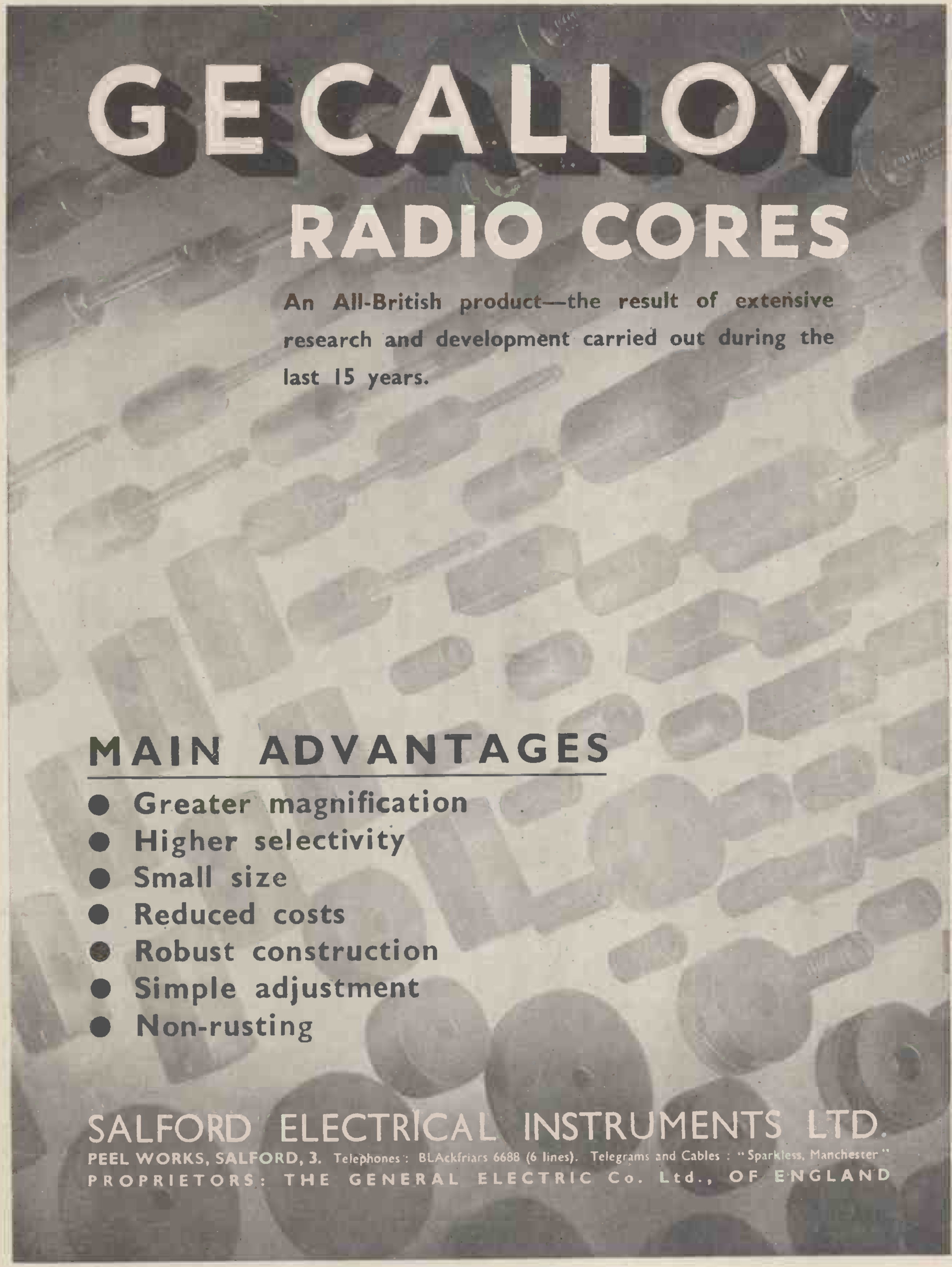
Electronic Engineering

INCORPORATING ELECTRONICS, TELEVISION AND SHORT WAVE WORLD

PRINCIPAL CONTENTS

2/- NOV., 1943



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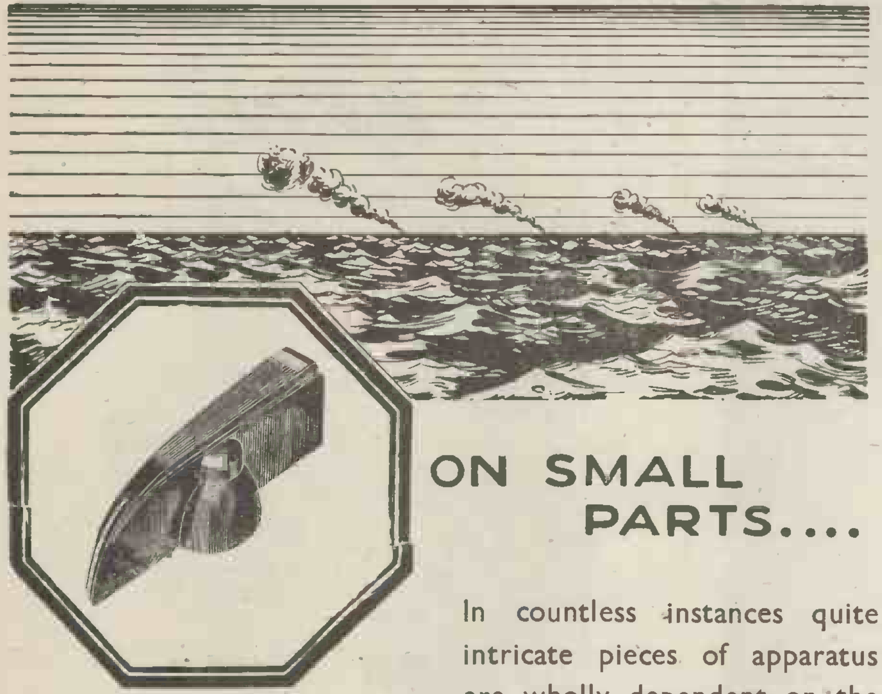

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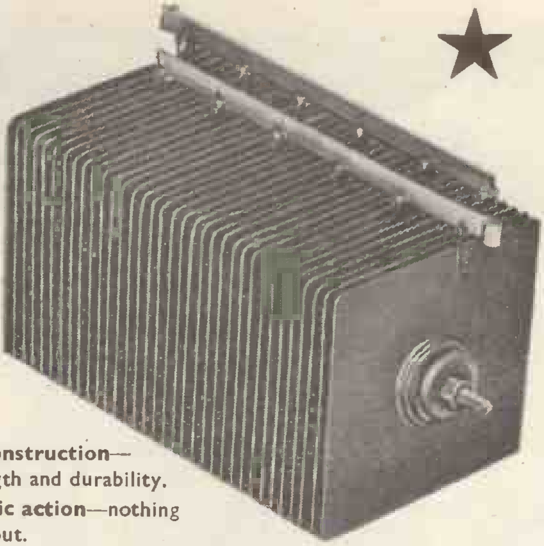

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NOVEMBER, 1943

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Discussions

THE scientific needs of the radio and telecommunications industry are catered for at present by at least four learned societies or institutions, besides many smaller groups in various parts of the country.

It has been debated from time to time whether all these scientific bodies need to continue a separate existence. The suggestion is that a single scientific body should be adequate for covering the various branches of the subject and that an amalgamation should take place so that radio, telecommunications, and the electronic industry should have a single platform for its discussions.

Most engineers have their own speciality, and are less interested in other branches of the subject. If one scientific body endeavoured to cater for the needs of all it would have to hold several meetings a week in order not to leave too long a gap between discussions on a particular subject.

The outcome of this is the formation of the discussion groups or sections, such as now exist under the aegis of the well-known scientific institutions, or, alternatively, the formation of separate specialist societies.

Both have as their aim the covering of one particular aspect of engineering or physics, and the only difference is that a section of a main institute is in a sense sponsored and confers the same status on its members as that of the parent body.

The plea for centralisation is put forward because the activities of certain specialist groups and societies tend to overlap. But surely it is better to overlap than to run the risk of dealing inadequately with the mass of development and research which is waiting to be published.

Four institutions mean four times the amount of information available for reference and discussion, and four choices of subject for those attending the meetings.

It has even been suggested that "this country may never attain the heights of international estimation to which its radio work entitles it if the scientific publications on the subject are scattered amongst the journals and proceedings of many different bodies."

What does this imply? That one scientific journal only should be responsible for publishing original communications in all branches of radio engineering? It would be a big one.

And why not apply the argument to the independent scientific journals? Who will examine the claims to be the only journal allowed to publish scientific articles of merit?

One can imagine that such a proposal would be supported enthusiastically by the abstractors and librarians, but what reader would like to be told "Read this, or nothing?"

The question of whether this or that society or discussion group is necessary, or whether this or that journal shall continue to be published is surely settled by the members of the radio profession themselves.

They decide which learned society is worthy of their support and attendance. They decide whether a scientific journal is worth reading, in the same way that they decide which theatre to go to or what music they will listen to.

If a learned society gives its members what they require—accurate information of a high technical standard, the right spirit of discussion, congenial surroundings and companionship, it need not worry about whether its work is redundant or inadequate.

A sure sign of a healthy industry is an increase in the number of discussions and meetings, and our only concern need be that they do not fall below the high standard which has been set up to the present time.

The Design of a C.R.-Tube Amplifier

By B. M. HADFIELD, B.Sc., (Hons.), A.M.I.E.E.*

In a recent article† describing a cathode ray oscillograph equipment in general outline, only a brief reference could be made to two major points in the specific design. These were (a) the minimum ratio between the amplifier and tube supply voltages, and (b) the design of the amplifiers by a novel method known as the limiting gain principle. The purpose of this article is to deal with these points in detail and in as general a manner as possible, because they constitute the basis of design of such equipment as distinct from the mere formulation of the circuit arrangements. The amplifier design method is also of great use when applied to all types of valve amplifiers.

