as the load is heated. It therefore becomes advisable to provide an automatic means of continuously matching the impedances to enable the generator to work at full output during the heating cycle and to prevent damage due to an excessive increase in the output. This brings about the following advantages:

(1) A considerable saving in power consumption.

(2) A reduction in the process time with further consequent saving in process costs.

(3) Since it is possible to keep the generator always matched for maximum power output, the equipment is able to handle larger loads.

Since the D.C. anode-input power of a self-excited oscillator is, to a first approximation, a linear function of the output power, the mean anode current may be used to control the impedance matching device.

There are many arrangements which may successfully be used. One simple method is to compare two potentials, of which one is a controllable reference potential, derived from the E.H.T. supply, and the other is a potential which is proportional to the anode current of the oscillator valve. The two potentials are applied to the grids of the valves $V1$ and $V2$ of Fig. 1. These valves form a long tail push-pull pair. The field coils of a split-field motor are separately connected in the anode circuits of the two valves. Any deviation of the potential, which is proportional to the oscillator anode current, from the reference potential will, therefore, result in an inequality of the currents in the field coils with consequent rotation of the motor in a direction corresponding to the sign of the potential deviation. The motor is connected, through suitable gearing, to the R.F. output control of the heater, usually a variable tapping on the oscillator tank coil. Thus, should the load change in such a manner as to produce an increase of anode current, the motor will reduce the output power until the potentials are again balanced, whereupon the motor will stop.

In order to retain the normal flexibility of operation, the reference potential may be adjusted by the rotation of the potentiometer $R2$ for different types of load in order to provide maximum power into a given load. If necessary, feed-back can be applied to the system to increase the damping factor.

It will be seen that this system can be applied with equal success to dielectric and induction heaters provided the amount of R.F. power output is capable of continuous adjustment.

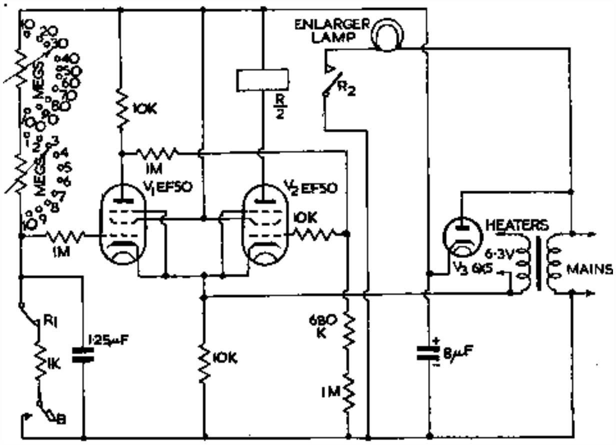
—Communication from E.M.I. Engineering Development, Ltd.

A Photographic Timer

By C. H. BANTHORPE*

THERE are a number of uses for a device which, when set, will close a circuit for a fixed time interval, and then open it. One such use is in the dark room, when enlarging. The dark room clock is far from satisfactory, as one must either wait for the hand to cross an " easy " time (15, 30, 45 or 60 seconds) or risk errors in mental arithmetic. Even then there is the risk of human error. The circuit shown was devised to overcome such difficulties, and has proved most useful.

In a circuit of this sort one or other of the cathode coupled pentodes takes current, but in the rest position *V*1 will take all the current, its anode will be at a low potential and its cathode at approximately 100 volts above chassis. *V*2 will be well cut off and the relay in its anode de-energised. Contacts *R*1 will be closed and contacts *R*2 will be open. When the button *B* is pressed, the capacitor is discharged, the grid of *V*1 falls to chassis potential, the valve becomes cut off, its anode potential rises to H.T. and the grid of *V*2 rises bringing in *V*2. The relay becomes energised and contacts *R*1 open and contacts *R*2 close, switching on the enlarger lamp. The button *B* should be released soon after it is pressed, but in any case contacts *R*1 will have opened, releasing the capacitor, which can then begin to charge via the resistors selected by means of the switches. After a time interval, determined by the resistor selected, *V*1 will be cut off and the relay will become de-energised, switching off the enlarger lamp. This condition will remain until the button is again pressed.



With the arrangement shown, any time between 1 and 110 seconds may be selected in one second steps, but, of course, personal choice or convenience may demand another selection, and it is simply changed, as each megohm of charge resistor gives approximately one second of time. If *very* exact timing is required, normally quite unnecessary in ordinary photography, it may be advisable to add further refinements such as a stabilised H.T. supply. Usually, however, it is quite sufficient if a timer will accurately repeat a time interval, and the circuit, as shown, will do this reliably.

* Central Equipment Ltd.

Transmitting Magnetic Compass

By A. HINE, B.Sc.*

IN these days of automatic navigational instruments, radar and precision weapon control, compass-operated instruments in all kinds of naval vessels and aircraft are well-nigh essential.

There was a time when the compass control of instruments was confined to large ships, and the gyro-compass was able to provide transmission for repeating instruments at various stations in the ship. The second World War, however, saw the extension of " big ship " methods to the smallest of H.M. ships, and light Coastal Forces found themselves in need of a repeating compass to co-ordinate the plotting, radar and executive functions in fighting the ship. For this reason the Admiralty Compass Observatory was called upon to provide a suitable instrument. A gyro-compass was not a practical solution due to the lack of space, small facilities for maintenance, complexity and the severe shocks and accelerations that these small ships are called upon to withstand.

The new compass, the Admiralty Transmitting Magnetic Compass, was, as its name implies, one in which a master magnetic compass, through an electrical pick-up system, a simple valve amplifier and " follow-up " system, was enabled to operate as many repeaters as were required.

The system used, that of a liquid Wheatstone's bridge, formed in the compass by the use of electrodes in the bowl and on the card and using the actual liquid as a resistance path, was originally invented by Mr. E. L. Holmes, but the compass designed by the Admiralty Compass Observatory makes use of modern electronic technique with all its advantages, and has enabled a simple, accurate and robust instrument suitable for small fast craft to be evolved.

There are several types of the " A.T.M.C.", one of which is suitable for larger vessels, such as destroyers, with a transmission capacity equal to the gyro-compass. The master compass can be mounted either as a steering or as a standard compass, and if the electrical supply should fail it retains its use as a simple magnetic compass. Transmission from the " A.T.M.C." provides a useful alternative to that of the gyro-compass for stabilising the radar plan position indicator, or orientating the automatic pilot.

In merchant vessels, where down to recent times the sole use of the compass has been that of correctly orientating the ship and objects in visual sight from her, the introduction of radar and other electronic navigational aids is today rendering the need for a transmitting compass imperative. The employment of a transmitting magnetic compass for such purposes will provide a reliable and inexpensive solution to the problem both in commercial vessels and the smaller warships.

* Admiralty Compass Observatory

Semi-Conductors

By E. J. HARRIS, Ph.D., D.I.C.*

THE electronic engineer meets semi-conductors in a number of familiar components, perhaps without realising it. The materials called "semi-conductors" are those which conduct electricity with more or less difficulty, generally having specific resistances many times higher than metallic conductors. As usual, it is difficult to draw an exact line of demarkation, for certain non-metallic substances, e.g., graphite, are nearly metallic in their properties, while thin metal films, or powders, often show the properties of semi-conductors. A particular distinction, however, is that the temperature co-efficient of the resistance is positive for metals and negative for semi-conductors. Because of the high specific resistance which semi-conductors can be made to have, they are used for making resistances of high ohmic value and small dimensions. There are the familiar moulded carbon compound resistors, and selenium or pyrolytic carbon film resistors. A further useful property of certain semi-conductors is that the resistance of a film of the substance varies if visible (or sometimes infra-red) light falls on it; this property forms the basis of photo-conductive cells. The contact resistance between a metal and a semi-conductor usually varies according to the direction of the applied potential, so that more current passes in one direction than in the other for a given potential. If an alternating potential be applied to such a contact there will be a net current in one direction, so the combination forms a rectifier (e.g., copper oxide or selenium disks for power supplies, and silica or germanium crystals in mixers for very high frequencies).

What, then, is the special character of these materials that makes them differ so from metals? To answer this let us start with a few remarks about the theory of conduction in metals. At very low temperatures some metals become supra-conducting, having practically zero specific resistance. In this state the outer electrons of the metal atoms are supposed to move in a body through the lattice formed by the atoms. At higher temperatures the thermal agitation of the atoms hinders this easy flow, because it then interferes with the passage of the electrons, and consequently the resistance increases as the temperature rises. Alloys, in which the atomic lattice is necessarily less regular than that of pure metals, have a higher specific resistance than pure metals. Passing now to the other extreme case, that of insulators, we find that the electrons surrounding the atoms are all so firmly bound that they cannot be moved by ordinary electric fields, so there is no conduction. This can be re-stated by saying that there are no vacant places to which electrons can be moved by the applied field. If enough energy be given to an electron in an insulator by the incidence of X- or γ-radiation, it is displaced and can travel some distance in the material before it falls back into a position where it is firmly held.

* Biophysics Research Unit, University College, London.

This is the mechanism by which diamonds, which are good insulators, can be used for γ-radiation detection. For this purpose a potential field is applied across the crystal, and a small current pulse is obtained each time an electron is dislodged by the incident radiation.

By modifying the structure of insulators it is, however, possible to make materials which contain "impurities," not necessarily different chemically from the main bulk, and these either provide a source of more readily detachable electrons, or they can take up electrons from the atomic shells leaving so-called "positive holes." In either case the material is made more or less conducting. "Positive holes" need explanation: they are places where electrons are normally found, and into them fresh electrons can move from adjacent atomic shells, in such a way that conduction can take place by migration of the positive holes in the opposite sense to an electron current. When the structure is quite perfect, the electrons are so firmly bound by the atomic nuclei that no ordinary field is sufficient to move them. Those materials in which the impurities provide electrons to carry the current are called excess (or n) semi-conductors (germanium) and those in which the impurities take up electrons and leave positive holes are called deficit (or p) semi-conductors (e.g., copper oxide). The specific resistance of the semi-conductor will measure the mean number of mobile current carriers per unit volume and their mobility. It depends on the ease with which the electrons are displaced from (or into) the impurities, and the temperature of the specimen. The more easily the electron can be displaced the less will be the resistance, and the higher the temperature the greater will be the number of current carriers, so the temperature coefficient of resistance will be negative. In special cases the incidence of light, or infra-red, energy of certain wavelengths will lead to a greater number of electrons being displaced, and in this event the material will be photo-conductive (e.g., selenium, lead sulphide).

In order to proceed further, to the explanation of the process of rectification at a metal-semi-conductor boundary, it will be helpful to draw an energy level diagram (Fig. 1), showing the potential energies of

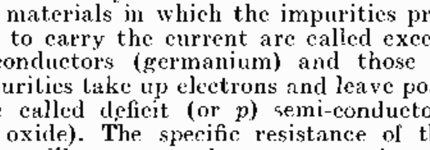


Fig. 1. Diagram of deficit semi-conductor in which there are two positive holes left by electrons which have been given enough energy to reach two of the impurities

electrons at various points in a deficit semi-conductor. The lower down the potential energy scale we find an electron the more firmly bound will it be; but it can still be raised by heat energy, or by light, if it can penetrate, into an impurity if the energy difference between its initial and final states is less than that of the available energy. After a time it will fall back into a positive hole, so there is a continual exchange of electrons between the impurity levels and the normally full band. In the diagram no zero of potential energy is shown as we are only concerned with the differences. The term " band " is often used to denote a group of energy levels, having very small differences between one another, which an electron can occupy. Conductivity arises from the fact that movement of electrons from the full band to the impurities leaves mobile positive holes in the " full " band of electrons. The electrons in the impurity levels are not mobile because the impurities are not continuously distributed in the volume of the material. The picture for an excess semi-conductor must include the levels representing the energy of mobile electrons, these are empty at low temperatures. At higher temperatures the thermal agitation, or light energy in suitable cases, may be sufficient to raise some electrons from impurity levels up into a conduction level from which they will fall back into empty impurity levels after a time. It will be seen that in this case the full band is not important (Fig. 2). Now compare

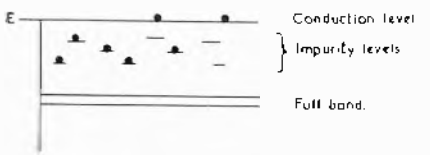


Fig. 2. Diagram of excess semi-conductor in which two electrons from impurities have received sufficient energy to reach the conduction level. E: the minimum potential energy an electron must have in order to be able to carry current

the picture of the energy levels in a metal, which has the so-called " Fermi " distribution. At ordinary temperatures there are an enormous number of conduction levels packed together above the full zone (Fig. 3). When a metal and an excess semi-conductor are placed in contact (Fig. 4), there is a

Fig. 3.—Diagram of electron levels in a metal. They are very narrowly separated and occur at the top of a zone in which most of the electrons are situated