THE following statements, although perhaps a trifle obvious, form the fundamental starting points in the design of an amplifier and give a clue to the method of attack:—

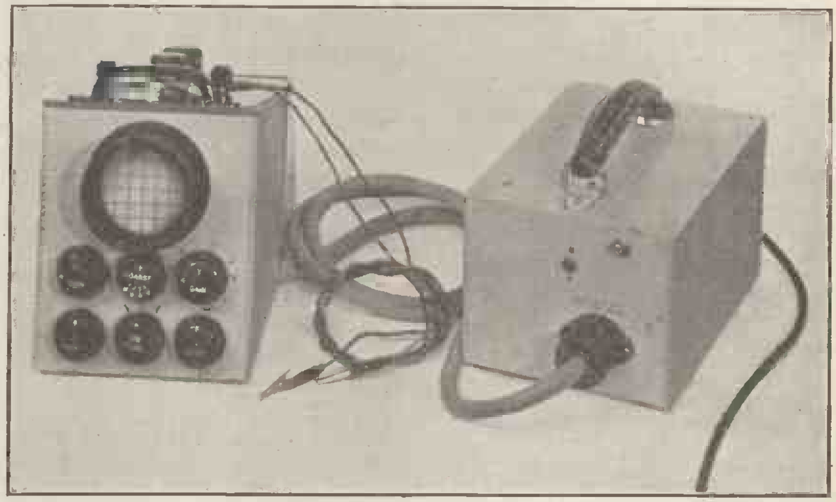
(1) No overloading distortion due to the amplifiers shall be visible on the screen of the tube, no matter how the controls are set.

(2) The most economical amplifier design is that which just satisfies (1) for both positive and negative inputs, and

(3) Quasi-linear distortion of the amplifiers due to the normally used valve characteristics, having a power law relationship between anode current and electrode potentials, occurs between the limits of (1), is not necessarily related to the overload distortion limits, and can be dealt with as a separate item when (1) and (2) have been satisfied. Quasi-linear distortion can be virtually eliminated by sufficient negative feedback, without affecting in any way the overload distortion limits of the valves.

Relation between the Amplifier and Tube Supply Voltages

In order to satisfy (1) above, it is necessary to establish the net maximum undistorted deflection voltage between the plates of the tube. In the present amplifier (*see* Fig. 1), this consists of the total voltage swing between the overload points of the valves, less the maximum plate-to-plate voltage due to the shift control, because the latter is incorporated in the anode resistances. Obviously, subtraction need only be considered, since the use of the shift control to deflect the spot in the same direction as the input, only aids the latter in moving the spot off the screen before the onset of amplifier overloading. If the shift control had been comprised by an input to the amplifiers, then its effect on the maximum undistorted output voltage need not have been included, for it would then form an input of a special type; the reasons for non-adoption of this form of shift control have been given on p. 2 of the article referred to, and although the present method results in a pessimistic design, such a tendency is valuable in providing a large factor of safety for all normal usage of the shift control. Having ascertained the net undistorted plate-to-plate output voltage, we must now ensure that it deflects the spot by at least the screen radius.



(*By courtesy of The P.O.E.E. Journal*).

Photograph of portable C.R. Tube Equipment with separate Power Pack.

The following symbols are used in the discussion:—

D	Maximum spot deflection due to the amplifiers (cm).
D_s	Maximum shift deflection (cm).
R_d	Radius of tube screen (cm).
q	Ratio of amplifier and tube supply voltages.
B	Amplifier supply voltage.
E	Final anode voltage of tube.
d/E	Tube sensitivity in cms. per volt between plates.
p	Ratio of maximum undistorted anode voltage range to amplifier supply voltage.
e	Negative input voltage to amplifier which gives zero anode current.
G	Gain of the amplifier.

The maximum undistorted spot deflection, less the maximum shift deflection must be greater than, or at least equal to, the screen radius, or $D - D_s \geqslant R_d$, whence

$$D \geqslant R_d\left\{1+\frac{D_s}{R_d}\right\} \quad \text{..............} \quad (1)$$

Now the overload characteristics of a valve amplifier are due to (a) zero anode current, and (b) maximum anode current, or converting these to anode voltages for a resistance anode load, anode voltages corresponding to the supply voltage and a fraction thereof (*see* Figs. 3, 4, and 5). Hence the maximum undistorted deflection due to the amplifiers is $\frac{d}{E}.p.B$, and as the supply voltage B is $q.E$, this becomes $d.p.q.$ cms. Substituting this for D in equation (1) we have,

$$d.p.q. \geqslant R_d\left\{1+\frac{D_s}{R_d}\right\} \text{ or,}$$

$$q \geqslant \frac{R_d}{p.d}\left\{1+\frac{D_s}{R_d}\right\} \quad \text{..............} \quad (2)$$

From this it will be seen that there is a definite minimum to q depending on the shift control ratio $\frac{D_s}{R_d}$, for a given tube, and a given amplifier p value, and independent of the actual tube voltage. If the shift control ratio be taken as unity, giving a total shift equal to the diameter of the tube, and let R_d be 3.5 cms., and d be 17 for the given tube, whilst p can be up to 0.8, then $q \geqslant 0.515$.

Hence a design based on a tube voltage of twice the amplifier supply vol-

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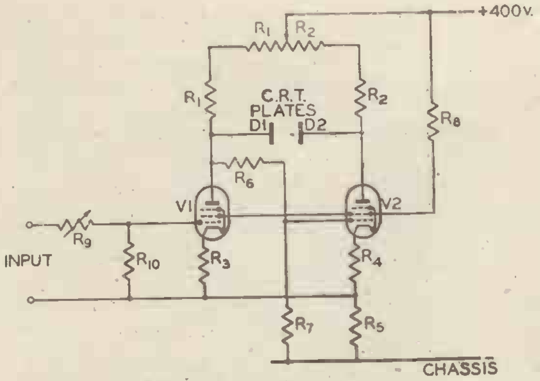
* Post Office Research Station.

† A Compact Two-Unit Cathode Ray Oscilloscope, *P.O.E.E.J.* 36, 1, 1943.



(By courtesy of The P.O.E.E. Journal)

Fig. 1.
Circuit diagram of deflection amplifier.

R_1 & R_2 = 50,000 Ω (i.e. the fixed portions).
R_1 & R_2 = 50,000 Ω potentiometer (i.e. the variable portions).
R_3 & R_4 = 1,000 Ω.
R_5 = 2,000 to 3,000 Ω (depending on initial D.C. balance).
R_6 = 5 M Ω
R_7 = 100,000 to 150,000 Ω (depending on initial gain of V_1).
R_8 = 500,000 Ω.
R_9 = 5 M Ω inverse log. variable.
R_{10} = 100,000 Ω.
V_1 & V_2 = EF 36 valves.

tage will be adequate, and a three-busbar power supply arrangement will ensure that q is never less than 0.5, because the final anode voltage of the tube will have to be as much below the amplifier positive busbar as the steady anode voltage, to avoid defocusing the spot. Such a power supply lends itself admirably to an economic mains rectifier design using only one high tension winding, by a species of voltage doubler circuit in which the centre tap of the condensers is used as the middle busbar. (*see* Fig. 2.) The positive and negative busbar rectifier supply circuits are, of course, designed independently to supply the differing load currents required by the amplifiers, etc., and the tube, respectively.

It should be noted, of course, that any higher value for q could be used, but the most economical design is given by the above equality and making full use of the maximum permissible anode voltage swing. As regards the latter, *i.e.*, the p value, this can be up to 1 for triodes and up to about 0.8 for pentodes. Thus the common figure of 0.8 is a reasonable assumption for the above calculation. However, if, as may appear later in the design of the amplifiers, such a p value results in too high a value of anode resistance, with consequent excessive loss at high frequencies, then p will have to be reduced and the minimum q correspondingly raised.

Amplifier design based on the limiting gain principal

Attempts were made to base the present design on normal methods involving a knowledge of the working slope, amplification factor and internal resistance of a given valve circuit, but it was always found that of the variety of ensuing designs all were unduly optimistic as regards gain, and selection of a practical design could only be made by reverting to a knowledge of the fundamental D.C. characteristics of a valve. This situation was probably aggravated by the fact that the circuit is direct coupled, but nevertheless the method proposed will be found to be much simpler and provide more factual information on any amplifier problem. Since the method is based entirely on the operation of the valve circuit at the limits of the quasi-linear range, so that if the input be increased by the smallest amount the output waveform becomes radically distorted or "limited," it has been called the limiting gain method. The first part of the following will outline the general treatment, whilst the second part will take the present application as an example.

General outline of the limiting gain principle

As mentioned before, the use of any valve amplifier is limited to a range of anode currents lying between zero and the permissible maximum. The former is produced by negative input voltage, and the latter by positive input voltage producing either grid current, or an anode voltage just within the normal anode characteristic, whichever is the smaller. Let the total anode voltage excursion between these input limits be $p.B$, where B is the anode supply voltage and p is a number whose magnitude depends on the general type of valve and anode circuit impedance (*see* Figs. 3, 4, 5). The limiting anode voltage swing is therefore $p.B$ volts. Let e be the negative input voltage to the amplifier circuit which produces zero anode current. Let the magnitude of the positive input which will produce the other limiting effect bear a known relationship to this negative input, according as to the specific use intended for the amplifier; in fact, let it be denoted by Ne volts.

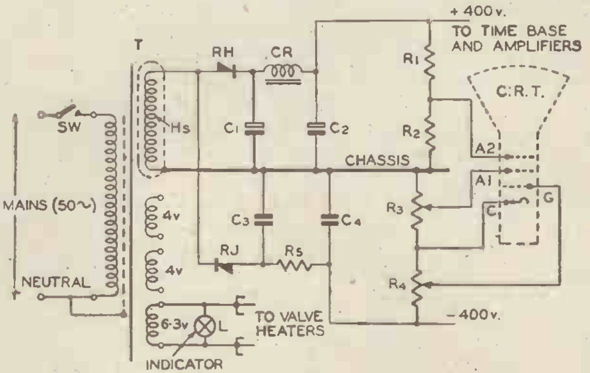
The limiting gain of the amplifier is therefore given by the expression $\dfrac{p.B.}{(N+1)e}$. Generally speaking, the required gain G forms the starting point in amplifier design, so that we must arrange that the limiting gain is at least equal to G, as follows,

$$\frac{p.B.}{(N+1)e} \geqslant G, \text{ or } e \leqslant \frac{p.B}{(N+1)G} \quad \text{.........................} \quad (3)$$

Now in a specific case, $p.B$ and N will also be known, or may be postulated, so that a maximum absolute value for e is easily obtained. But by definition, e must be related in some simple manner to the cutoff grid voltage of the valve; for instance, it is equal to it if cathode resistance bias is used (*i.e.*, without decoupling), and it is substantially one half if the working bias is steady (these examples assume that there is no other permanent input bias voltage). In this manner the cutoff bias of the valve may be found readily.

If the value should turn out to be unreasonably small (for instance it must not be less than 1 volt with indirectly heated cathodes and normal grid biases, otherwise grid current will flow), then the postulated values used in equation (3) must be altered, for instance by reducing G on this stage, when one or more prior amplifying stages are indicated. The most economic design is then the one having the smallest e value for the last stage.

The usefulness of the above method lies in the inclusion of all the relevant factors in a practical form. For instance, the maximum output voltage swing will be given by the requirements, so that the product $p.B$ is



(By courtesy of The P.O.E.E. Journal)

Fig. 2.
Circuit diagram of power supply unit.

R_1 = 500,000 Ω and 1 M Ω in parallel.
R_2 & R_3 = 1 M Ω.
R_4 = 100,000 Ω
R_5 = 250,000 Ω.
C_1 & C_2 = 8 μF.
C_3 & C_4 = 0.5 μF.
CR = 30 H. at 10 mA.
RH = Westinghouse 100 H.
RJ = Westinghouse 100 J.
Hs = 400 volts, 20 mA, completely screened.
C.R.T. = E 40 — G3, or VCR 139A.

known, and since p cannot exceed 1 for resistance load, or 2 for resistance shunted by inductance, then the minimum supply voltage is known. If the practicable minimum B is desired, then p may be taken as 0.8 for all valve types without incurring excessively large anode load resistances. The value of N will be given by independent consideration of the intended use of the amplifier; and if no special use is required, then N can be 1, when the amplifier will overload on equal positive and negative inputs. In the case of a pentode or tetrode, the maximum screen voltage is immediately determined by the above maximum value for e, whilst for a triode the minimum μ is determinable by dividing B by e for a resistance anode load with cathode bias resistance (since the anode current cutoff bias is substantially $\frac{1}{\mu}$ th of the supply voltage). Hence the choice of valves and practical operating conditions are no longer indeterminate absolute quantities.

It may be argued that the limiting gain is not the same as the differential gain, but this implies considerable non-linearity in the amplitude/gain characteristic, which is not the aim of the designer. In any case the resulting differential gain will be larger than required, with normal valve characteristics, so that the design by this method can only be pessimistic.

Specific example of method applied to the present purpose

By combining equations (2) and (3), or by considering the overall action of the amplifier and tube (which requires that an undistorted deflection of $R_d \left\{1 + \frac{D_s}{R_d}\right\}$ shall be given by the input e for a minimum overall sensitivity of D cms/volt) we obtain the following:—

$$e < \frac{R_d}{D}\left(1 + \frac{D_s}{R_d}\right) \quad\ldots\ldots\ldots\ldots (4)$$

This equation is entirely determined by the required overall sensitivity, the tube radius, and the shift control ratio, all of which are known, and without having to know the valve type or the specific nature of the grid and anode circuits. In the present case, when R_d is 3.5 cms. and the required overall sensitivity is 2 cms./volt with a shift control ratio $\left(\frac{D_s}{R_d}\right)$ of 1, then e must not be greater than 3.5 volts. As this is a reasonable value for a valve, it follows that only one valve per deflection plate is necessary, which in turn means that only one amplifier supply voltage is necessary. Had the value been much lower (*i.e.*, approaching the grid current value of 1 volt) it would mean that a prior stage of amplification would be needed, which, as the amplifier is to be direct coupled, would have involved additional supply voltages.

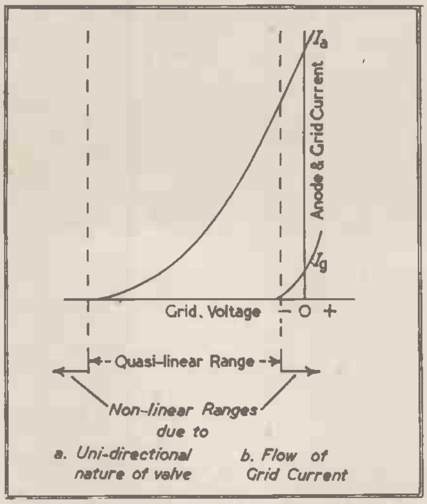


Fig. 3. Grid-Anode Characteristic showing limitation of range.

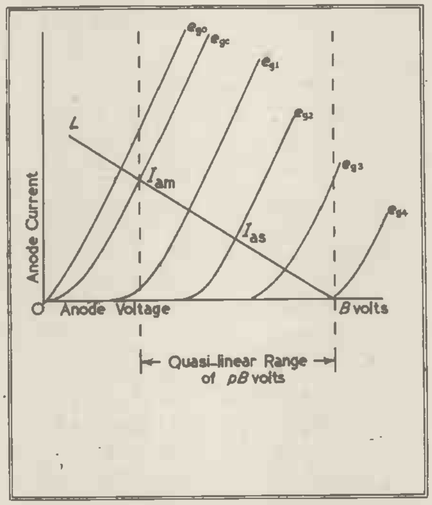


Fig. 4. Load-line Anode Characteristic for a triode with resistance load, p can be 0—1 inclusive.

It is now interesting to consider what type of valve may be used, although a pentode is indicated by the shift control circuit requirements. The tube voltage (E) will have to be about 700 for adequate spot intensity, which means that the amplifier voltage must be of the order of 400 volts. If cathode resistance bias is used on the valves, then e represents the cutoff grid voltage (*i.e.*, the grid base), which gives a minimum amplification factor for a triode valve of $\frac{400}{3.5}$, or 114. This is obviously impracticable, so that a triode need no longer be considered. On the other hand, a pentode valve, whose amplification factor to the screen grid is also limited to the same extent as for a triode, will be usable because the working screen voltage can be reduced at will until the required grid base is obtained. For instance, the EF36 has a screen μ of 20, and hence the required screen voltage is 70, whilst the SP41 has a screen μ of 50 and will require 175 volts on the screen.

The choice of a valve, for instance, between the EF36 and SP41 cited above, will be governed by the conflicting requirements of minimum loss of gain at high frequencies due to the anode capacity, and minimum steady current drain from the supply. For the required maximum anode voltage change of $p.B$ volts may be produced by a variety of anode resistances according to the maximum limiting anode current of the valve, which in turn will determine the steady anode current. The grid bias remains constant, of course, because it will be about $\frac{1}{2}e$, so that the upper frequency limit can only be raised by using a valve of higher "slope" and correspondingly higher steady anode current. In the present case economy of current consumption has been aimed at, rather than a maximum of frequency response, so that the EF36 has been specified. Nevertheless, the gain at 200,000 c/s is within 3 db of the gain on D.C., for a current consumption of only 4 mA per pushpull amplifier. By using the SP41, having a maximum current limit of about 6 times the EF36, and by proper attention to the effects of grid capacities on the paraphase coupling between the valves, the upper frequency limit can be raised to 1.2 Mc/s at the expense of a corresponding increase in the steady current.

Having decided on the valve, by considering the above inevitable situation, the designer is now in a position to determine the remaining circuit constants rapidly. The maximum anode current at the inception of grid current, may be calculated knowing the cutoff bias e and the grid current grid voltage, and using a figure for the average "slope" or preferably a $\frac{3}{2}$-power law relationship for the grid characteristic. The required anode resistance is given by the total output voltage swing $p.B$ (where p may be taken as 0.8) divided by this maximum anode current, and the cathode bias resistance is given substantially by e

divided by the maximum cathode current. The screen resistance is similarly determined from a knowledge of the screen to anode current ratio, and the required screen voltage.

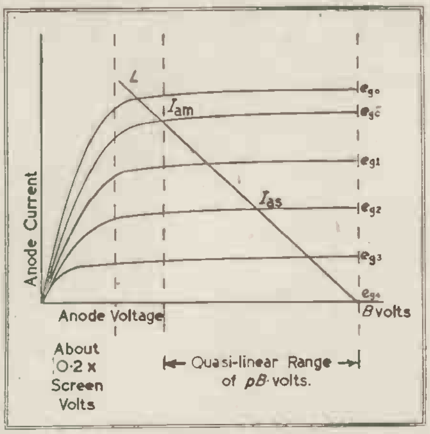


Fig. 5. Load-line Anode Characteristic for a pentode or tetrode with resistance load.
Iam **Maximum Anode Current.**
Ias **Steady Anode Current.**
ego **Anode Characteristic at zero grid volts.**
egc **Anode Characteristic at grid current start.**
egl, e_{g2} **etc., Characteristic at other grid voltages.**
L **Load-line characteristic.**
p **can be 0—0.8 if the screen voltage is not greater than B.**

The quasi-linear distortion of the amplifier

As a pentode valve is used, no reduction of distortion due to the effect of the anode resistance on the grid volts/anode current characteristic will be obtained. The distortion will be due, therefore, solely to the well-known $\frac{3}{2}$ power law of the grid characteristic and the degree to which this power is reduced towards unity by feedback. If the cathode bias resistance comprises the feedback, and is of value producing a working bias such that overloading takes place on equal positive and negative inputs, then it follows that the intrinsic gain has been reduced by 6 db and the quasi-linearity will be the same whatever the type of valve used. If further reduction of distortion is required, then the cathode resistance must be increased and, to maintain equal overload input limits, a steady positive input must be applied. This in turn means that *e* will now be larger than the normal cutoff bias, and the circuit parameters must be calculated on this basis. This is perfectly feasible, in general terms, if the desired degree of non-linearity be stated in terms of a simple ratio between *e* and the cutoff bias.

However, in the present case, the simple cathode feedback proved to be adequate, since the maximum distortion was of the order of 3% second harmonic. This satisfactorily low value is due to two causes in addition to the feedback effect, (a) the voltage *e* is twice that required without the present type of shift control, and hence with normal displays only one-half the maximum input is necessary for full screen deflection, and (b) the quasi-linear distortion produced by the first stage is cancelled out in the second stage, so that the overall distortion is one-half that expected from one stage. Of course, with maximum shift, the deflection in the opposite direction will show greater distortion, but this means that a rectified waveform of amplitude filling the screen is being viewed, and this combination is sufficiently rare to permit of some additional distortion.