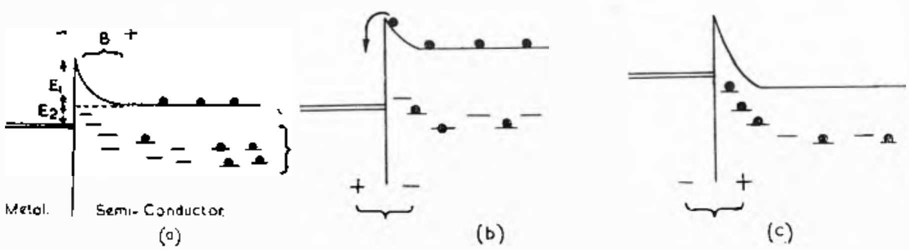


Fig. 4 (a).—Metal—excess semi-conductor boundary. E: space charge in the carrier layer. B: barrier layer, showing sign of space charge. E_1: a measure of the contact potential

Fig. 4 (b).—Metal—excess semi-conductor boundary, with field applied making metal positive to s.c.(direction of easy flow), and (c) making metal negative with respect to semi-conductor

flow of electrons of short duration which leads to the development of a contact potential between the metal and the semi-conductor. It has a value such that on an average the mobile electrons in the two substances have equal potential energies; its development is comparable with the levelling of water on the two sides of a U-tube. At the boundary, however, conditions are different, for electrons in the conduction band have a high potential energy and cross over into the metal. This leaves the semi-conductor positively charged, and the level in the vicinity of the metal is raised, so there is a shortage of electrons there, making the resistance higher than in the bulk of the material. If we now apply a field across the contact so as to reduce the space charge (i.e., the metal is made positive to the semi-conductor) more electrons flow towards the barrier layer and some will pass over into the metal so that the resistance in this direction is diminished. On the other hand, when the metal is made negative, the electrons in the conduction band of the semi-conductor are repelled from the boundary or barrier layer, and any which do reach it have to pass over a high potential energy peak, so that it is difficult to cause the current to flow in this direction. The possibility of electrons passing from the metal into the semi-conductor is small when the energy difference in Fig. 4(b) is large compared with the average thermal energy of the electrons in the metal.

For a deficit semi-conductor the picture is somewhat altered (Fig. 5(a)). Here the positive holes in the full band tend to be filled from the metal, imparting a negative charge to the semi-conductor with respect to the metal. Any electrons in impurity levels near the metal flow across into the metal because their potential energy is thereby diminished. If we now apply a potential across the boundary (Fig. 5(b)) in such a way that the contact potential is diminished, more positive holes move towards the boundary, there to be filled up from the metal so that a current flows. When the applied field adds to the contact potential difference (Fig. 5(c)) the positive holes are repelled from the metal and so no current flows. This corresponds to the high-resistance direction. So, to sum up, for either case the direction of easy flow is for an applied potential which tends to neutralise the space charge at the contact.

We can now use the same concepts to explain the mode of action of barrier layer photo-cells. In these a potential is developed across a pair of metallic electrodes in contact with a semi-conductor when light falls on one contact. They are frequently made in such a way that one of the electrodes is a transparent film, or a wire mesh, on the exposed surface of the semi-conductor, which is itself supported on a thick metal plate. Suppose we have an excess semi-conductor with its normal contact potential established between its bulk and the metal at each electrode, so that no net potential difference is present between the electrodes (Fig. 6). Now illu-

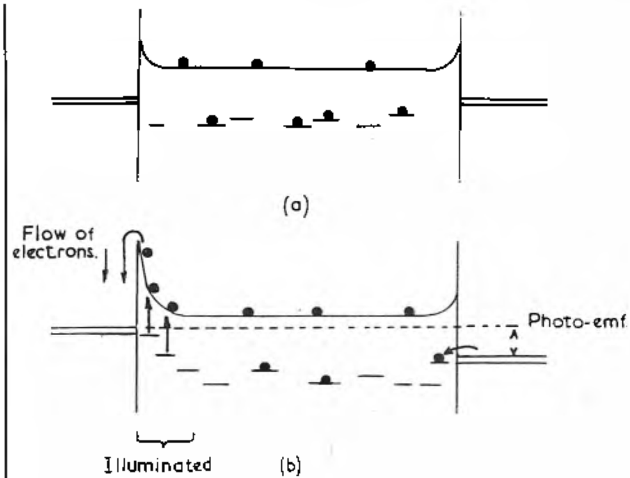
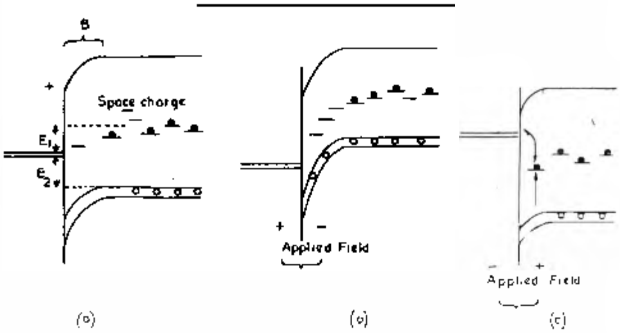


Fig. 6 (*right*).—**(a) Excess s.c. with metal electrodes. (b) The same when one boundary is illuminated**

Fig. 5 (*below*).—**(a) Metal-deficit-semi-conductor boundary. (b) Metal made positive with respect to semi-conductor. (c) Metal made negative with respect to semi-conductor (direction of easy flow)**



minate one boundary. If the light energy is sufficient to raise electrons from those impurity levels near the metal into the conduction band they will flow over the boundary into the metal, so that the semi-conductor will become more positive with respect to the metal than it was in the dark state. The result will be to cause an electron current to flow from the light electrode to the dark electrode, when they are joined, or to establish a net potential difference when the circuit is open. At the dark electrode the electrons pass into the impurity levels and into the conduction level. For a deficit semi-conductor a similar picture can be made, but in this case the sign of the photo E.M.F. is reversed because when the electrons are raised into impurity levels they leave more positive holes and these are filled from the metal, thus making the semi-conductor more negative with respect to the metal at the illuminated barrier. The use of similar energy level diagrams allows qualitative explanations to be given of other phenomena. Fluorescence and phosphorescence are cases in point. Here the incidence of light of a certain frequency provides the energy to raise electrons into an "excited" state from which they drop into impurity energy levels of traps intermediate between the unexcited and the excited states. From those levels they later fall into their original state, emitting light of lower frequency, i.e., more towards the red than the original light. The persistence of the phosphorescence is a measure of the time the electrons stay in the impurity levels, and is reduced if heat energy is provided, either by increase of temperature or the incidence of infra red radiation; for increased thermal energy increases the probability that the electron acquires enough extra energy to escape from its trap. The mechanism of the breakdown of insulators under high stress can also be described in terms of electron energy levels, but the practical application of the theory is still hindered by our lack of knowledge of the values of the various energies involved.

Helium Disappearance in Arc Discharge Tubes

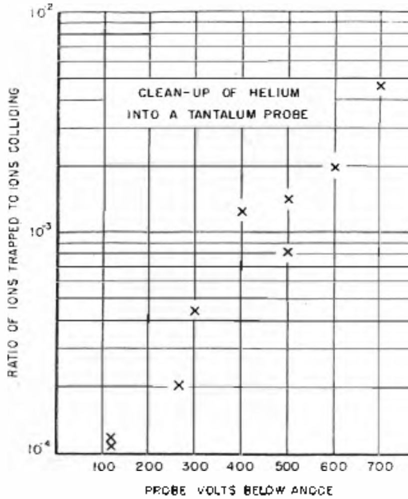
By MICHAEL LORANT

ELECTRON tubes filled with a noble gas such as argon, neon or helium are now widely employed in many kinds of electronic equipment, and the problem of gas disappearance in these tubes is of considerable importance. Since gas density is independent of temperature, gas tubes have a distinct advantage over those filled with a metallic vapour such as mercury where the electrical characteristics change with the thermal variations in vapour density. On the other hand, the life of gas-filled tubes is limited by a gradual reduction in gas pressure with use. This tendency of filler gases to disappear from the tube volume is known as "clean-up" and is generally thought to result from the bombardment of negatively charged electrodes by high-velocity positive gas ions that penetrate the metal surfaces and become permanently trapped.

An understanding of clean-up under laboratory conditions will enable tube designers to choose the best combination of structural materials for longest tube life in a given application. Past studies of gas absorption in eletrical discharges are difficult to apply because of wide variations in experimental conditions and techniques.

Martin Reddan, of the Electron Tube Laboratory of the U.S. National Bureau of Standards, has been carrying on a study of clean-up phenomena in a specially-designed discharge tube with a replaceable tantalum probe wire to collect the positive ions. During operation, the rate of gas clean-up is measured for various negative D.C. potentials on the probe in the presence of an arc discharge. In addition to the probe wire, this helium-filled discharge tube employs an oxide-coated cathode and a nickel anode.

All gas disappearance other than clean-up into the negative probe is designated as "self" clean-up. It is reasonable to expect that this gas loss is caused



The plotted points summarise data giving the ratio of the number of helium ions trapped by a tantalum probe to the number striking the probe in an experimental arc discharge tube. The ion current to the probe wire has not been corrected for secondary electron emission. Since more than half of the observed current at higher probe voltages may be electronic, the trend of the plotted points should rise more rapidly as the probe voltage is increased

by clean-up into the other electrodes and into sputtered deposits or by leakage through the tube wall. The diffusion of helium through hard glass envelopes has been checked and found to be negligible at the usual operating temperatures and pressures. Since the anode in the discharge tube is maintained at a higher positive potential than any other element, positive gas ions will not be attracted to the anode and clean-up there is not to be expected. On the other hand, the cathode probably accounts for the major part of self clean-up in arc discharge tubes.

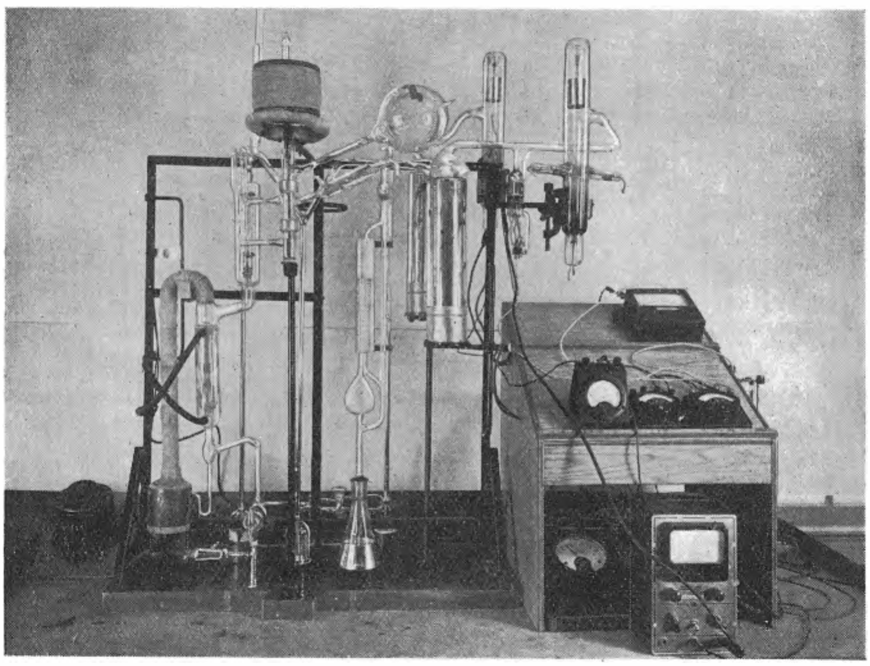
Since self clean-up cannot be avoided completely, its value is determined experimentally by operating the discharge tube with a positive probe voltage so that electrons rather than positive ions are drawn to the probe. Each test run is preceded by a self clean-up run, yielding a correction factor for the net clean-up into the probe. To avoid overheating the probe wire, negative voltage is applied in pulses of several milliseconds duration repeated several times a second.

A necessary condition for reproducible results is that the filler gases be of uniformly high purity. Barometrically operated mercury cut-offs have been employed in the vacuum system, and contamination from stopcock vapours or leakage is avoided by introducing the gas through a pair of fritted glass disks which can be completely covered with mercury to interrupt the gas flow. Before a noble gas is admitted to the discharge tube, the small amounts of impurities which may exist is the unopened flask are eliminated by passing the gas over hot zirconium and tantalum gettering wires.

With a known tube volume, the total number of ions trapped during a test run may be computed from the observed drop in pressure, while the number of ions striking the probe can be found directly from the observed probe current. These data have been used to construct a graph illustrating the dependence of clean-up on probe voltage. Care was taken to ensure that the thickness of the ion sheath around the probe wire was considerably smaller than the mean free path of the gas ions, so that the ion energy could be determined from the probe potential.