Thin Case Hardening with Radio-Frequency Energy

Notes from a paper presented to the Institute of Aeronautical Sciences, N.Y. by V. W. Sherman*

THE present paper is concerned with induction heat-treating in the 1-20 megacycle frequency range. It is further restricted by the proposition that an induction heating process should be able to establish a thin case of hardened metal on the surface of a hardenable steel without distortion of the part, scaling of the surface, or disturbance of any prior heat-treat already established in the core. By a thin case is meant one between 0.005 and 0.030 in. This case thickness should be controllable to within ± 0.001 in. and should be capable of reliable duplication in quantity production. The author shows that the time required for establishing the case should not exceed 1.0 sec. Examples are given wherein thin cases were produced in times ranging between 0.6 and 1.0 sec. For this class of heat-treatment a frequency above 1 megacycle and available power output of 25-75 kW. was commonly required.

The principal frequencies in use at the present time for commercial melting, preheating, and annealing are, in general below 12,000 cycles. For surface hardening of relatively large parts where considerable depth of case can be permitted, even frequencies near 12,000 are of value. For thin case hardening (0.005-0.030 in.) frequencies above 5 Mc/s are indicated.

The versatility of induction heating equipment increases cumulatively with the frequency used. For example, 5 Mc/s energy can, in addition to melting, annealing, etc., also produce thin surface hardening without disturbing a prior heat-treatment of the core. The same 5 Mc/s energy can also be used for drying paper, bonding plywood, softening thermoplastics, and many other operations in the dielectric heating field. It is important to note that the efficiency of frequency conversion with vacuum tubes can be as high or higher than that of lower frequency means. Depending upon the efficiency of the equipment, heating energy may cost from 3 to 6 cents per killowatt hour as compared to a 60 c/s base cost of 2 cents.

For most heating processes the 5-15 Mc/s range of frequency is recommended by the author. It is shown that in order to produce thin hardened cases two fundamental energy requirements exist; (1) the frequency should be in the Mc/s range so that the induced energy is confined to a thin surface layer; (2) power must be applied to the surface of the work at not less than double the rate of heat conduction loss from the surface to the core.

Macro- and micro-photographs show that the thin cases produced with Mc/s energy are homogeneous and uniform. The transition from case to core takes place smoothly and in a short distance compared to the case thickness. Because of the speed with which the surface layer is heat-treated, no measurable tempering action was found to have occurred in the adjacent core layer. The case was found to be under compression, but because of its relative thinness the total force was negligible. A mathematical expression is given which has been found to express the temperature after a time *t* of a point located a distance *x* beneath a heated surface. By use of the expression a set of curves is developed showing a temperature distribution that is in good agreement with experimental evidence.

The expression involves constants that may require reinterpretation if the geometry of the part is appreciably changed.

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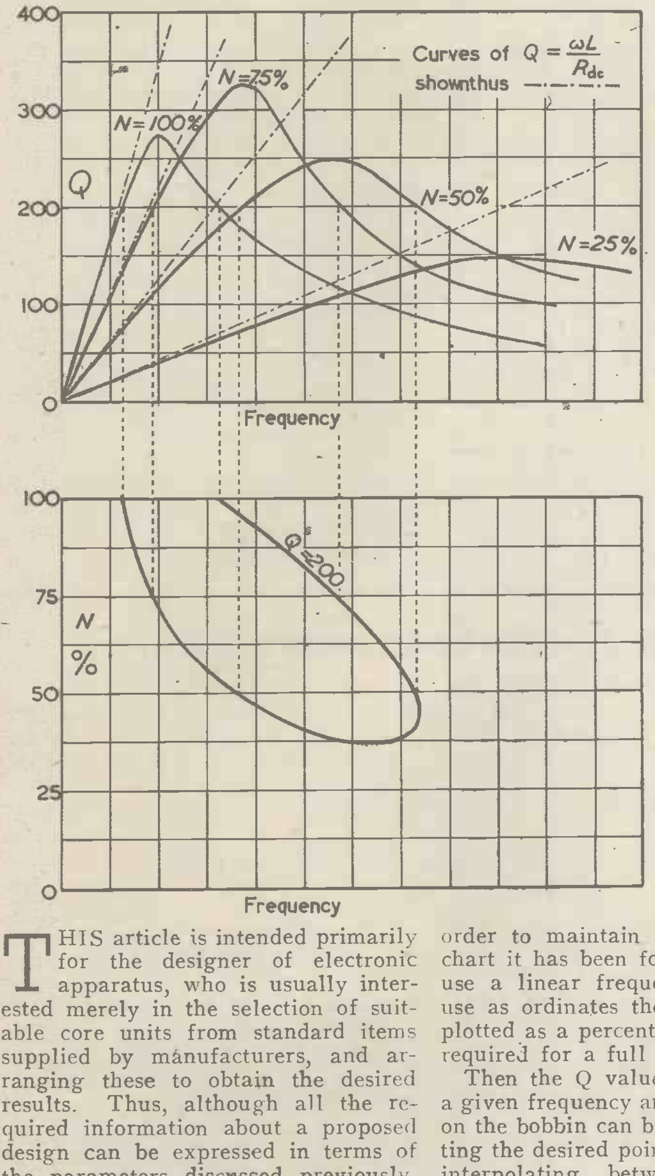
* Electrical Communication. 21, 2, p. 127, 1943

Dust Cored Coils

Part IV.—Equi-Q Charts

By V. G. WELSBY, B.Sc. (Eng.)*



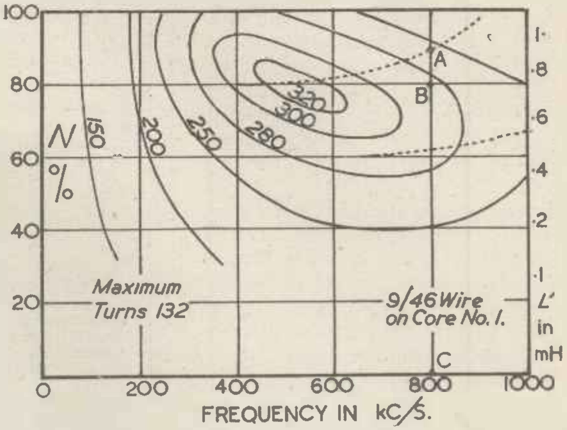


Fig. 4.1. (left) Showing the construction of an Equi-Q chart. (a) Curves of Q at various frequencies and (b) a typical Q contour line.

Fig. 4.2. (top) Typical Equi-Q Chart with inductance scale added.

THIS article is intended primarily for the designer of electronic apparatus, who is usually interested merely in the selection of suitable core units from standard items supplied by manufacturers, and arranging these to obtain the desired results. Thus, although all the required information about a proposed design can be expressed in terms of the parameters discussed previously, it is not in a form which would enable a rough idea of its performance to be obtained at a glance. For this reason, the author has developed a graphical method of presenting the required information in the form of charts of the type shown in Fig. 4.2. Essentially these consist of lines of constant Q plotted on a graph with inductance and frequency as ordinates and abscissae respectively, and the term "Equi-Q" charts has been applied to them. For ease of plotting, and in order to maintain a uniform size of chart it has been found convenient to use a linear frequency scale and to use as ordinates the number of turns plotted as a percentage of the number required for a full winding.†

Then the Q value corresponding to a given frequency and number of turns on the bobbin can be obtained by plotting the desired point on the chart and interpolating between adjacent Q curves in much the same way as that in which the height of a point on the earth's surface can be estimated from the contour lines on a map.

The first step in the construction of an equi-Q chart is to plot the values of Q against frequency for coils with 100%, 75%, 50%, and 25% respectively of the maximum turns for the wire under consideration. The data necessary to enable this to be done can be calculated from a knowledge of the loss factors, etc., but, if the actual core is available, a more convenient method, yielding results of sufficient accuracy for this purpose, is to wind the four test coils and to measure their Q at various frequencies on a direct-reading "Q-meter," merely checking the peak Q values by means of more accurate measuring apparatus if desired.‡ In this way a series of curves will be obtained, having the general form shown in Fig. 4.1a. A useful hint to remember in plotting these curves is that at low frequencies the Q curve must become asymptotic to the straight line representing $Q = \frac{\omega L'}{R_{dc}}$. This often reduces the number of measurements necessary. The next step is to construct the equi-Q "contour" lines. The method of doing this is illustrated in Fig. 4.1b, which shows the construction for the Q=200 line. As soon as a few lines have been drawn in this way, the general trend of the chart becomes apparent, and remembering that the lines must all consist of smooth curves without any sudden discontinuities, it is quite a simple matter to fill in as much of the chart as required. It will be noticed that the chart of Fig. 4.2. has an inductance scale added at the right hand side, and also a series of dotted lines. The latter are intended merely as a rough indication of the value of the self capacitance correction factor $(1 - x^2)$. For example, the point A on the dotted curve corresponding to 80% turns is plotted so that $\frac{BC}{AC} = (1 - x^2)$, where $x = f/f_r$ and f is the frequency denoted by the

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* P.O. Research Station.

† For a toroidal coil, a "full winding" is somewhat difficult to define, so an arbitrary standard winding is chosen in which the diameter of the central hole is half that of the inner diameter of the core.

‡ For description of one type of Q meter, see *Electronic Engineering*, April 1943, p. 452.

point C. These dotted curves are intended to show at a glance the effect of self capacitance, and to serve as a warning that the region where their curvature becomes noticeable is to be avoided if coils are required whose apparent inductance does not change appreciably with frequency.