Further problems under study include the complete recovery of trapped gas, a determination of the amount of gas which can be absorbed by the probe before saturation occurs, and a correction of the probe current for electron emission. Now that satisfactory techniques have been developed for a particular probe material and filler gas, these methods can be extended to other solids and noble gases of interest to tube designers.

A general view of the apparatus used in the experimental investigation of helium clean-up by tantalum in an arc discharge. The vacuum system includes diffusion pump, a gas purifying tube, fritted glass valve, mercury cut-offs, liquid air trap and ionisation gauge. The two arc discharge tubes are at the upper right. The meters just below are used to measure voltage and current for each electrode in the discharge tube



B.B.C. Television Progress

THE B.B.C. have recently projected three television developments. They have ordered two high-power television transmitters from E.M.I. Ltd., and two associated 12kW sound transmitters from Standard Telephones and Cables Ltd. Additions have been made to the technical facilities at Alexandra Palace, and new studio facilities have been acquired from the J. Arthur Rank Organisation at Lime Grove, Shepherds Bush, London.

The transmitters, intended for Scotland and the West of England, will be ten times more powerful than the American stations, and bigger than the Emitron transmitter supplied to the B.B.C. for Birmingham. The total population within the range of the B.B.C. Television Service when these new stations are completed will be between thirty-five and forty millions.

The technical facilities at Alexandra Palace comprise a film dubbing suite for the production of newsreels and other films by the B.B.C. film unit, a telefilm recording room, where television programmes are recorded on cinematograph film, and a central telecine room, in which films are televised for transmission in the programmes.

The film dubbing suite comprises apparatus of the latest design and best obtainable performance, for carrying out the following operations: recording sound in synchronisation with a film camera operating in the dubbing theatre or in one of the studios; post-synchronisation, i.e., the addition of lip synchronised speech to a film shot silent; projection of 16 mm. films; copying of disks on to film sound tracks, and the addition of live sound from the theatre to a silent film during transmission.

The projectors and sound film reproducers in the projection room are driven by Selsyn motors fed from a master Selsyn generator, and hence keep exactly in step. Synchronisation between these machines and the sound-on-film recording machine is achieved by driving the recording machine and the master Selsyn generator by synchronous motors, which are supplied from a motor alternator, the speed of which is electronically controlled and independent of the frequency of the mains supply. The speed can be set remotely from the recording room to operate the film machines at either 24 frames per second, the standard speed for cinematograph film, or at 25 frames per second—the speed used for televising films. Once set the speed remains constant within 0.1 per cent without further control, even though the mains supply frequency may drift as much as 5 per cent.

One drawback of the sound-on-film system of recording is that processing introduces a delay of about six hours before the composite sound and picture film is ready. In television film production especially, a delay of this order is a real handicap, and a method of reducing it, by the introduction of high-grade magnetic film recorders, is being considered. In this method the negative produced by the camera is cut and then televised direct, and simultaneously a fully-edited sound commentary recorded on magnetic film is reproduced synchronously as an unmarried print. With the installation of this equipment the time taken to produce a newsreel will be far less than the best hitherto attained. In the meantime a non-synchronous magnetic tape recorder has been installed, which records in parallel with the sound-on-film machine and makes possible an immediate playback for checking purposes only.

The telefilm recording installation consists of duplicate recording cameras facing a pair of picture monitors on which is displayed the television programme that is to be recorded. The cameras have no shutters, so that the film is drawn through continuously. They incorporate a system of rotating and rocking mirrors which makes the image of the television picture follow the film in its downward progress through the gate, thus keeping the image stationary relative to the film. In this way a succession of television images is formed on the film as it passes through the gate, the brilliance of each image rising from zero at the top of the gate, then increasing to a constant intensity over the central part of the gate and finally fading out to zero on reaching the bottom of the gate. With this arrangement exposure takes place continuously and the system dispenses with the need for the very high film accelerations.

The picture monitors have 12-inch tubes giving a white fluorescence. A special feature is a device effectively eliminating the line structure of the image recorded on the film, so that no interference patterns result when the film is subsequently scanned for transmission. The method adopted is to deflect the scanning spot with a sine-wave displacement in the vertical direction, the deflecting frequency being several times higher than the maximum detail frequency of the television system.

The recording system was developed by W. D. Kemp of the Engineering Planning and Installation Department of the B.B.C., in conjunction with P. H. Dorté, Head of the Television Films. Also collaborating were H. W. Baker (Engineer-in-Charge, Alexandra Palace), H. G. Whiting (Engineer-in-Charge, Sutton Coldfield), and D. R. Campbell, who together devised the original system of recording television programmes on films in 1948.

The central telecine room consists of two film scanners made by Electrical and Musical Industries Ltd., and a temporary machine made by Cinema-Television Ltd., which will shortly be replaced by two permanent machines of the same make. This installation was illustrated in the June, 1949, issue of *Electronic Engineering*.

The method of televising the film is broadly the same in both makes of scanner. The principal components are a projection cathode-ray tube, an optical system, a film projector, and a photo multiplier tube. A scanning pattern, with an aspect ratio of 5 : 2, is traced on the fluorescent screen of the cathode-ray tube by the electron beam, and two images of this pattern are projected by the optical system on the gate of the projector.

The film runs continuously through the projector at a speed equivalent to 25 frames per second, and each film frame is exposed for 1/50th second first to one scanning image, and then to the other, by the action of a rotating shutter. The light that passes through the film is focused on a photo-multiplier tube, which generates the picture signal, the signals corresponding to the exposure of each frame to the two scanning images being combined to give an interlaced signal. Though the aspect ratio of the scanning pattern on the face of the cathode-ray tube is 5:2, this is increased to an effective ratio of 5:4 by the motion of the film.

The new machines give much better television pictures from film than have previously been possible. In particular, the definition and tonal gradation are much improved, and the quality of the pictures is much less affected by the density of the film stock.

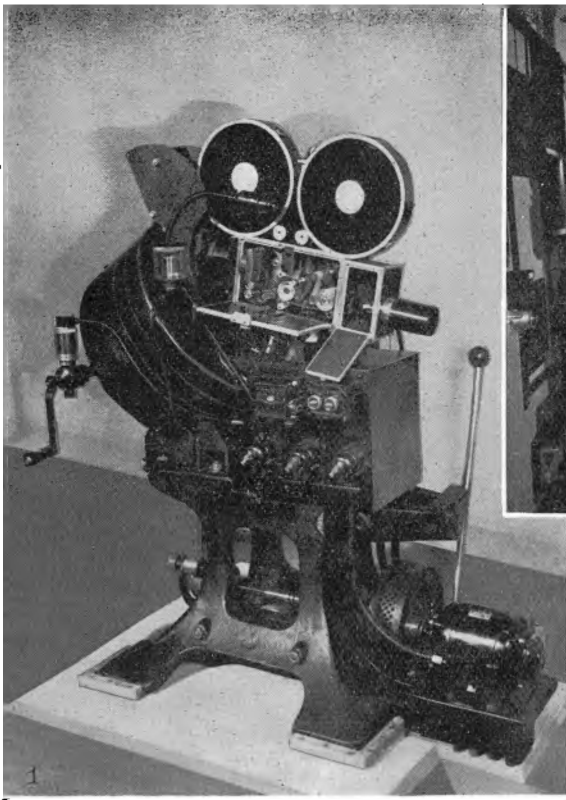
A fuller account of this equipment is contained in "The B.B.C. Quarterly" Vol. 4, No. 4, Winter 1949-50.

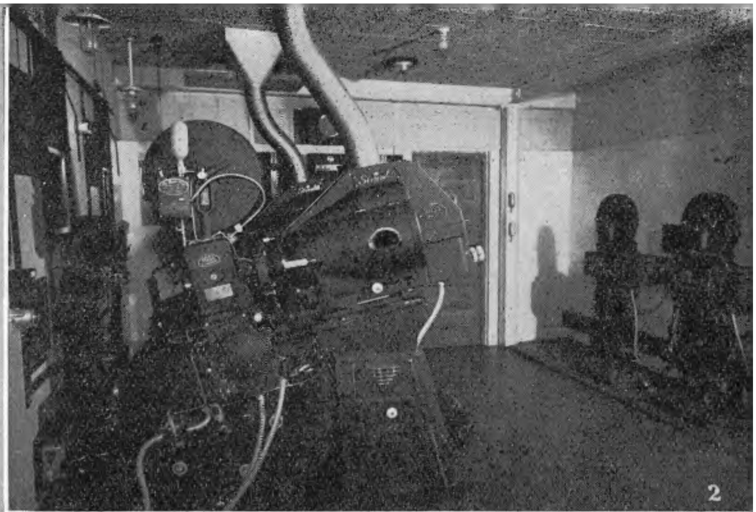
Considerable extension to the present Alexandra Palace studios has been made possible by the recent acquisition of the film studios at Lime Grove, Shepherds Bush. Besides film studios, which are suitable for conversion to television studios, there is accommodation for dressing and make-up rooms, together with a film dubbing suite and associated viewing rooms.

The area that the five studios cover is approximately 28,100 sq. ft., and it is interesting to note that Studio F, the largest (about 9,600 sq. ft.), has a floor space of more than twice the combined area (approximately 4,000 sq. ft.) of the two existing studios at Alexandra Palace.

The studios are already acoustically treated, and have lighting galleries, scene hoists, etc., but it will be necessary to construct studio control cubicles, and to equip them, as also the studios themselves, with the special apparatus needed for television.

The first conversion to be undertaken will be that of Studio D, which it is hoped to bring into service in the late spring of this year, and work is already in progress to that end. The programmes produced at the Lime Grove Studios will be fed by special television cable to Alexandra Palace.





Telecine Equipment at Alexandra Palace

1. ***Telefilm Recording.*** *One of the cameras used for recording television programmes on film. The television pictures are displayed on a cathode-ray tube screen facing the camera, and are photographed on the film as it runs through the camera. Inside the casing at the front are rotating mirrors which cause the image of the television picture to follow the film in its downward progress through the gate of the camera. The lever on the right controls a variable friction clutch and enables the camera speed to be adjusted.*

2. ***Film Dubbing Suite.*** *The projection-room, showing the two projectors, and right, the duplicate sound-on-film reproducers.*

3. ***Film Dubbing Suite.*** *The mixer-room. Left, equalisers for modifying the frequency characteristics of any of the channels ; centre, the mixer desk ; and right, a twin-turntable disk reproducer.*

4. ***Film Dubbing Suite.*** *The mixer-room where the commentary music and effects are blended and controlled before being recorded on the sound track. An engineer works the twin-turntable disk reproducer, while Philip Dorté (centre), Head of Television Films, sits at the control panel with John Byers, senior film recordist. By watching through the glass panel the pictures of the film being projected on a screen in the adjoining dubbing theatre, they can tell when to introduce each item of sound so that it will be recorded at the right moment to match the pictures. Through the window on the right is the machine on which the sound-on-film recording is made.*

A Portable Geiger Counter

By M. MICHAELIS, B.Sc.(Eng.), A.M.I.E.E.,A. Inst.P.*
and R. O. JENKINS, A.R.C.S., D.I.C., F.Inst.P., Ph.D.*

RECENT years have seen a considerable extension in the use of radioactive substances and installations producing ionising radiations. As a consequence, the need has become apparent for equipment to measure the intensity of such radiations. While fairly elaborate, bulky and costly apparatus is already available in many fixed locations for this purpose, the present design is aimed at a simple and compact instrument, relatively cheap to manufacture, for use in rough comparative assays and in general radiation surveys. The latter purpose is becoming of increasing importance in assessing the necessity of providing suitable protection of personnel against ionising radiation.

General Description of Instruments

Among the various physical techniques used for the detection and measurement of ionising radiation the two most important employ (a) an air ionisation chamber and (b) a Geiger-Müller tube. The former is used extensively for accurate measurements, the unit of radiation, the roentgen, being defined in terms of ionisation in unit volume of air. The latter, on the other hand, is more versatile, requires less elaborate auxiliary equipment and can achieve far higher sensitivities for a given volume. Such tubes do not measure the radiation intensity directly in roentgens, but, for the purposes of the present instrument this was not considered to be sufficient drawback to offset the advantages already enumerated. The instrument could, if necessary, be calibrated in roentgens for specified qualities of radiation. The Geiger-Müller tube was therefore chosen as the radiation-sensitive element and the information it provides, in arbitrary units, regarding the intensity of radiation is adequate for the comparative purposes entailed in the proposed applications of the instrument.

The Geiger-Müller tube is of particular advantage when using radioactive isotopes for measurement of concentrations and also for ensuring that benches, apparatus and clothing have been thoroughly cleaned after work involving the use of such substances.

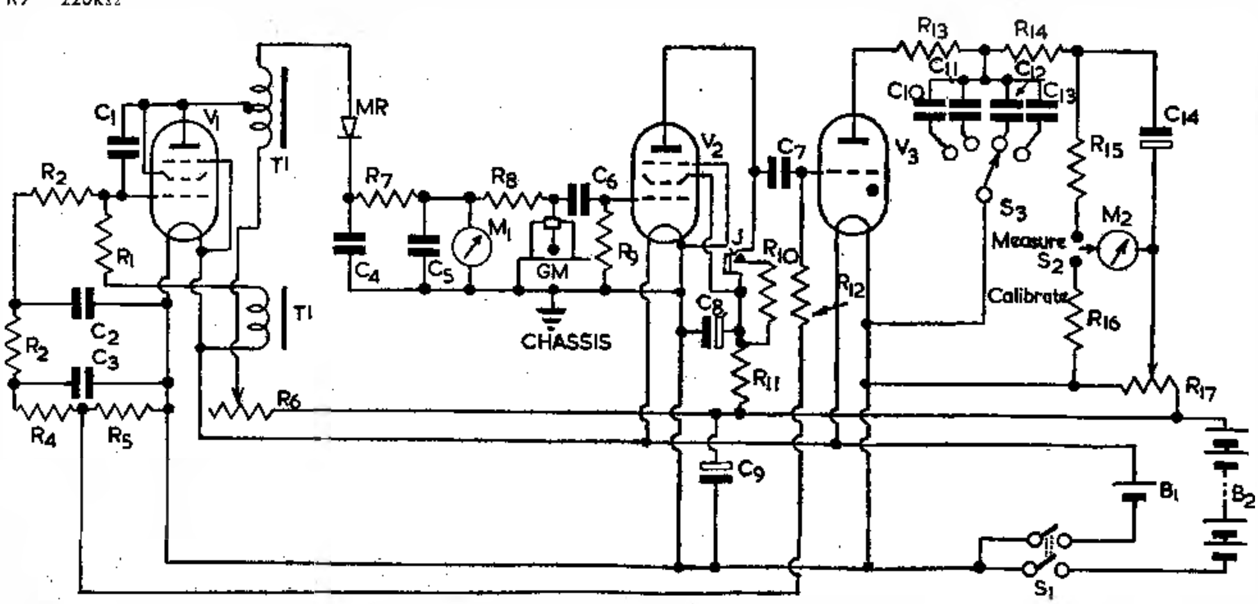
The essential components of equipment for making quantitative measurements are (i) The Geiger-Müller tube, (ii) a source of high voltage, (iii) an amplifier, (iv) a pulse recording circuit which may be either a true counting circuit registering the individual pulses, or an averaging circuit which records the mean rate of arrival of the pulses.

The present instrument employs a standard G.E.C.

* G.E.C. Research Laboratories, Wembley, England.

Fig. 1.—Circuit of Portable Geiger Counter Equipment

R1	3.3kΩ	R10	15KΩ	B1	1.5 volts	C7	50pF	V1	Marconi-Osram N17	MR	Westinghouse Type 36 E.H.T.40
R2	2MΩ	R11	417KΩ	B2	67.5 volts	C8	4μF	V2	Marconi-Osram W17	M1	2,000 Volts Electrostatic
R3	100kΩ	R12	1MΩ	C1	200pF	C9	4μF	V3	C.V. 123	M2	25μA Moving-Coil
R4	1MΩ	R13	10kΩ	C2	0.01μF	C10	0.001μF	T	Oscillator Step-up Transformer	GM	Geiger-Muller Tube
R5	5.6MΩ	R14	220kΩ	C3	0.001μF	C11	0.005μF			J	Headphone Jack
R6	4.7kΩ	R15	100kΩ	C4	0.125μF	C12	0.02μF			S1	D.P. On-Off
R7	470kΩ	R16	4MΩ	C5	0 01μF	C13	0.1μF			S2	S.P. 2-way
R8	1MΩ	R17	47kΩ	C6	50pF	C14	30μF			S3	S P. 4-way
R9	220kΩ										



type G.M.2 or G.M.4 self-quenching Geiger tube which can be used for either beta, gamma, or X-ray detection; thus making the apparatus as versatile as possible, although other types could be used for particular application. For portability and use in any location, operation from batteries contained within the instrument is provided. The instrument shown in Fig. 4 measures 9 in. by 6 in. by 3½ in. and weighs 7 lb. In addition, when a high degree of portability is not needed, provision is made to use an external higher power-capacity battery or a mains unit.

The high tension supply to operate the tube must be variable between 1,000 and 1,500 volts D.C. While various methods can be used, considerations of reliability and compactness led to the use of an audio-frequency blocking oscillator with a metal rectifier, all components being operated within their normal ratings.

A single valve amplifier to provide sufficient output on a pair of headphones for audible observation of signals and to operate a rate of count circuit, for visual observation, presented no difficulties. For quantitative measurements, a scaling circuit to count individual pulses up to high rates involves a large number of valves and would be out of the question for portable operation, so a rate-of-count circuit, which should be sufficiently accurate for the type of application envisaged, was used.

Circuit Details

The complete circuit is given in Fig. 1.

(a) H.T. Supply

The valve $V1$ (Marconi Osram N17) operates as a blocking oscillator at a few hundred cycles per second. The sudden cessation of oscillation once every cycle is accompanied by a very rapid collapse of anode current in $V1$. This produces a voltage surge across the input terminals of the transformer $T1$, which is stepped up through auto-transformer action. The H.T. surge across the output terminals is reflected by a metal rectifier M.R. (Westinghouse 36 EHT 40) and smoothed through the resistor-capacitor network $R7$ $C4$ $C5$. The resulting D.C. voltage is applied to the Geiger tube anode through the high resistance $R8$, the actual voltage being measured by a 2 in. electrostatic 0-2,000 V voltmeter $M1$. The voltage is varied by adjustment of the rheostat $R6$ in the anode circuit of $V1$.

The transformer is wound on a core of No. 101 "Silcor II" stampings.

(b) The Amplifier

The signal from the G.M. tube is fed through a 50 pF, 1,500 volt working, capacitor $C6$ to the grid of amplifier valve $V2$ (Marconi Osram W17). The output from this valve operates:

(a) A pair of 4,000 ohms headphones, normally plugged into the jack J provided, thus replacing the load resistor $R10$; and

(b) the rate of count circuit.

The amplifier $B2$ supply is decoupled through $R11$ $C8$. This was found necessary for suppressing the audio-frequency from the H.T. blocking oscillator in the amplifier circuit.

(c) The "Rate of Count" Circuit

The output from the amplifier is taken through capacitor $C7$ to the grid of gas-filled relay $V3$ (type

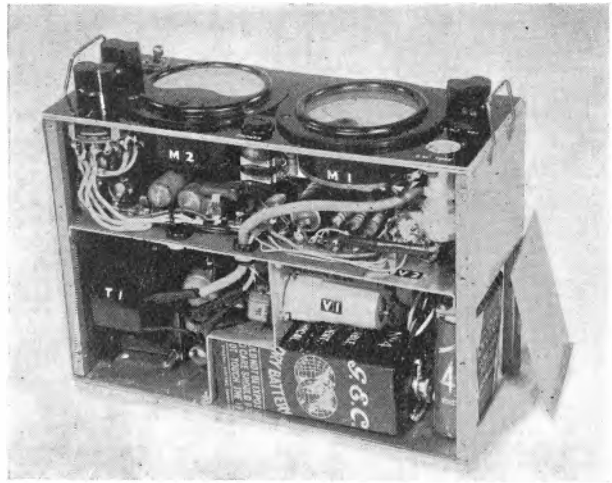


Fig. 2. Portable Geiger counter equipment (side panel removed)

CV123) which is biased so as to be non-conducting in the absence of a signal. The bias is obtained from the blocking oscillator through a capacitor-resistor network. Each signal pulse on the grid is of such amplitude as to remove momentarily the effective bias and allow the valve to conduct. Each pulse of current passing through $V3$ discharges one of capacitors $C10$-$C13$ as chosen by the rotary switch $S3$. Resistor $R13$ limits the peak current which is allowed to flow through the valve. The charge on the capacitor, however, is being replenished from a voltage chosen by the potentiometer $R17$ across the $B2$ battery. The current required to replenish the charge is measured by the microammeter $M2$, and is proportional to the number of counts per minute. This current, which is limited by resistor $R14$, is not sufficient to maintain $V3$ in the conducting condition and the latter therefore extinguishes when the chosen capacitor has discharged to a voltage of about 15-20 volts. The current is passed through a resistor-capacitor network $R15$-$C14$. The time constant of this network is adjusted so that the meter reads the mean charge-replenishing current over a period of 3 seconds. For low rates of count this serves to give a reading sufficiently steady for comfortable observation, in spite of relatively large random fluctuation of the incidence rate of the ionising rays or particles. With switch $S2$ in the "calibrate" position, meter $M2$ serves as a voltmeter and enables the slider of resistor $R17$ to be set to the chosen value for the given calibration of the meter in the rate-of-count "measuring" position. It should be noted here that capacitor $C14$ is made up out of 6 electrolytic "Picopack" capacitors in parallel, each of 5 μF, 50 volts working rating. This combination was chosen because it gave the lowest leakage current of different types of electrolytic capacitors of about 30 μF total capacitance. (Electrolytics were chosen because of their small size).

It will be appreciated that the capacitor $C14$ shunts the microammeter, and its leakage current will increase with the voltage across it. This voltage increases from zero to 2.5 volts for full-scale deflexion of the microammeter. The increasing leakage current will make the calibration curve of

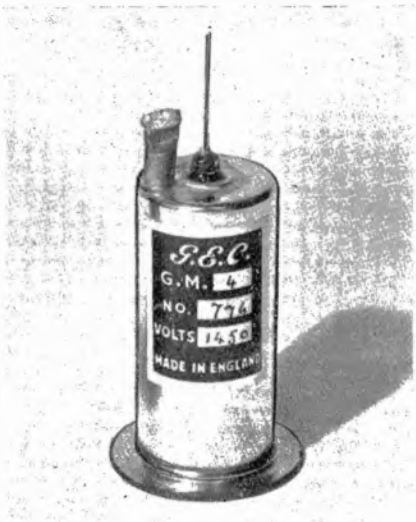


Fig. 3. G.M.4 Geiger Muller tube

" counts per minute " against " microammeter reading " depart from linearity at the upper part of the scale.

Constructional Details

Fig. 2 shows a view of the instrument with its side panels removed.

The case, partition and sides are constructed of aluminium, the sides being recessed to give additional strength to the structure.

A horizontal platform divides the instrument in two. In the lower half are the batteries, oscillator valve $V1$, transformer $T1$, rectifier and smoothing circuit: in other words, those components generating an audio-frequency capable of interfering with the measuring circuits in the upper half. The platform and sides act as electrostatic screens to prevent such interaction.

The measuring circuits, consisting of the amplifier valve $V2$ and its associated components are mounted on top of the horizontal platform. This also carries component group-boards with the rate-of-count circuit and $V3$ wired to them.

On the top panel are the two instruments $M1$ and $M2$, the on-off switch $S1$, H.T. adjustment $R6$, G.M. tube concentric connector, headphone jack, measure-calibrate switch $S2$, calibration adjustment $R17$ and rate-of-count range switch $S3$.

The horizontal and vertical partitions with their group-boards and valve holders form a complete sub-assembly which may be wired up independently of the main frame. This sub-assembly is then screwed into position and joined to the components on the top panel and the batteries to form the complete instrument.

A feature worth noting is the sliding door in the case seen removed on the right of Fig. 2. This allows access to the batteries for replacement purposes without the need for unscrewing the sides.

The batteries used are $B1$: $1\frac{1}{2}$ volt G.E.C. No. 4 cell, $B2$: $67\frac{1}{2}$ volt G.E.C. type BB501.

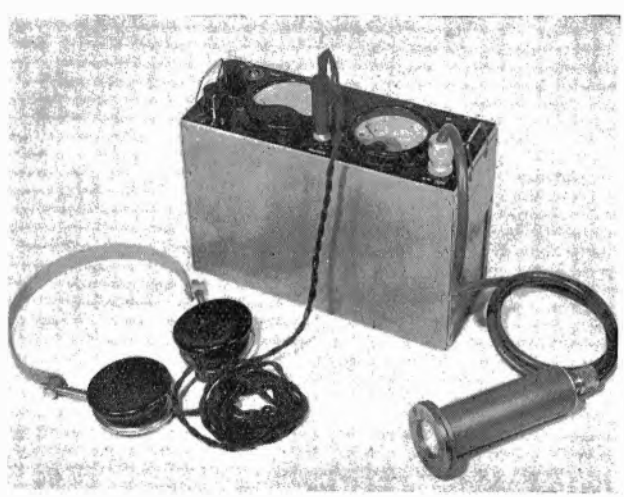
The G.M. tube itself, shown in Fig. 3, comprises a metal tube 1 in. diameter and approximately 2 in. long with the insulated anode lead in the centre of one end and a $1\frac{3}{8}$ in. flange on the other, over which is sealed the end window, made of duralumin, for allowing entry of beta particles. The tube is inserted into a holder and retained by a clamping ring as shown on the right of Fig. 4. The anode connector makes contact with a clip attached to the central electrode of a concentric cable socket. The concentric cable which connects the tube holder to the supply unit has plugs on each end which fit into corresponding sockets on the main unit and tube holder.