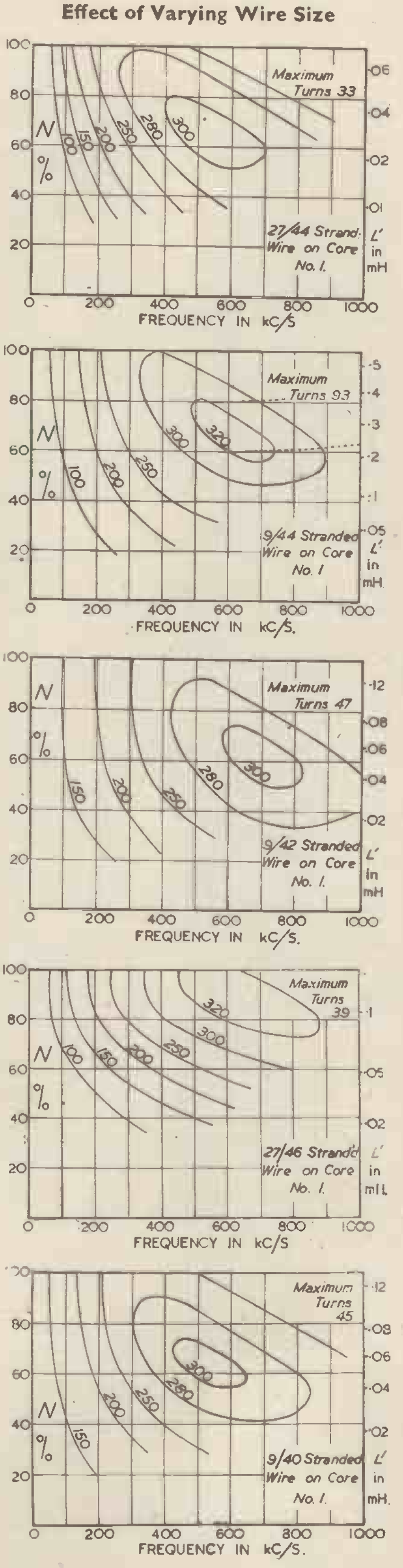
Table I.
Details of Cores Used

CORE	Overall Diam.(ins)	Height ins	μ_e	F_e	F_c	F_h
No. 1.	0·86	0·60	4·3	14×10^{-9}	5×10^{-3}	1·4
No. 2.	1·70	0·94	4·8	14×10^{-9}	3×10^{-3}	1·2
No. 3.	2·13	1·13	5·0	85×10^{-9}	4×10^{-3}	1·5
No. 4.	2·50	1·75	5·1	480×10^{-9}	3×10^{-3}	3·5

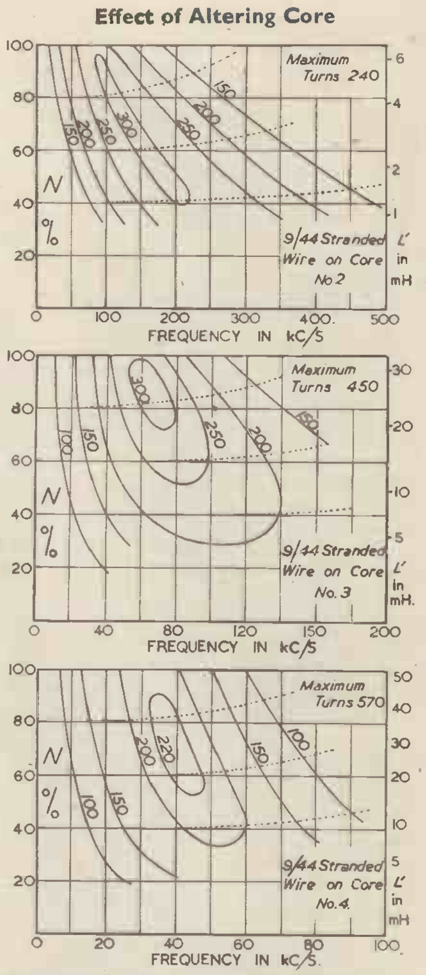
Use of Equi-Q Charts

In order to illustrate the use of these charts, four "pot" type cores have been selected, which although not exactly similar in shape, have roughly the same proportions and are made of materials having comparable properties. The dimensions and other details of these cores are set out in Table 1. Figs. 4.2 to 4.7, inclusive show the effect of using various types of stranded wire on the same core, whilst Figs. 4.4, 4.8, 4.9, 4.10 show the results for the same type of wire on each of the four cores. It will be seen that, as predicted by the above theory, the frequency of maximum Q on core No. 1 does not vary widely for a considerable range of wire sizes. Also, for the same wire, the frequency of maximum Q is progressively lower as the volume of the core is increased, whilst the actual value of the maximum Q does not change very much. Now suppose that a coil is required to have an inductance of about 2mH and to have the highest possible Q at frequencies near 150 Kc/s. First of all, a glance at the charts for core No. 1 shows that this inductance value is outside the range of the smallest stranded wire (assuming for the moment that no others are available) and, in any case, core No. 1 is obviously intended for use at much higher frequencies. A coil of this inductance could be wound on either core No. 3 or No. 4. Core No. 4 appears to be designed for lower frequencies, and must be ruled out, leaving core No 3 as a possible solution with a Q at 150 Kc/s of, perhaps, 150. It can now be seen, however, that the best results are likely to be obtained with core No. 2, which gives a Q of about 300 for the desired coil.

Having selected the correct core, the next step would be to examine the charts for various types of wire on the selected core to determine the best type of wire.



Figs. 4.3 to 4.7. Core No. 1 wound with varying sizes of stranded wire.



Figs. 4.8, 4.9, 4.10. Cores Nos. 2, 3 and 4 wound with 9/44 stranded wire. The corresponding curve for Core No. 1 is given in Fig. 4.4.
Fig. 4.10. This chart was prepared for a special bobbin which restricted the winding-space. With the full winding-space occupied it should be possible to increase the maximum Q to over 300, the optimum frequency then being about 20-30 kC/S.

Interpolation of Curves

This leads to another advantage of the Equi-Q chart method. It is possible in many cases to predict from the general trend of charts constructed for other types of wire the form of the chart for a wire type which is not available for test. For example, referring to Figs. 4.2 to 4.7, it will be appreciated that assuming the same make-up of the stranded wire and the same arrangement of the winding it would be fairly safe to predict that a coil wound with 9/45 wire would have the best Q when wound about 75% full, and that this result would be obtained with a coil of about 0.5 mH at 550 Kc/s. Unfortunately, these particular charts do not illustrate the point very well because they represent coils having a relatively small number of turns so that slight differences in the way in which the wire is laid on will influence the result.

Appendix

Self Capacitance of Coils

Although a rigorous treatment of the self capacitance of coils will not be attempted here, the following approximate analysis is helpful in showing the factors by which the self capacitance is controlled.

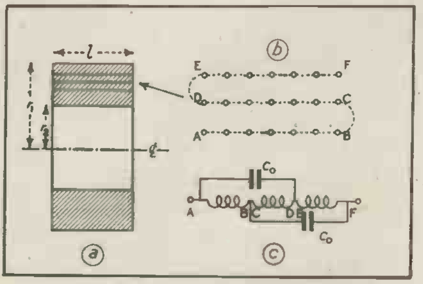


Fig. 4.11. Diagram to illustrate the self-capacitance effect of a solenoidal coil.

Consider first of all, a simple layer-wound air-cored solenoidal coil of which a section is shown in Fig. 4.11a. Now suppose that AB, CD and EF represent sections of three consecutive layers of wire. (*See* Fig. 4.11b.) There will be capacitances of approximately the same magnitude between adjacent turns, whether or not they form part of the same layer. This being so, it follows that the capacitances between turns near A in layer AB and turns near D in layer CD will have a greater effect than any others between the same layers, because the former are across a larger proportion of the total reactance of the coil. Thus, approximately, the distributed capacitances associated with the three layers can be replaced by two lumped capacitances C_0 as shown in Fig. 4.11c. Then, for the whole winding, consisting of N layers, there will be N_L such capacitances, each shunted across a fraction $\frac{4}{N_L^2}$ of the total reactance of the winding, so that regarding the winding as a series of auto transformers, each capacitance can be replaced by $\frac{4C_0}{N_L^2}$ shunted across the whole coil. To obtain some idea of the way in which the value of C_0 varies, two adjacent layers can be regarded as the cylindrical plates of a condenser with the wire insulation forming the dielectric. Thus, very roughly, it is possible to assume that C_0 will be proportional to the surface area of the layers and inversely proportional to the thickness of insulation t.*

Then, if C_r is the value of C_0 for two adjacent layers of mean radius r, we have

$$C_r \doteqdot S.\frac{rl}{t}\ \ldots\ldots\ldots\ldots\ldots\ (24)$$

Where S is a constant whose value depends on the dielectric constant of the insulation. The number of layers N_L will be given by

$$N_L = \frac{r_1-r_2}{D}\ \ldots\ldots\ldots\ldots\ldots\ (25)$$

So that the total shunt capacitance

$$C_1 = \frac{4}{N^2}\Sigma\, C_r = \frac{4\,D^2S}{(r_1-r_2)^2}\,.\,\Sigma\,\frac{rl}{t}\ \ldots\ (26)$$

In the limit, for a large number of layers, this tends to:

$$C_1 = \frac{4DSl}{t(r_1-r_2)^2}\int_{r^2}^{r^1} r\,dr = \frac{2DSl}{t}\,.\,\frac{(r_1^2-r_2^2)}{(r_1-r_2)^2}\ \ldots\ (27)$$

$$\text{or } C_1 = \frac{2DSl}{t}\,.\left(\frac{r_1+r_2}{r_1-r_2}\right)\ldots\ldots\ldots\ldots\ldots\ (28)$$

This means that, for a large number of layers, C_1 is independent of the number of layers, and dependent only on the following factors.

(1) Ratio of inner and outer radii of coil.
(2) Length of coil.
(3) Dielectric properties of insulation.
(4) Relative thickness of insulation.

Note that if the inner radius and length of bobbin are fixed, C_1 *decreases* as r_1 is increased; i.e., the self-capacitance reaches a *minimum* when the bobbin is fully wound.

Insertion of Dust Core

The insertion of a dust core into the centre of the coil will have very little effect on the value of the self-capacitance of a multilayer coil.

When the coil partly or completely encloses the coil, however (e.g., a "pot" core) there will be additional capacitances C_2 and C_3 between the core and the inner and outer layer of the winding respectively. Then assuming that the core is insulated from the winding, C_2 and C_3 in series will be shunted across the winding, so that the total capacitance C is given by

$$C = C_1 + \frac{C_2\ C_3}{C_2 + C_3}\ \ldots\ldots\ldots\ (29)$$

The second term will clearly reach *maximum* when the winding space is completed filled, so that C may have a minimum value when the bobbin is only partly filled. This point is illustrated by Fig. 4.12, which shows measured values of C for a typical "pot" type core. It should be noted here that the total self capacitance will be increased if the core is allowed to come into contact with either end of the winding. This is important because coils are often used with one end earthed, the whole coil being enclosed in an earthed screening can. Thus the above undesirable condition could arise if the outer surface of a "pot" core were allowed to touch the inside of the can.