Operation

The instrument is normally contained in a leather case, together with the G.M. tube in its holder, the connecting lead and headphones. The unit can be removed from the case if so desired and can then be carried by a strap round the shoulder. The headphones are connected by telephone jack and plug and the G.M. tube by a concentric cable. After switching on, the H.T. is adjusted to the value specified for the G.M. tube, the switch $S2$ is set to " calibrate " and potentiometer $R17$ is adjusted to give a reading of 50 on the meter $M2$. The switch $S2$ is then set to " measure " and the appropriate rate-of-count range is selected by switch $S3$ for the strength of radiation to be measured. The calibration of these scales is carried out by applying the amplifier output to a scaler gear, and calibrating meter $M2$ in rate-of-count against meter divisions. A typical calibration is shown in Fig. 5. By selecting the capacitors $C10$, $C11$, $C12$ and $C13$ close to their normal values, the single curve is accurate for all the scales. The accuracy of measurement of rate-of-count neglecting random fluctuations (which can be reduced by watching the needle for a while and noting its mean reading) should be of the order of 5 per cent. The scales cover rates of count sufficient for most applications for which the instrument is likely to be used.

For the control of health hazards from radioactive materials,[1] the figure of 500 counts per minute on bench tops, floors in the work area and laboratory clothing is quoted as the maximum allowable. This counting rate refers to a Geiger counter with a $1\frac{1}{2}$ in. diameter window, thin enough to accept the radia-

Fig. 4. Portable Geiger counter equipment. The instrument measures 9 in. by 6 in. by $3\frac{1}{2}$ in. and weighs 7 lbs.



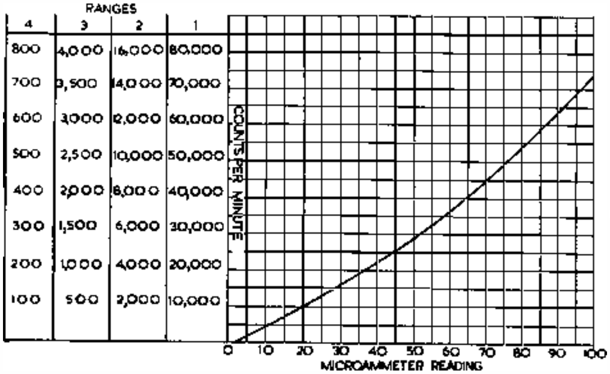


Fig. 5. Calibration curve for portable Geiger counter equipment

tion of the particular contaminant expected. G.E.C. type counter GM2 accepts beta radiation above 0.2 MeV and type GM4 above 0.1 MeV. Both have a window of about 1 in. diameter and the respective maximum allowable counting rate is therefore 222 counts/minute. Fig. 4 shows this rate to be well within range 4 of the instrument here described.

The counting rate meter may be calibrated directly in terms of tolerance dose rate for various energies of ionising radiation such as radium gamma rays and X-rays of different kilovoltages. Turner and Sinclair,[2] for instance, have calibrated a G.E.C. type G.M. counter and have found that 54,000 counts per minute corresponds to tolerance dose rate (10^{-5} roentgens/second) for radium gamma rays. For 200 kV X-rays a counting rate of 60,000 counts per minute represents 40 per cent of tolerance dose rate. With such calibrations the instrument can conveniently be used in studying leakage radiation distribution around X-ray installation and in teleradium departments in hospitals and industrial research establishments. Observations on patients given radioactive isotope treatments is another example of the uses of this portable Geiger counter equipment.

References

[1] *Introductory Manual on the Control of Health Hazards from Radioactive Materials.* (Prepared for the Medical Research Council by the Ministry of Supply, Atomic Energy Research Establishment.) Issue No. 2, January, 1949.

[2] A Mobile Geiger-Muller Tube Counting System and some of its Medica Applications. R. C. Turner and W. K. Sinclair, *British Journal of Radiology* XXI, 252, 632. December, 1948.

Binary Counting

Few of our readers if asked to explain in simple language the Binary scale of counting could do so without considerable thought. The following account, given by a representative of the N.P.L. in charge of the Automatic Computing Engine exhibit at the Jubilee Exhibition (See Notes from the Industry, page 123), is thought to be a concise and lucid explanation worthy of note :

ORDINARY decimal numbers are constructed from groups of tens, e.g., a number 3,065 is really

$$3\times 1{,}000+0\times 100+6\times 10+5\times 1$$

or $\quad 3\times(10\times 10\times 10)+0\times(10\times 10)+6\times 10+5\times 1$

that is $\quad 3\times 10^3+0\times 10^2+6\times 10^1+5\times 10^0$

10^0 of course equals 1.

It can be seen that the digits of a decimal number represent the quantities of each power of 10 (10^0, 10^1, 10^2, etc.) present in the number, and further that the largest possible digit will be one less than 10, i.e., 9.

It is possible to construct numbers from any other base, apart from 10. In every case, the largest possible individual digit will be one less than the base.

The binary system of numbers is constructed from a base 2. The digits of a binary number represent the quantities of each power of 2 present in the number (2^0, 2^1, 2^2, etc.) and the largest possible value for each digit is 1.

A binary cricket team consists of 1,011 men,

i.e., $\quad 1\times 2^3+0\times 2^2+1\times 2^1+1\times 2^0$

which is a group of just the same size as the one we now call eleven on the decimal scale.

Arithmetic in the binary scale is very simple: there are two elementary rules to remember, 1+1=0 and carry 1 (just as 5+5, or 6+4, = 0 and carry 1 in the decimal scale), and 1 + 1, and 1 to carry = 1 and carry 1, otherwise one proceeds as in any other arithmetic. Two examples are given for purposes of illustration :

Addition

```
  10110   (twenty-two)
  01101   (thirteen)
 ------
 100011   (thirty-five)
 ------
```

Multiplication

```
   1011   (eleven)
    101   (five)
   ----
   1011
  0000
 1011
 ------
 110111   (fifty-five)
 ------
```

Two apparent disadvantages of the binary system will be noticed from these examples: Firstly, we are used to decimal notation, and it is hard for us to detect the size of a binary number by casual inspection. Secondly, a binary number is much longer than its corresponding decimal number; on an average a binary number contains three times as many digits as a decimal number.

The binary system is very suitable for high-speed computing machines. Since digits can only be either 1 or 0, a relay that is either on (1) or off (0), or any similar two-stage device, may be used to indicate each digit. The extra length of a binary number is no disadvantage, since it is easier to make a machine with, say, 30 two-state devices than one with 12 ten-state devices as required for an equivalent decimal machine. The simplicity of the arithmetic enables multipliers and adders to be constructed without great difficulty, and a machine can be arranged to convert information from decimal to binary form, and back again, so that the familiar decimal notation may be used for setting the problems, and for reading the results.

LETTERS TO THE EDITOR

(We do not hold ourselves responsible for the opinions of our correspondents)

The Effect of Valve Impedance on Phase Shift Oscillators

DEAR SIR,—Mr. W. R. Hinton's article on R.C. oscillators has introduced a valuable method of calculating the formulae for these circuits.

It may be of interest that it is possible, by an extension of Roorda's[1] method to derive similar formulae for frequency and attenuation of uniform ladder networks which take into account the effect of valve impedance, and these agree with Mr. Hinton's results. Curves of four important cases have been plotted, which should be of use to designers.

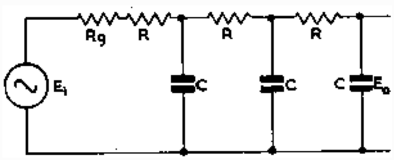


Fig. 1. Equivalent circuit of R-C oscillator

The equivalent circuit of an oscillator of this type is shown in Fig. 1 where Rg is the equivalent generator impedance of the valve and its anode load, and appears in series with the first section of the phase shift network. It is necessary to treat R.C. and C.R. networks separately, so that k is the ratio of Rg/R in both cases.

The R.C. network of n sections with added amplifier impedance is shown in Fig. 2, the amplifier impedance being represented by KR. The mesh equations of the circuit can be written down as follows:

$$i_1[(1+k)R+X]-i_2X=Ei$$
$$-i_1X+i_2(R+2X)-i_3X=0$$
$$-i_2X+i_3(R+2X)-i_4X=0$$
$$-i_{n-2}X+i_{n-1}(R+2X)-i_nX=0$$
$$-i_{n-1}X-i_n(R+2X)=0$$
$$i_n=Eo/X$$

The equations are first simplified by putting $R/X = a$.

Then $i_1[(1-k)a+1]-i_2=Ei/X$

$$-i_1+i_2(2+a)-i_3=0$$
$$-i_2+i_3(2+a)-i_4=0$$
$$-i_{n-2}+i_{n-1}(2+a)-i_n=0$$
$$-i_{n-1}+i_n(2+a)=0$$
$$i_n=Eo/X$$

We may now proceed to eliminate i_1, i_2 - - - i_n as follows:

3 Section R.C. Network $n=3$

$$i_3=Eo/X$$
$$i_2-i_3(2+a)=Eo/X(2+a)$$
$$i_1=Eo/X\ [(2+a)^2-1]$$

Substituting these values in the first equation in the set

$$Eo/X\ [(2+a)^2-1](1+a+ka)-(2+a)=Ei/X$$
$$Ei/Eo=(2+a)^2(1+a+ka)-[3+a(2+k)]$$

Now $R/X=a=j\omega CR=j\alpha$. Whence $f=\alpha/2\pi CR$ and the frequency coefficient $=\alpha/2\pi$. Therefore $Ei/Eo=1-\alpha^2(5+4k)+j[6\alpha+3\alpha k-\alpha^3(1+k)]$.

Oscillations will be maintained at a frequency such that the phase change through the network is 180°, in which case the imaginary part of the above equation must be zero. The frequency of oscillation will thus be determined by

$$6+3k=\alpha^2(1+k)$$
$$\alpha=\sqrt{\frac{6+3k}{1+k}}$$

In order to find the attenuation coefficient β the value of α thus obtained must be substituted in the expression

$$\beta=1-\alpha^2(5+4k)$$

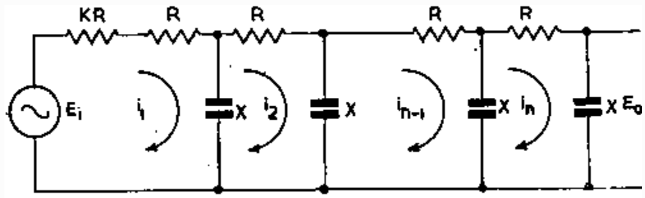


Fig. 2. R-C network of n-sections with added amplifier impedance

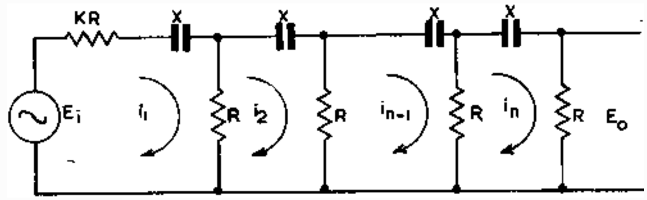


Fig. 3. C-R network of n-sections with added amplifier impedance

The equivalent network for the generalised C.R. case is shown in Fig. 3 and gives mesh equations as follows:

$$i_1[(1+k)+a]-i_2=Ei/R$$
$$-i_1+i_2(2+a)-i_3=0$$
$$-i_2+i_3(2+a)-i_4=0$$
$$-i_{n-2}+i_{n-1}(2+a)-i_n=0$$
$$-i_{n-1}+i_n(2+a)=0$$
$$i_n=Eo/R$$

where $X/R=a=1/j\omega CR=j\alpha$ and $f=1/\alpha 2\pi CR$.

These equations may be solved as shown for the R.C. case.

The tabulated results for 3 and 4 section networks are given below. (Note that α is different for the R.C. case to the C.R. case.) Curves of these results have been plotted in Figs. 4, 5, 6 and 7. The frequency is found by dividing the frequency coefficient by C.R., and the attenuation coefficient is read directly.

It can be seen that in every case the effect of valve impedance is to reduce the frequency of oscillation and increase the attenuation.

More complicated cases in which one or more of the capacitors are variable can be dealt with by the use of a further constant in the mesh equations.

R. TOWNSEND,
Wembley Park, Middx.

n	R.C.		C.R.	
	α	β	α	β
3	$\sqrt{\frac{6+3K}{1+K}}$	$1-\alpha^2(5+4K)$	$\sqrt{6+4K}$	$1+3K-\alpha^2(5+4K)$
4	$\sqrt{\frac{10+4K}{7+6K}}$	$1-\alpha^2(15+10K)+\alpha^4(1+K)$	$\sqrt{\frac{10(1-K)}{7+K}}$	$1+4K-\alpha^2(15+6K)+\alpha^4$

[1] J. Roorda, correspondence, ELECTRONIC ENGINEERING, p. 270, July 1949.

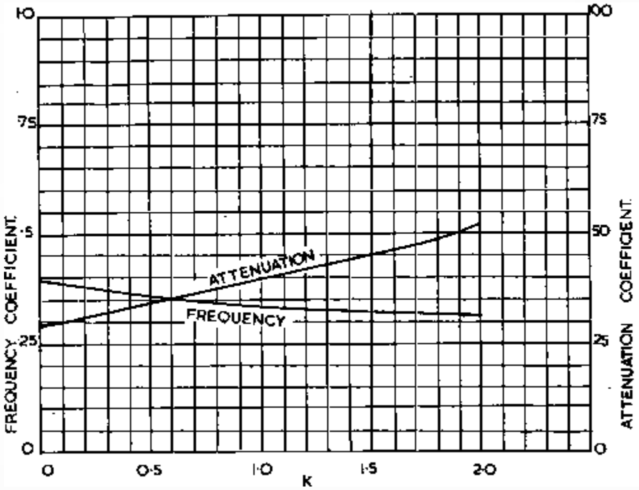


Fig. 4. Frequency and Attenuation Coefficients, 3 section uniform R.C. network.

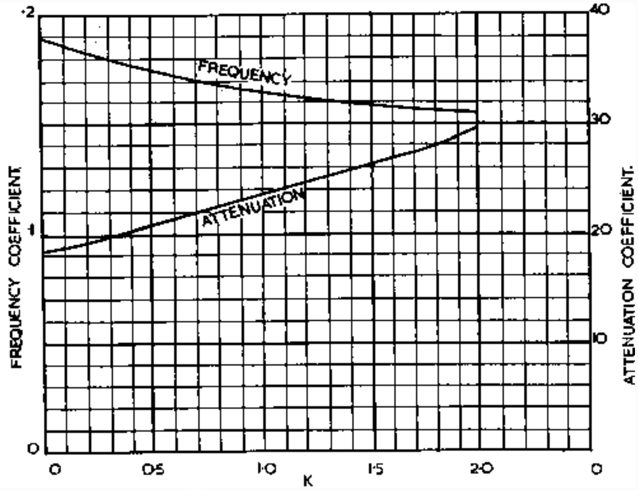


Fig. 5. Frequency and Attenuation Coefficients, 4 section uniform R.C. network.

(See letter on Page Opposite)

Fig. 6. Frequency and Attenuation Coefficients, 3 Section uniform C.R. network.

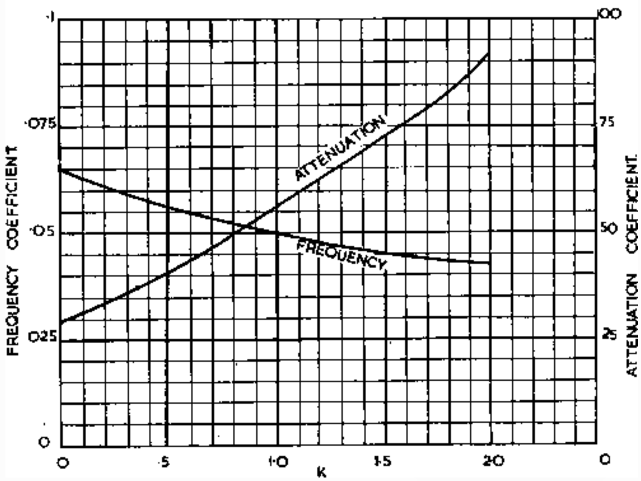
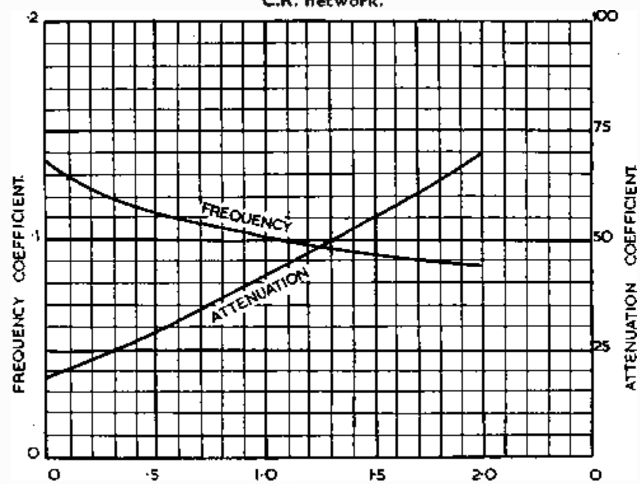


Fig. 7. Frequency and Attenuation Coefficients, 4 section uniform C.R. network.



Obstacle Detection Using Ultrasonic Waves in Air

DEAR SIR,—Your article describing and depicting a supersonic sound operated object locator (ELECTRONIC ENGINEERING, December, 1949, p. 464) is of interest to me as I have been working on a somewhat similar device for a purpose your contributor has not mentioned—a burglar or intruder alarm.

It will be seen that the sound waves can be deflected a number of times at varying angles, but always in a defined direction. This enables a room to be scanned sufficiently for the purpose of causing the interruption of scan by any object placed in its path, such as a human body; allowance can be made for animals. If the detecting device is caused to operate a relay when sound waves are not impinging upon it, whether absence of waves are occasioned by an intruder or cessation of operating power, one then has an intruder alarm which cannot be interfered with by wire cutting or spurious responses. If the operating power is derived from suitable dry cells, power cuts would not give a false alarm. A time clock can, of course, be used for setting and disconnecting. Sunrise lighting, artificial light and audible sounds would not trigger the device.

F. M. STAUNTON-LAMBERT,
Kilburn, London, N.W.6.

Television on 25c/s Mains

DEAR SIR,—With the extension of the television service to the Midlands area, the existence of a number of pockets of 25-cycle mains will undoubtedly lead to the temptation to use television receivers designed primarily for frequencies of 40 to 60 cycles.

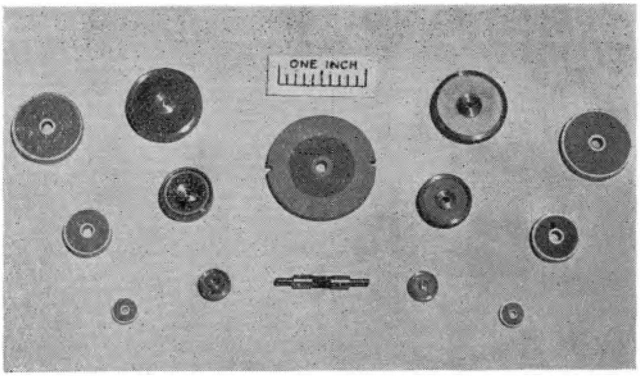
Each individual design of equipment involves certain problems and, in many cases, the addition of several hundred microfarads to the existing smoothing capacitor, while yielding a tolerable performance, is not without hazard.

May I suggest that in each case the receiver manufacturer be consulted in advance, to ensure that dependable information regarding the modifications required is obtained, and carried out, to reduce this hazard to a minimum.

O. G. COX,
A. H. Hunt Ltd., London, S.W.18.

Electronic

A monthly record of British elec-
accessories, compiled from information



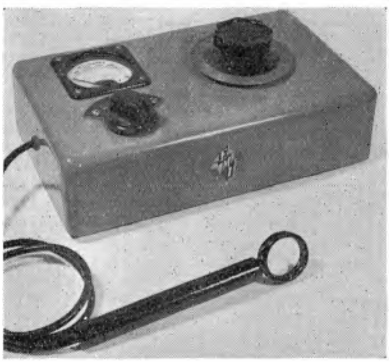
Co-axial Line Resistors

A NEW range of resistors, illustrated above, suitable for inclusion in co-axial lines either as terminating impedances or in assemblies to form T or π attenuators, has been introduced by the Welwyn Electrical Laboratories, Ltd.

There are two types of this component. The first is a disk resistor which is symmetrical and available in many sizes; the other is a rod element suitable for inclusion in the central conductor in order to make up networks.

The makers claim that there is reason to believe these resistors retain their characteristics up to several hundred megacycles because of the very thin film employed.

Welwyn Electrical Laboratories, Ltd., Bedlington Station, Northumberland.



Absorption Wavemeter

THIS instrument consists of a variable tuned circuit, across which is connected a germanium crystal in series with a 500 μA meter. The external coupling element comprises a three-turn loop connected to the wavemeter by 3 feet of co-axial cable. Frequency range is continuous from 1.6-30 Mc/s. Calibration is accurate to within $\pm$2 per cent. This instrument is used for detecting harmonics and standing waves and also for field strength comparisons.

The absorption wavemeter is housed in a metal case, finished in pale green and fitted with rubber feet.

E.M.I. Sales & Service, Ltd., Sheraton Works, Greenford, Middx.

Cathode Ray Oscilloscope

THE Nagard Oscilloscope and Oscillometer Type 103, shown below, is applicable to universal servicing and the usual comparative measurements. It is also capable of measuring quantitatively time, frequency and voltage from D.C. to Mc/s. with accuracy.

The unit is constructed in two cases, one containing the cathode ray tube and controls. It is arranged to accommodate, in removable form, unit assemblies such as time bases and amplifiers with various performances, beam switches for double and multiple traces, and special units. The other case contains the power supplies needed to provide accurate potentials, both D.C. and A.C. to the tube, time base, amplifier units, etc.

The makers claim that the basic construction has the following advantages: weight is divided by having two parts, each of which is portable; standard units for time bases and amplifiers of differing performances can be inserted and coupled to the C.R.T.; units with additional features, e.g., beam switches, can be added or interchanged; the power supply is separated from the oscilloscope enabling it to be free from stray fields and high temperatures; measuring facilities cover a wide field; time bases are calibrated in frequency and time to an accuracy of 2 per cent with linearity of 1 per cent. The amplifiers are types 103/1 and 103/2, employing new principles with direct coupling. A 6-inch C.R.T. is used in this unit.

Nagard, Ltd., 245, Brixton Road, London, S.W.9.

Oscillograph Type D-365-A

(Illustrated above)

THIS oscillograph is of the Duddell type employing an oil-damped bifilar suspension. It has been designed for modulation of the light beam in the Muirhead-Jarvis picture telegraph receiver where it is required to operate at frequencies up to 1,000c/s. The frequency characteristic is flat over this range while still maintaining reasonably high sensitivity.

The D.C. resistance of the loop is approximately 11 ohms, and the sensitivity is 0.65 mm. per mA at a distance of 60 cm. The maximum current should not exceed 150 mA. When operating from a D.C. signal a bias control can easily be fitted to provide an adjustment of the oscillograph zero setting.

A Ticonal magnet is used which gives flux density of the order of 10,000 lines/sq. cm.

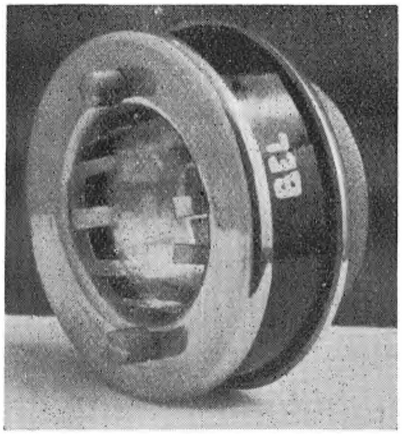
Muirhead and Co., Ltd., Beckenham, Kent.

Equipment

tronic apparatus, components and supplied by the manufacturers.

P.M. Focusing Assembly

BEL Sound Product's well-designed focusing device uses a sintered Ticonal magnet, which gives adequate focus control for nine or twelve-inch tubes. Two models are available, one being for tetrode tubes and the other, a rather stronger version, for triodes. The more powerful type can also be used to focus tetrodes if the magnetic flux is weakened slightly. The makers recommend unscrewing the "micrometer" gap adjustment to the full and then closing it up again for this purpose.



Centring the picture is comparatively simple, as the whole assembly is held in position on the tube neck by an annular spring. The first adjustment is to rotate the assembly until centring is correct either vertically or horizontally, and then to make a final correction by loosening the two knurled screws on the front of the assembly and moving the front plate slightly at right angles to the direction of image movement required. Normally, these adjustments should not be necessary, as each product is magnetically centred at the works. Price thirty-five shillings (triode) or thirty-two shillings and sixpence (tetrode).