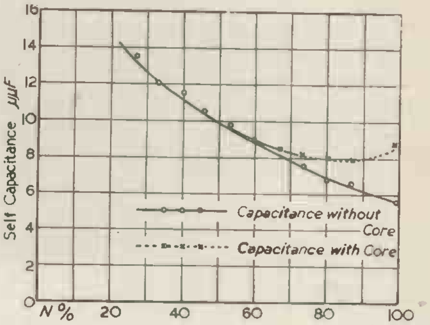


Fig. 4.12. Variation of self-capacitance of a typical pot-type coil.

Toroidal Coils

The self-capacitance of a toroidal coil is even more difficult to predict accurately owing partly to the fact at the outer circumference of the ring-shaped winding, the increased winding space tends to allow turns in outer layers to "bed down" until they lie in close proximity to turns in lower layers. Furthermore, the results are affected to a great extent by the way in which the winding is applied. Fig. 4.13 shows measured values of self-capacitance of a typical toroidal coil for various number of layers of a particular type of wire. The sudden jumps in capacitance as the first few layers are completed should be noted. For large numbers of layers, the capacitance starts to fall, following a curve somewhat similar to that defined by equation 28.

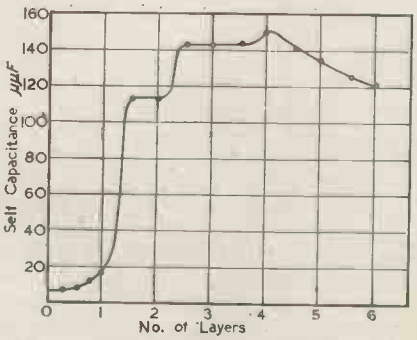


Fig. 4.13. Variation of self-capacitance of a typical toroidal coil.

(To be continued.)

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* For stranded wire, t can be taken as the difference between the outer radius of the wire and the radius of an imaginary concentric circle drawn so that it just encloses the conductors.

Defects in Direct Disk Recording

By DONALD W. ALDOUS, M.Inst.E.*

This table is reproduced from the author's new book, "Manual of Direct Disk Recording," which is published in the technical series of Messrs. Bernards (Publishers), Ltd.

This Table should prove of assistance to sound recordists, both amateur and professional, using the direct recording system, *i.e.*, instantaneous play-back disks, with little or no processing, which to-day is finding increasing applications, and when blanks (disks) are again available in quantity to non-priority consumers, the subject will undoubtedly become even more popular.

The following tabulated data are intended to be self-explanatory, and many of the faults and their remedies are immediately apparent, but the cause(s) of others, and the necessary correction(s) to apply, are often very difficult to determine precisely.

When investigating these more obscure troubles, e.g., flutter, chatter, types of "wow," a systematic approach is advisable. A recommended method, found to be most helpful, involves the use of a note-book to jot down all the symptoms as they occur, or are observed subsequently. It is then possible to study these notes at leisure and to sort out the problem, without having one's memory forget the insignificant but all important point. Another principle of treatment, basic, of course, to all scientific work, is to check and remove only one probable cause of the defect at a time, and then observe the result, if it is desired to isolate the trouble and its cure. The information thus obtained will enable the correct remedy to be employed, if the trouble should recur in the future.

The same careful procedure is useful when endeavouring to improve the overall mechanical and electro-acoustic quality of a direct recording/reproducing system that has deteriorated over a long period, or which has always been slightly below the possible optimum standard with the particular equipment used.

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* Tech. Secretary, British Sound Recording Association.

DESCRIPTIVE TERM	SYMPTOMS (Visible and/or Audible)	CAUSES AND CURES
Banding Defective Tracking	Uneven groove-spacing.	Faulty action of traversing mechanism, *e.g.*, binding. Also may be due to lack of precision in feed gear or lead screw in cheap equipment.
Chatter	An erratic "spotted" pattern in grooves, with short alternate light and dark strips.	Poor stylus or one set at a wrong angle; or by insufficient vertical damping. Too deep a cut in this disk coating may also produce a similar effect, which is most likely to occur close to centre of record.
Cut-over Over-cutting; Groove-wall breakdown; Cross-over.	One groove running into the next, causing "repeating."	Overmodulation, *i.e.*, too high recording level, for particular groove-pitch in use, or cutting too deep.
Cutting-through	Penetrating through coating of disk and into base material, usually thereby damaging stylus.	Cutting too deeply; extraneous vibration; damaged gear tooth in feed mechanism; dirt on lead screw; feed mechanism not fully engaged when cutting-head lowered on record surface, and later slipping into engagement with a jar; hard drop in setting down cutting-head; cutting-head bouncing after thread-tangle; failure to raise cutting-head as end of feed mechanism reached.
Dry-cut	A bad groove-cut, indicated by the thread appearing kinky, brittle and dry.	Incorrect cutting-angle; bad stylus; old or inferior quality blank.
Echo Pre-echo; "Ghost" effect; Double-talk	The modulation from one groove is impressed faintly on the adjacent groove.	Overmodulation; too deep cut; too light pick-up; use of blunt non-ferrous play-back needles; soft type of blank coating; and with solid-stock pressings, displacement of grooves during processing, or surface flow of matrices in pressing operation; or surface flow of original wax during cutting.

DESCRIPTIVE TERM	SYMPTOMS (Visible and/or Audible)	CAUSES AND CURES
Flutter	A type of " wow " having fluctuation changes between 6 to 30 per second. Produces harmonic distortion in lateral groove, and increases residual noise-level by modulating surface-hiss.	Undesired vertical oscillations of cutting-head caused by mechanical resonance, *e.g.*, the mass of the cutting-head in combination with blank coating material, or the compliance of the turntable. Remedy by adding vertical damping, say, oil-dashpot type. Also due to irregular blank surface, non-level or unbalanced turntable; or transmission of motor vibration through turntable drive or suspension; poor play-back equipment. Effect can also be caused by magnetic pull of cutting-head on steel turntable beneath; remedy is to place a ¼ in. thick circle of lino or beaver-board between the turntable and blank.
Grey Cut	Reflected light reveals that record grooves have dull greyish appearance. Results in increased surface-noise.	Imperfect or worn cutting-stylus; incorrect cutting-angle.
Groove-jumping	Pick-up needle will not remain in groove on play-back.	Too shallow cut; uneven play-back turntable; pick-up carrying arm stiff or out of alignment; unsuitable needles.
Groove-skating	Pick-up needle tends to climb or " skate " the groove walls, causing fluctuations in output, with accompanying several db. rise in surface-noise, in addition to increased harmonic distortion and record wear.	Usually pick-up with too low vertical pressure, particularly if combined with appreciable tracking error and horizontal inertia. Can also be caused by cutting with broken-tipped sapphire, resulting in flat bottom to groove. One remedy, other than the obvious replacement, is to use a non-ferrous needle for play-back. (A minimum force of 12 grams is required to prevent " skating " with the 0.002 in. maximum amplitude and 90 degree groove commonly employed.)
Hum	Small arrow-head (Vs) patterns, distributed over record surface.	May be due to excessive hum in recording amplifier. Often occurs with cheap recorder, where hum is masked in play-back by restricted low-frequency response.
Kinky Thread	Thread breaks off into short loops or tends to curl tightly, instead of lying straight like a flexible chain.	Either dull, worn stylus or over-dry or aged blank.
Orange-Peel Effect	Mottled appearance (similar to skin of orange) on blank surface that increases surface-noise.	This surface irregularity is usually attributable to manner of applying surface-coating, *e.g.*, dipping.
Patterns **Patterning ; Pattern-weaving**	Generic term applied to peculiar designs that are sometimes visible on blanks examined, at a certain angle, under direct light.	Usually turntable vibration-vertical or lateral, or a combination of both. Check adjustment of rim-drive tension, with this type of turntable; and, on rubber mountings, adjust tightness of mounting bolts.
——Moiré	A pattern (resembling the cloth of the same name) or " watered-silk " effect.	Usually indicates vibration in turntable mounting or transmitted to it by motor-drive coupling; or worn rubber-drive wheels; thread or dirt in feed mechanism; overloaded motor; amplifier hum.
——" Skip "	Cutting-head has " skipped " portion of blank surface (on one radius), due to " bouncing " during recording.	Produced by dented or bent base of blank, or swirled coating. Occasionally due to hard spot in coating. Keep weight of cutting-head arm and counterweight at minimum; use advance ball.
——Spoke	Recurrent design in the form of curving spokes; *i.e.*, alternate light and dark areas, or arrow heads (Vs)	Light and heavy cutting, due to motor-drive vibration, or worn pulley or bearings; or impulses from an overloaded motor.
Piano-Whine	Unpleasant whine when reproducing pianoforte recording.	Sudden variations in recording and/or reproducing turntable speed, due to large initial amplitudes occurring in piano music. One remedy is to use a heavier turntable.

DESCRIPTIVE TERM	SYMPTOMS (Visible and/or Audible)	CAUSES AND CURES
Rumble	Undesired low-frequency noise present in disk play-back.	Vibration ; sometimes due to external noises, *e.g.*, traffic or movement of people. Effect is particularly noticeable when too much bass boost in reproduction is being used, especially with circuits of condenser type, without inductance. Remedies : record more bass frequencies ; oil turntable shaft with thick motor oil.
Surface-Noise **Scratch ; Background Noise**	Hissing noise in disk reproduction.	Dust and foreign particles in grooves ; aged blank or type of blank used ; worn cutting-stylus ; wrong depth of cut, usually too deep ; incorrect stylus "rake" angle ; stylus not straight in cutting-head; cutting-head not tracking across a radius (approx.) of blank ; type of pick-up and needle used. In solid-stock pressings noise is due to their granular structure, steps in processing, and embraces all frequencies.
Swirl Lines	Curving areas of extra thick coating radiating from centre of certain blanks.	Often present in blanks coated by "dipping" ; sometimes causes "skip" patterns.
Thread Tangle	The coating thread during cutting becomes tangled at the stylus, and if pulled to release, or allowed to remain, may cause cutting-through or uneven groove-spacing ; also responsible for crackling noises in play-back.	Usually due to removed coating thread coming around stylus on outside, *i.e.*, side nearer to outer edge of blank, instead of around inside. Correct by slight biasing (not more than 5 degrees) of stylus cutting-face ; use of brush or other means of thread control ; or, an effective method, cut inside-out.
Twinning **Twin-grooving**	Irregular groove-spacing, making width of walls or "lands" uneven, (generally in pairs, *i.e.*, "land" is alternately wide and narrow).	Faulty action, *e.g.*, binding, of traversing (feed) mechanism, or of drive to this mechanism.
Whine	Fluctuation in apparent loudness and frequency of a reproduced sound. A type of "wow."	Speed of recording and/or reproducing turntable varying at a slow rate.
Whistling	Whistling noise of any kind heard during cutting ; usually occurs in conjunction with dull cut and dry, crumbly thread.	Denotes a bad stylus, the wrong cutting-angle, or both. Occasionally due to aged blank coating.
Wows **Wow-Wows**	Rhythmic or arrhythmic change in intensity (up to 6 per second) in reproduced sounds.	Fundamentally arises from speed fluctuation in either recording or reproducing equipment, or in both, but made more apparent by phenomena of stationary waves in an enclosure. If of regular periodicity identifiable with turntable rotation speed, it is probably connected with turntable drive system, *e.g.*, slippage due to flat pulley, or oil on pulley (in rim-pulley drives) ; incorrect motor thrust bearing adjustment ; loose set screw ; worn gear section or defective gear teeth ; governor trouble. Also produced by blank slippage where no centre clamp used ; oversize or eccentric centre-hole, *i.e.*, a "swinger" ; warped blank ; warped or out-of-round turntable. Occasionally, binding, or non-aligned bearings in feed mechanism.
——Gargle	Speed variation 30 to 200 c/s.	
——Whiskers	Speed variation over 200 c/s. (As a rule not visible in the form of patterns, unless associated with vertical vibration. Stroboscope may reveal certain types of "wow" by appearing to oscillate. Aurally disturbing).	
——Waver **Wobble**	Intermittent fluctuation.	Worn turntable bearing or insufficient tension on drive or idler pulleys.

An Improved Low Frequency Analyser

By W. GREY WALTER, M.A.[*]

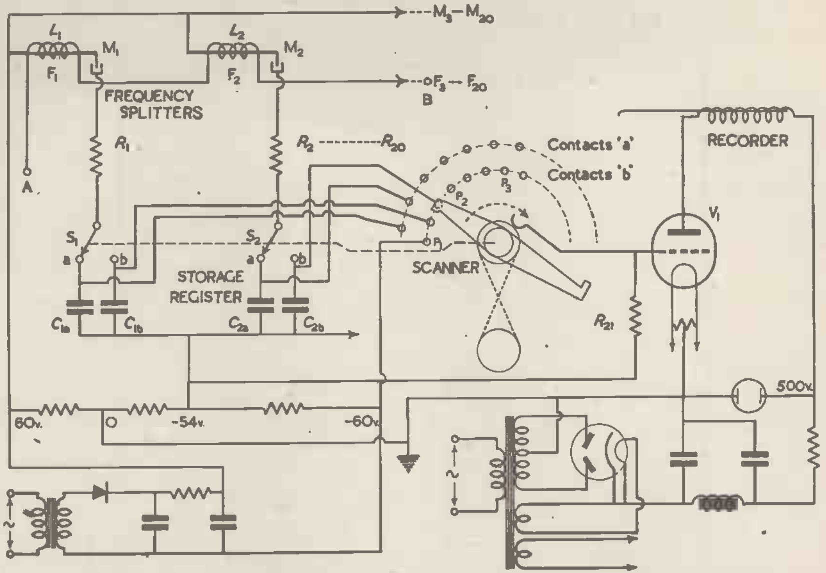

Fig. 1. Circuit of Frequency Analyser showing frequency splitting circuits, changeover switch, and scanning device (see p. 9, June, 1943 issue). A and B are the output terminals from the main amplifier. S_1 etc.: Changeover switch contacts $R_1 R_{20}$: 4 Meg. C_{1a}, C_{1b} etc.: 1.0 μF. L_1, L_2: driving coils for reeds, F_1, F_2: reeds; M_1, M_2 etc.: Mercury contacts. Contacts P_1, P_2 etc. provide negative pulses to mark start and finish of each epoch and divide the frequency bands.

IN a previous article[1] a method was described whereby a complex low-frequency wave-form could be analysed automatically, into its component frequencies. This apparatus, the circuit of which is shown in Fig. 1[†], consists essentially of a bank of tuned reeds, each responding to a particular frequency, an electrical integrating circuit and storage register for summation of the energy in each component frequency, and a scanning switch to deliver this energy to the recording system.

The method was developed primarily for electro-encephalographic (EEG) research, but has been applied successfully to other problems. Over 500 records have been analysed in this way, and since about 100 separate analyses are made automatically for each record, one may say that about 50,000 operations have been performed by the mechanism.

There has been comparatively little trouble with maintenance and adjustments, but, as was pointed out in the previous contribution, the weak point of the method is the use of a mercury-contact and high resistance as a charging circuit for the storage condenser. The advantage of this feature is its cheapness and for EEG purposes it is reasonably satisfactory, but it was realised that a more trustworthy and portable analyser could only be achieved by the use of photo cells as a medium for integrating the energy of the components.

Vacuum-type photo cells are prohibitively expensive when used as a direct replacement for mercury contacts in a 20- or 30-frequency analyser, but recently an arrangement has been developed to give results comparable with those of a vacuum cell at a very much lower cost.

The modern barrier-layer selenium cell described by Veszi[2] is convenient and economical, but its dark resistance is not, of course, infinite and it is difficult to use alone in an integrating circuit. In combination with a pentode, however, an arrangement can be found which has properties very similar to those of a vacuum photo-cell.

Circuit

The most satisfactory circuit appears to be that in Fig. 2. The problem is to bias the various electrodes so that the anode current is cut off sharply with the cell dark, but rises proportionally to the illumination over a wide range. It is essential that during the integration epoch of ten seconds little or no charge should accumulate in the condenser unless the cell is illuminated, while with maximal illumination (when the cell generates an e.m.f. of about 0.3 volt with a 200 watt bulb 6 inches away) the condenser should charge up to about 60 volts in 5 seconds. If the condenser has a capacitance of 1 μF and the charging voltage is 150 volts, these conditions are achieved with a type SP4B valve heated with a 2v. a.c. the screen grid being at about 0.5 v positive to the cathode, the suppressor grid earthed, and the positive pole of the cell connected directly to the control grid.

With this rather peculiar arrangement the valve is functioning very much as it would in a time-base charging circuit, and the linearity of the condenser charging curve is an added advantage over a simple resistance circuit. This constant current property means that no compensation for curvilinear charging characteristics is necessary later on.

On the mechanical side, each tuned reed is fitted with a small shutter which, in the position of rest just excludes all light from the surface of an 11 × 18 mm. "Eel" selenium photo-cell. When the reed oscillates light is admitted in proportion to the amplitude and duration of the oscillation. The relationship between the final condenser charge and varying intensities and durations is shown in Fig. 3, and is linear over the desired range.

All the reeds are grouped around a common light source and their associated valves are on the same chassis so that the frequency-splitting assembly forms a single transportable unit. The storage, scanning and writing mechanisms are the same as for the mercury contact model. By fitting masks of suitable shape, any desired sensitivity curve can be provided. For example, it is sometimes desirable in an analysis to neglect all components below a certain size or to reduce the response to very large components, and this can easily be arranged.

The performance of the frequency splitting unit can be checked by connecting all the photo-cells through high resistances to the input of an amplifier-recorder channel which will then trace out the combined e.m.f.s from all the cells as their respective reeds vibrate, thus reconstituting the original wave form with certain systematic distortions. Over or under-sensitivity of any element can be quickly detected and corrected.

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[*] The Burden Neurological Institute, Bristol.

[†] Reproduced from the article in the issue of June 1943.

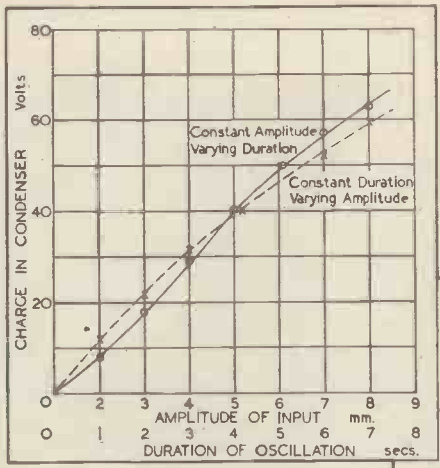


Fig. 3. Curve showing the integration accuracy of the circuit of Fig. 2.

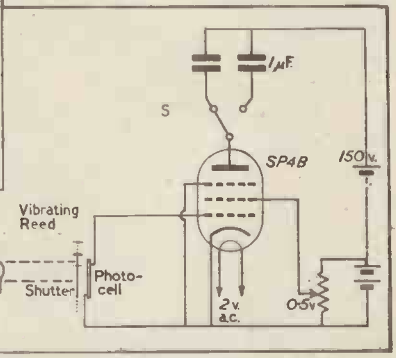


Fig. 2. Integrating Circuit using photo-cell and valve in place of the mercury cups of Fig. 1.

Considerable experiment was necessary to obtain the best operation and great variation was found between different types and makes of valve, the SP4B being quite the easiest to adjust to sharp cut-off. Underheating the cathode simplifies adjustment considerably. Since the photo-cell drives the grid positive, grid current flows and this exceeds the anode current by an amount depending upon the *durchgriff* of the valve.