Bel Sound Products,
Marlborough Road,
London, N.19

Breeze Concentric Plugs and Sockets

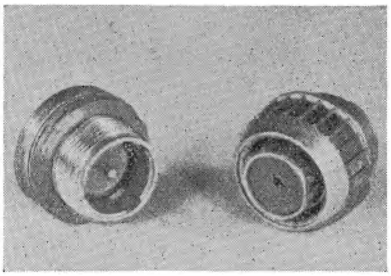
(Illustrated centre)

THE Breeze Mark 4 concentric plug and socket are available in two sizes, and are designed for the unmatched coupling of Uniradio 4 and Uniradio 39 cables. They have a maximum D.C. continuous working voltage of 2.5 kV and 3.0 kV respectively and a common current rating of 19 amps. Both types conform to specification RIC/C/321.

The complete connector consists of a fixed, or "panel" member, mountable from front or rear, and a free, or "cable" unit to which the flexible cable is attached, and with which either straight or right-angle outlets may be used. The cable being soldered to the connector, a rubber or P.V.C. sleeve should be fitted over the pin or socket bucket end.

The die cast aluminium housings are of identically similar design to those used for all other Mark 4 range connectors and, in common with them, the pin and socket mouldings, which in this case are of high quality polythene having an insulation resistance of not less than 10^{15} ohms, are interchangeable and obtainable in either panel or cable units according to circuit requirements.

The Plessey Co., Ltd.,
Ilford, Essex.



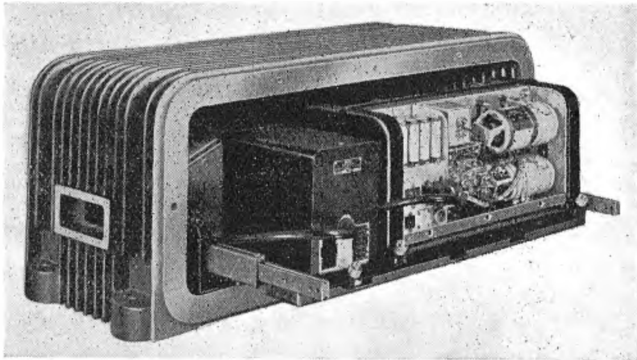
Segic Electric Soldering Iron

(Illustrated right)

THE Segic Electric Soldering Iron incorporates the following features: instant heating; temperature control at the finger tip; a slender bit which can be bent to reach corners, and an automatic feed of molten solder by magnetic induction. It has a low voltage bit, insulated from the earthed casing, and is shock proof.

The iron weighs only 30 oz. and has a consumption of 100 watts (intermittent). It is for A.C. supply only, and the voltage is 220-250 (50 cycles). The retail price of this tool is £3 3s. 0d.

S. Guiterman & Co., Ltd.,
Alderman House,
37, Soho Square, W.1.



V.H.F. Radio Equipment

THE General Electric Co., Ltd., have designed a low power V.H.F. radio transmitter and receiver specially for use in railway systems, mines, quarries, large agricultural schemes and similar applications where rough usage might be expected.

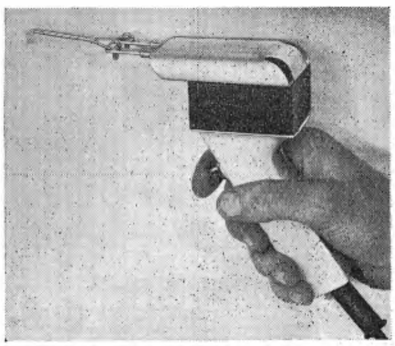
The equipment consists of a 15/20 watt frequency-modulated transmitter and receiver mounted in a cast light-alloy dust and weatherproof case. The equipment can be installed in any position for remote control from the footplate of a railway engine.

A particularly interesting feature of the apparatus is the (optional) built-in selective calling device. This is applicable to simplex, two-frequency simplex or duplex working and is generally arranged so that all the unwanted stations are locked-out during use of the main transmitter. It is always possible, however, to call groups or all the sub-stations by using special dial numbers.

The number of sub-stations which can be called by this system is unlimited, although a two-digit scheme to cover 70 individual stations or a three-digit scheme to cover 500, will suit most circumstances.

The V.H.F. equipment at the main or sub-stations, can be supplied for mains or battery operation and if the user so desires, amplitude modulated transmitters can be substituted for frequency modulated.

The General Electric Co., Ltd.,
Magnet House, Kingsway,
London, W.C.2.



BOOK

The Principles of Scientific Research

By Paul Freedman. 222 pp. Macdonald & Co., Ltd., 119 Ludgate Hill, London, E.C.4. Price 15s.

A PRESENTATION of the principles of modern scientific research is sure to be welcomed, not only by the ever increasing number of students and young research men intending to devote their lives to work on the advancing border lines of knowledge, but also by industrialists, and the less fortunate scientists and engineers ingloriously engaged on routine tasks yet keenly interested in the progress of science and scientific method.

The author commands a wealth of knowledge in many fields, coupled with thirty years' experience in industrial research. He is also gifted with a lively style and could therefore be expected to write just the kind of book one has been waiting for. Having read it one can only hope, however, that a second edition will give him an opportunity to remove the many blemishes from which the first one suffers. Its fourth chapter, entitled "The Mental Approach," opens with the sentence: "It is the author's hope that the reader has reached this chapter by reading the three preceding ones and not by skipping them as a long-winded historic introduction." The reviewer, on the contrary, would advise readers to begin the book at this important and readable chapter. By doing so they will avoid wading through a historical survey of many branches of science too compressed to be of much benefit, and will escape a number of verbose commonplaces, unscientific formulations, and highly debatable assertions, such as: "Successful scientific reasoning appears always to require as its starting point a consideration of available data relating to the specific problem," Leonardo da Vinci's discoveries "were doomed to long forgetfulness," "The fact that nature is not static and its laws change with time," "Of the four fundamental principles embodied in Dialectic Materialism the first is that everything in nature has a history. The other principles which . . . . must be accepted by any scientist are unity of opposites, change of quantity into quality, negation, and negation of negation." "The transition of quantity into quality is perhaps most strikingly illustrated in the case of radio-activity." In certain astronomical phenomena "increase of mass negates the volume that mass may occupy." "The radiation of atoms of long extinct stars does influence a man's future at his birth, though it does so to a negligible extent in comparison with the influence of his heredity or of the society in which he is born and develops."

The main part of the book is more calmly written and well rewarding. It deals with the planning of research, organisation, experimentation, accuracy, economy of effort, and the minimum number of essential observations. It contains much sound advice, astute observations, and many detailed examples from the author's personal experience. The concluding chapter, entitled "Patrons," is a particularly lively description of the organisation and financing of research in this country. Suitably modified it might well have been chosen as the introduction to the whole book.

R. POHL

The Quarterly Journal of Mechanics and Applied Mathematics

Vol. I, Part 3 (1948), and Vol. II, Parts 1, 2, 3 (1949). Oxford University Press. 40s. per annum.

UNTIL last year theoretical papers of a more mathematical nature were difficult to publish in this country. The mathematical journals published a small number and most of the remainder were published in technical journals, whose editors naturally wished less emphasis to be laid on the mathematics and more on the meaning of the theory and its applications. The "Quarterly Journal" has for the last year or so filled this rather serious gap in the scientific journals of this country. From its first issue the standard of the papers has been high, and the printing and paper of the fine standard which is customary from the Oxford University Press.

Up to date, however, the papers published have been mainly on problems in elasticity and hydrodynamics and of little direct interest to the electrical engineer or radio physicist, although the mathematical methods used may sometimes be relevant to his problems.

In the last two issues four papers are of more direct interest. Two short notes deal with the numerical solution of simultaneous equations and the numerical integration of differential equations by new methods. A paper by G. E. Reuter discusses the behaviour, when an

REVIEWS

external force is applied, of an oscillating system where the restoring force is neither simple harmonic nor symmetrical about the equilibrium position, a problem arising in the theory of loudspeakers. In such a case it is possible for the normal forced oscillation to become unstable and a sub-harmonic of double or higher frequency to take its place. The fourth paper mentioned contains a theory of the induction of currents in non-uniform thin sheets and shells of conducting material, by Professor A. T. Price. Such a theory is needed in geomagnetism to infer the distribution of conductivity in the earth from observations of the variations of the earth's magnetic field, and then to use this distribution to investigate the production of magnetic storms and similar effects.

G. J. KYNCH

Radio Frequency Heating

By L. Hartshorn. 237 pp. 102 figs. Geo. Allen & Unwin, Ltd. Price 21s.

As Dr. Hartshorn suggests in his preface, the literature on this subject is considerable but scattered, and there is need for books which survey the whole field and present a concise account of the principles and practice of induction and dielectric heating.

Much of the available literature falls, broadly speaking, into either of two categories. On the one hand are highly theoretical treatises which the practising engineer may unfortunately have neither the time nor the background to understand; on the other, descriptive illustrated articles and papers, some of which indicate what has been and is being done in the field of industrial application of these relatively new processes, while others encourage the suggestion of pure magic.

Dr. Hartshorn deals with those applications of H.F. heating, dielectric and induction, for which valve-driven generators are used, and succeeds in presenting fundamentals without a surfeit of mathematics. His treatment of the underlying principles is sound and yet easy to follow, and a variety of industrial applications are described. The whole has obviously been carefully written; the sections on dielectric heating theory and practice are particularly well done, as one would expect of this author.

One or two points may perhaps be criticised; thus Figs. 4.15 and 4.16 do not represent typical surface-hardening practice, as the authors of the paper from which they are taken made clear in discussion. Also, the illustrations of induction-heating applications are chosen principally to indicate what kinds of work may be done, rather than how it may be done under industrial conditions; that is, they show chiefly components and experimental set-ups. Instructive as such illustrations may be, it is true to say that the heating of a component under laboratory conditions is in many cases quite easy; but the subsequent development of a reliable, and preferably automatic, industrial process often calls for considerable engineering and metallurgical knowledge.

These are minor criticisms, however. Dr. Hartshorn has the gift of making difficult concepts clear, and since a great deal of the engineering and design work of this country is done, and done very well, by very ordinary people, books such as this, which help us to make use of these concepts, are of great value.

E. MAY

Radio Mains Supply Equipment

By E. M. Squire. 180 pp., 166 figs. Pitman. Price 12s. 6d.

As the author points out in his preface, the efficient working of the mains supply section of any radio or electronic equipment is a factor vital to its successful operation, and a large proportion of faults occur in this portion of equipment. This book treats the problem by first explaining the supply requirements—heater supplies, H.T. supplies, and bias supplies; after which the essential components are described and their required specifications discussed. The remaining half of the book is devoted to the application of these components to the requirements.

H.T. supply regulation is given quite full consideration, and there is much useful data for the designer in this chapter. There is a separate chapter to deal with the special problems in A.C./D.C. equipments. Another chapter deals with voltage and current stabilisers for use on both A.C. and D.C. circuits, while a final short chapter is devoted to the use of fuses. The various useful formulæ given throughout the book are accompanied by numerical examples of a practical nature.

In writing this type of book, the question of how much theory to include is always a problem. The book is intended for the use of the practical man—service engineer, radio mechanic, and wireless operator. The author seems to have chosen his theory well for his purpose, although the connexion

BOOK REVIEWS (Continued)

between the three halves power law $I_a = KV_a^{3/2}$ and the rectifying action of diodes, where it appears, is not made clear, and it would appear that statement of this law is superfluous here. There is a serious error in Fig. 35, representing the mean magnetic path length for a choke.

The book makes a useful addition to the series of books from this author, giving a greater quantity of practical information than its predecessors.

N. H. CROWHURST

Science in Industry

Report for the Year 1947-48. H.M.S.O., 1949. 103 pp. 2s. net.

TEN years of development in industrial science is reviewed in the Department of Scientific and Industrial Research's "Report for the Year 1947-48," published recently by H.M.S.O., price 2s.

The Report covers the change to war conditions, and briefly outlines the researches undertaken by the D.S.I.R., including the British work on the atomic bomb. Even during the war the Department was planning for peace.

The Research Association movement is explained, and an account of the examinations conducted by the Industrial Grants Committee in 1943 is given. The Committee's recommendations on the collaboration between the D.S.I.R. and other research establishments have been implemented. The principles of the Establishment are laid out, including the high degree of autonomy essential to the success of a Research Association, and the bridging of the gulf between development of a new technique and its adoption in works practice.

The position of Development Councils in industry is also mentioned, and the report recommends that the nationalised industries should study with the D.S.I.R., using the facilities available.

The report states that it has been the policy of the Department to concentrate its efforts on short term investigations of obvious utility and on advisory work using present knowledge at the expense of longer range and more fundamental research. The major problem of policy is the balancing of the need for giving assistance on problems of immediate and pressing importance and the need for providing the basis for more far-reaching advances in industrial technique and practice on which the continued prosperity of the country must ultimately depend.

M.C.K.

Television Story

By Frank Tinsley. 68 pp. 1949. British Broadcasting Corporation. 1s.

THIS booklet reviews the work and organisation of the B.B.C. Television Service, with special mention of important features which have been presented since the post-war resumption of transmission. Since the B.B.C. are the publishers, it is obvious that the author must give a fairly favourable view of the programmes mentioned, but having due regard to this one feels that his cathode-ray tube must be fitted with a rose-tinted filter.

However, non-viewers will find this booklet interesting insomuch as it will give them a very good idea of what type of programmes have formed the highlights of post-war television.

E.F.

Electrical Engineer's Reference Book

Editor: E. Malloy. 216 pp. cr. 8vo. VIth Edition. George Newnes Limited.

THE first edition of this book was published during the war years, and there have been many changes in the electrical field since then, so a thorough revision has been made.

Four new sections have been added on magnetic materials, factory wiring systems, house services and diesel-electric traction. Useful additions have been made in many sections, such as: servo-mechanisms, supervisory remote control equipment, and semi-conductors. Non-linear resistance elements are now dealt with in the automatic control section, and the electrical materials section includes bimetals, superconductivity, semi-conductors, solders and fluxes, and colloidal graphite. Other chapters coming under revision include power station practice, cables and wires, illumination and lamps, electrical measurements, electric traction, electric furnaces and high-frequency heating, and electrical literature.

NOTES FROM THE INDUSTRY

British Council's New President

Sir Henry Dale, O.M., has been elected President of the British Council by its Executive Committee in succession to Lord Riverdale, who has reluctantly resigned for private reasons.

Sir Henry was a member of the Council's Executive Committee from 1943-1949, and Chairman of its Science Advisory Committee from 1942-1949.

Jubilee of the N.P.L.

On Monday, January 30, a reception was held in the room of the Royal Society to celebrate the 50th anniversary of the founding of the National Physical Laboratory. All ten divisions of the Laboratory were represented, as well as the Electronics section of the Mathematics division, by experimental apparatus illustrating their different fields of research. Of interest to the electronic engineer were the demonstrations of the Electricity and Radio divisions and the Electronics section. The last-named section showed a typical working section of the Automatic Computing Engine (Electronic Engineering, *18*, 372, 1946).

Further mention of the A.C.E. exhibit will be found on page 115.

New Television Cameras for the B.B.C.

The B.B.C. has placed an order for five Marconi Image Orthicon cameras with Marconi's Wireless Telegraph Co., Ltd.

For many months both the B.B.C. and the Marconi company have subjected Image Orthicon cameras to the most rigorous tests, particularly outside broadcasting. The outside broadcasting tests have covered a wide range of subjects and have been conducted under greatly diverse conditions.

Retrospect

In the table published in the leading article, February issue, the value of exports of transmitters, navigational aids, communication equipment and industrial electronic apparatus for the first ten months of 1949 should have been £2,686,000. These are Customs and Excise figures and they take no account of indirect exports, in the form of equipment installed in ships and aircraft, which are worth probably more than half as much again.

Admiralty Portable Radio Interference Measuring Set

The Committee on Radio Interference of the Institution of Electrical Engineers have issued the following information.

The recent publication of B.S. 1597 "Radio interference suppression on marine installations" has focused attention on the need for a measuring set suitable for marine use and conforming to the appropriate clauses of B.S. 727 "Characteristics and performance of apparatus for the measurement of radio interference."

It has recently been announced that the Electrical Research Association has designed for the Admiralty a suitable portable measuring set complying with fine limits of weight and size, suitable for use in conjunction with B.S. 1597 and equally suitable for land purposes. Sets constructed to the Admiralty specification are now being manufactured by Messrs. Electric and Musical Industries, Ltd., of Hayes, Middlesex, and the Lords Commissioners of the Admiralty have stated that they have no objection to civilian organisations using the design, no charge being made to cover the cost of development. Interested authorities who wish to view the set are asked to approach the Electrical Research Association, Perivale, Middlesex, or Messrs. Electric and Musical Industries, Ltd.

Radio Components Exhibition, 1950

The seventh annual Exhibition of British Components, Valves and Test Gear for the radio, television, electronic and telecommunication industries will be held in the Great Hall, Grosvenor House, Park Lane, London, W.1, from Monday, April 17, to Wednesday, April 19, 1950.

Admission is by invitation of the organisers, the Radio and Electronic Component Manufacturers' Federation (22 Surrey Street, Strand, London, W.C.2.).

PAPER RESTRICTIONS

With the lifting, in March, of paper restrictions on all periodicals there should be no difficulty in regularly obtaining a copy of "ELECTRONIC ENGINEERING" from newsagents.

In cases of difficulty, readers are requested to write to the Circulation Department at these offices.

1949 INDEX

The 1949 Index, Volume 21, is now available. Copies may be obtained post free on application to the Circulation Department.

The Society of Instrument Technology

The Society of Instrument Technology has recently announced the formation of a new section dealing with the control field. The section is intended to cover the theory and practice of closed loop control systems, including servo-mechanisms, regulators and process controllers: also problems of the human operator as a controller and when part of a larger control system.

An inaugural meeting will be held on Tuesday, March 28, at 6.30 for 7 p.m., at the Royal Society of Tropical Medicine and Hygiene, Manson House, Portland Place, London, W.1, when three short papers will be read. These are as follows:—

Prof. K. A. Hayes, "Servomechanisms Recent History and Basic Theory."

Dr. A. Utley, "The Problem of Stabilisation."

Prof. A. Tustin, "Problems in Control Systems which await Solution."

All who are interested in control mechanisms and allied subjects are invited to attend the inaugural meeting. If sufficient response is obtained, the inaugural meeting will be followed by a business meeting to deal with the formation of the Control Section within the framework of the Society of Instrument Technology.

Demonstration of Ediswan Electro-Medical Equipment in Denmark and Sweden

Ediswan electro-medical equipment, including the electro-encephalograph, electronic wave analyser, shock therapy apparatus, and nerve stimulator, was recently featured in an interesting demonstration given at the Rigshospitalet, Copenhagen, by Mr. E. G. Elton and Mr. F. Wilson of the Edison Swan Electric Co., Ltd. Among those attending the demonstration were Dr. F. Buchtal of the Universitetets neurofysiologiske Institut, Dr. Pirelli from Italy, who was visiting Copenhagen, and 31 other doctors from various hospitals around Copenhagen.

Change of Address

Hazlehurst Designs, Ltd. have moved from their old address to 34 Pottery Lane, London, W.11.

Electrical Sound and Television Patents, late of 12 Pembroke Street, N.1, have acquired new premises at 2, 3 and 4 Manor Way, Boreham Wood, Herts.

MEETINGS THIS MONTH

Institution of Electrical Engineers

Unless otherwise stated, all meetings are held at the Institution of Electrical Engineers, Savoy Place, W.C.2.

Ordinary Meetings

Date: March 25. Time: 5.30 p.m.
Annual General Meeting.

Measurements Section

Date: March 7. Time: 5.30 p.m.
Lecture: The Fundamental Limitations of Second-Harmonic Type of Magnetic Modulator as Applied to the Amplification of Small D.C. Signals.
By: Prof. F. C. Williams, O.B.E., D.Sc., D.Phil., and S. W. Noble.
Lecture: A New Theory of the Magnetic Amplifier.
By: A. G. Milnes, M.Sc.(Eng.).

Date: March 14. Time: 5.30 p.m.
Lecture: A new Approach to the Design of Pulse-Monitored Servo Systems.
By: A. Porter, M.Sc., Ph.D., and F. W. Stoneman, M.B.E., M.Sc.(Eng.).

Radio Section

Date: March 7. Time: 5.30 p.m.
Lecture: As the Measurements Section—Joint Meeting.

Date: March 15. Time: 5.30 p.m.
Lecture: The Structure, Electrical Properties and Applications of the Barium-Titanate Class of Ceramic Materials.
By: Prof. Willis Jackson, D.Sc. D.Phil.

Date: March 27. Time: 5.30 p.m.
Informal Lecture: The Operation and Maintenance of Television Outside-Broadcast Equipment.
By: T. H. Bridgewater.

The General Secretary, The Institution of Electrical Engineers, Savoy Place, W.C.2.

South Midland Radio Group

Date: March 15. Time: 6 p.m.
Held at: Malvern.
Lecture: Some Electromagnetic Problems.
By: Prof. G. W. O. Howe, D.Sc., LL.D.

Date: March 27. Time: 6 p.m.
Held at: The James Watt Memorial Institute, Great Charles Street, Birmingham.
Lecture: A Storage System for Use with Binary Digital Computing Machines.
By: Prof. F. C. Williams, O.B.E., D.Sc., D.Phil., and T. Kilburn, M.A., Ph.D.

Hon. Secretary: W. H. Brent, B.Sc., Regional Director's Office, Midlands Region (G.P.O.), Civic House, Gt. Charles Street, Birmingham, 4.

Cambridge Radio Group

Date: March 21. Time: 6 p.m.
Held at: The Cambs. Technical College, Cambridge.
Lecture: The Acoustics of Studios and Auditoria.
By: W. Allen.

Secretary: G. E. Middleton, M.A., University Engineering Laboratory, Cambridge.

Mersey and North Wales Centre

Date: March 15. Time: 6 p.m.
Held at: The Temple, Dale Street, Liverpool.
Lecture: The Nature of the Electric Spark.
By: Prof. J. M. Meek, D.Eng.

Date: March 22. Time: 6.45 p.m.
Held at: The Philharmonic Hall, Hope Street, Liverpool.
Lecture: Faraday Lecture on "Radar."
By: R. A. Smith, M.A., Ph.D.

Hon. Secretary: J. Gledhill. B.Sc., A.M.Brit.I.R.E., 123 Portelet Rd., Liverpool, 13.

North Eastern Radio and Measurements Group

Date: March 20. Time: 6.15 p.m.
Held at: King's College, Newcastle-on-Tyne.
Lecture: The B.B.C. Short-Wave Transmitting Station at Skelton.
By: S. A. Williams.

Hon. Secretary: G. A. Kysh, Carliol House, Newcastle-on-Tyne, 1.

North Midland Centre

Date: March 6. Time: 7 p.m.
Held at: The Town Hall, Leeds.
Lecture: Faraday Lecture on "Radar."
By: R. A. Smith, M.A.. Ph.D.

Date: March 14. Time: 6.30 p.m.
Held at: Yorkshire Electricity Board Offices, 1 Whitehall Road, Leeds.
Lecture: The Motor Uniselector and the Technique of its Application in Telecommunication.
By: W. H. Grinsted. M.B.E.

Hon. Secretary: F. W. Fletcher, Yorkshire Electricity Board, Manor Farm, Bramhope, near Leeds.

British Sound Recording Association

Date: March 24. Time: 7 p.m.
Held at: Royal Society of Arts, John Adam Street, Adelphi, Strand, W.C.2.
Lecture: Microphones and Balance Technique.
By: F. W. Alexander, Ph.D., A.M.I.E.E.

Secretary: R. W. Lowden, "Wayford," Napoleon Avenue, Farnborough, Hants.

The Television Society

Constructors' Group

Date: March 2. Time: 7 p.m.
Held at: The Cinema Exhibitors' Association, 164 Shaftesbury Avenue, W.C.2.
Lecture: Interlaced Pattern Generator.
By: F. Cox.

Secretary: T. M. Lance, 35 Albemarle Road, Beckenham, Kent.

Midlands Centre

Date: March 6. Time: 7 p.m.
Held at: The Lecture Hall, The Crown Restaurant, Corporation Street, Birmingham.
Annual General Meeting.

Secretary: W. Summer, 31 Beech Road, Birmingham, 30.

Leicester Centre

Date: March 1. Time: 7 p.m.
Held at: Room 104, the College of Art and Technology, Leicester.
Lecture by Ultra Electric, Ltd.

Date: March 16. Time: 7 p.m.
Held at: The Mitre and Keys Hotel, Applegate Street, West Bridge.
Annual General Meeting.

Date: March 22. Time: 7 p.m.
Held at: Room 104, the College of Art and Technology, Leicester.
Lecture: The Construction and Use of Wobbulators for Alignment of T/V Receivers.
By: R. H. Hibberd, B.Sc.

Secretary: A. E. Moore, 110 Doncaster Road, Leicester.

Radar Association

Date: March 7. Time: 7 p.m.
Held at: Albert Tavern, Victoria Street, London.
Monthly Meeting.

Hon. Secretary, Technical Committee: J. C. Warren, 57 Gallows Hill, Kings Langley, Herts.

Institution of Post Office Electrical Engineers

Date: March 28. Time: 5 p.m.
Held at: Institution of Electrical Engineers, Savoy Place, W.C.2.
Lecture: Television Radio-Relay Link.
By: A. H. Mumford, O.B.E.

Informal Meeting

Date: March 22. Time: 5 p.m.
Held at: The Conference Room, 4th Floor, Waterloo Bridge House, S.E.1.
Lecture: The Practice of Telecommunications Maintenance.
By: J. W. Rivis.

Secretary: W. H. Fox, Engineer-in-Chief's Office (T.P. Branch), Alder House, E.C.1.