Application to E.E.G. Records

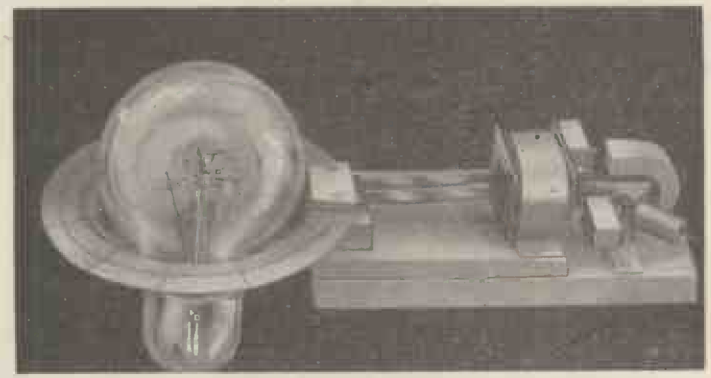
It is now possible to estimate how much advantage is likely to be gained by analysis in EEG work. The operation is performed on every record continuously as a routine, and since it is done while the record is being taken, spontaneous variations can be studied as easily as induced ones. The improvement is twofold. First, the analysis greatly eases the burden of routine work by eliminating the process of wave-counting with a cursor, so that a quantitative report can be made straight away in terms of energy, frequency, variability and location. Secondly, planned research into the origin and significance of the cerebral potential changes also becomes quantitative and intricate where before it tended to be qualitative and absurdly over-simplified. The human brain is the most complex organ or mechanism in existence and its electrical rhythms mirror most intimately its mysterious functions; we must not be dismayed when the methods by which we study this master problem become proportionately elaborate.

In the original records the analysis record is traced in red ink to distinguish it from the blue primary traces. In order to make this discrimination even more obvious, the records reproduced here have been coloured by hand, using the convention that the lowest frequencies are red and the highest violet, the intermediate being appropriately tinted in the spectral shades. This method of display seems to assist appreciation of the records by those unaccustomed to the reading of line spectra.

Fig. 4a was taken from a normal female subject. The primary records show a dominant rhythm at 10-11 c/s, augmented by closing the eyes and (Fig. 4b) blocked by mental activity. Analysis shows, in addition, the spread of frequencies associated with the modulation of the dominant rhythm by spontaneous variations in mental alertness. It shows also how the mid-frequency rises transiently when the eyes are shut and also during the mental arithmetic. The irregularity and asymmetry of waveform in the primary trace is shown to be due to the sidebands and a large amount of second harmonic at 20-22 c/s. This "rectified" appearance of some records has been noticed by most electro-encephalographers, but its significance has not been studied properly because its magnitude is so hard to assess directly. Now, faster rhythms, sometimes called "beta" rhythms, have been described in the EEG. They have a frequency of 20-25 c/s, and though their existence has been questioned they certainly occur sometimes. If a normal "alpha" rhythm shows signs of asymmetry and analysis shows a high second harmonic content, it is a reasonable working hypothesis that some cell units are oscillating in this harmonic mode, but with an amplitude so much smaller than that of the dominant that their activity is seen merely as an asymmetry of the waveform. It is conceivable that in other circumstances the harmonic amplitude may be increased and the record will show a 20 c/s ripple tending to mask the lower frequency altogether. A record of this type, taken from a neurotic subject was reproduced in the previous article. Study of such harmonic variations may have great value in fields beyond the reach of the simpler methods, notably the study of nervous and mental disorders.

Phase Relations in Records

The presence of both odd and even harmonics appears to be a character of many—but not all—EEGs. In the lower, abnormal, bands, waveforms of all types, from surprisingly pure sine-waves to triangular, trapezoidal, square, dimpled, cusped, rectified and so forth, are seen. Analysis of these reveals the harmonic content responsible for the wave-form and in many cases the components can be separated by recording from different areas, suggesting again that the brain rhythms are inter-related in a regular and intelligible way. In other cases, particularly brain tumours, less closely related frequencies are seen, causing the



View of lamp and one pair of reeds of the photo-electric analyser. On the other side of the exciting coil are the photo-cell boxes and permanent magnet. A tuning weight for one of the reeds is also shown. The remaining reeds are mounted in pairs radially round the ring.

irregular appearance commented on by many workers. This suggests the possibility that the spreading influence of a tumour evokes a more "forced" oscillation, poorly synchronised in the various cell units. It is too early to carry this speculation further, but work now in progress is directed toward testing such hypotheses. One line of possible advance is illustrated in Figs. 4c and d. The former is an example of the most dramatic type of abnormal EEG, the "Spike and Wave" rhythm of minor epilepsy. The analysis is characteristic of that particular patient, and a similar spectrum is found even when there is no obvious spike and wave rhythm, indicating that the phase relations of the many components may become too irregular to produce the recognisable wave-pattern. Like the cochlea of the ear the mechanical frequency analyser is insensitive to phase differences. Fig. 4d is an attempt to clarify the problem by *synthesising* this pattern with a photo-oscillator. The synthetic wave has the same analysis as the natural one, and the phase relations are adjusted to produce the same form. Such complementary syntheses are a great help and much has already been done to develop the method into a practical tool.

Fig. 5a shows how a slight EEG asymmetry is emphasised and quantified by analysis. The case was an air-raid casualty with a brain injury on the right side. The EEG, taken some weeks after the injury, shows that the wounded brain area is still producing an abnormal rhythm at 7 c/s. This combines with the normal rhythms to produce beats and is scarcely distinguishable as an entity in the primary record, but the analysis of the two sides is entirely different. The clinical and physiological interest of such a record are naturally greater when it can be quantitatively compared with others from the same patient, so that a precise correlation with recovery can be established.

Other Applications

Further applications of the method are indicated in Fig. 5b, which shows analysis of both the mechanical vibration and electrical action potential (ECG) of a normal heart. Only components up to 22 c/s are included, but first impressions suggest that even in this range interesting results are possible, and an upward extension of the range is little trouble.

Analysis of mechanical vibration is seen in Fig. 5c (direct) and d (with rubber mounting). The subject was an electric motor and gear assembly. It is seen that the rubber springing eliminates from the complex spectrum the components at 5, 10, 15, and 20 c/s and reduces 3, 6, 9 c/s, whereas 2, 4, 11-12 c/s are augmented. The natural period of the rubber mounting was about 2 c/s. The 3 and 5 c/s components and their harmonics were from the gearing while the 2 c/s was the whole assembly. The vibration pickup was an adapted crystal microphone. The presence of such very low frequency vibrations may escape notice since they are neither heard nor felt until their amplitude is very high. However, although their inherent energy is low they can be quite destructive. With the photo-cell integrating arrangement there is no difficulty in extending the frequency-splitting into the audible bands.

Phase Discrimination

It has been said that the analysis is phase-indifferent, and although this could be avoided by great complexity, the writing-out of an analysis-cum-vector diagram would seem to require three-dimensional paper. The apparatus can be made phase-sensitive in another sense, however. Reference to an earlier article (Parr and Walter[3]) will show how the source of a rhythm in the brain is located. Two or more channels are connected to electrode pairs in such a way that a change of potential of one electrode with respect to the others is seen as a deflection 180° out of phase in the two channels connected to that electrode. Thus when a rhythm is traced out by two channels and the waves are out of phase in the two traces it is known that the part of the brain generating the waves is under the electrode common to the two channels. Now, instead of being connected to the push-pull output of a single channel, the analyser can be connected across the anodes of corresponding valves in two channels. If this is done, the analyser will not be affected when both channels are carrying the same signal in phase and at the same amplitude, but will be fully driven when the signal is out of phase in the two channels. If the gains are adjusted so that the mean amplitude is the same in the two channels, the analysis will be of those components which are generated under the electrode common to the two channels. This phase discriminating arrangement has already been found useful, particularly when a very complex record is being analysed.

It is far too early to foresee the depth and scope of future development, but certainly as quantitative methods become more common the main problems of brain function will at least be more clearly defined.

In concluding, the writer would like to record his gratitude to Dr. G. Dawson for advice and encouragement, to Mr. G. R. Baldock, B.Sc., for his patient handwork, and to Miss V. J. Dovey, M.S.R., for her preparation of the records.

REFERENCES.

1 Walter, *Electronic Engineering*, June, 1943.

2 Veszi, *Electronic Engineering*, May, 1943.

3 Parr and Walter, *Electronic Engineering*, April and May 1943.

November Meetings

Institution of Electrical Engineers

Ordinary Meetings

At 3 p.m. on Thursday, November 25, the Nikola Tesla special commemorative meeting will be held. The lecture, illustrated by examples of his experimental work, will be given by Dr. A. P. M. Fleming, C.B.E., M.Sc.

Wireless Section

On Wednesday, November 3, at 5.30 p.m., the address will be given by J. Kemp on "Wave Guides in Electrical Communication."

On Tuesday, November 16, at 5.30 p.m., the meeting will take the form of a discussion on "The Rôle of Ultra-high Frequencies in Post-War Broadcasting." The discussion will be opened by K. I. Jones and D. A. Bell, M.A., B.Sc.

On Wednesday, November 24, at 5.30 p.m., an address will be given by C. P. Edwards, M.Sc., Tech., on "Enemy Airborne Radio Equipment."

Measurements Section

The next meeting will be held on Friday, November 19, at 5.30 p.m., and the address will be given by A. Hobson, B.Sc., Tech., on "Instrument Transformers."

Students Section

The Chairman's address, by Mr. J. D. McNeil, B.Sc. (Eng.), will be given on Tuesday, November 9, and the subject will be "Remote Control of Traction Supplies."

At the meeting to be held on Monday, November 29, Mr. P. J. McMahon will give the address on "Multi-Channel Voice-Frequency Telegraphs."

Brit. I.R.E.

The next meeting of the above will be held on November 25, at 6.30 p.m., at the Institution of Structural Engineers, 11 Upper Belgrave Street, London, S.W.1. A paper on "Stabilising Electronic Circuits" will be read by M. M. Levy.

The British Kinematograph Society

The next meeting of the above will be held on November 10, and will take the form of "The B.K.S. Brains Trust." The Question Master will be Leslie Mitchell.

Association for Scientific Photography

On November 13, at 2.30 p.m., a meeting will be held at the Institution of Electrical Engineers. The subject will be "The Photography of Cathode-Ray Oscillograph Traces." Papers will be given by N. Hendry, A.M.I.E.E., and W. Netherest, M.A., B.Sc.

Institute of Physics

Electronics Group

A meeting will be held on Thursday, November 18, at 5.30 p.m., in the theatre of the Institution of Electrical Engineers, Savoy Place, Victoria Embankment, W.C.2, the subject being "High Vacuum Technique" by G. W. Warren, of the G.E.C. Research Laboratories.

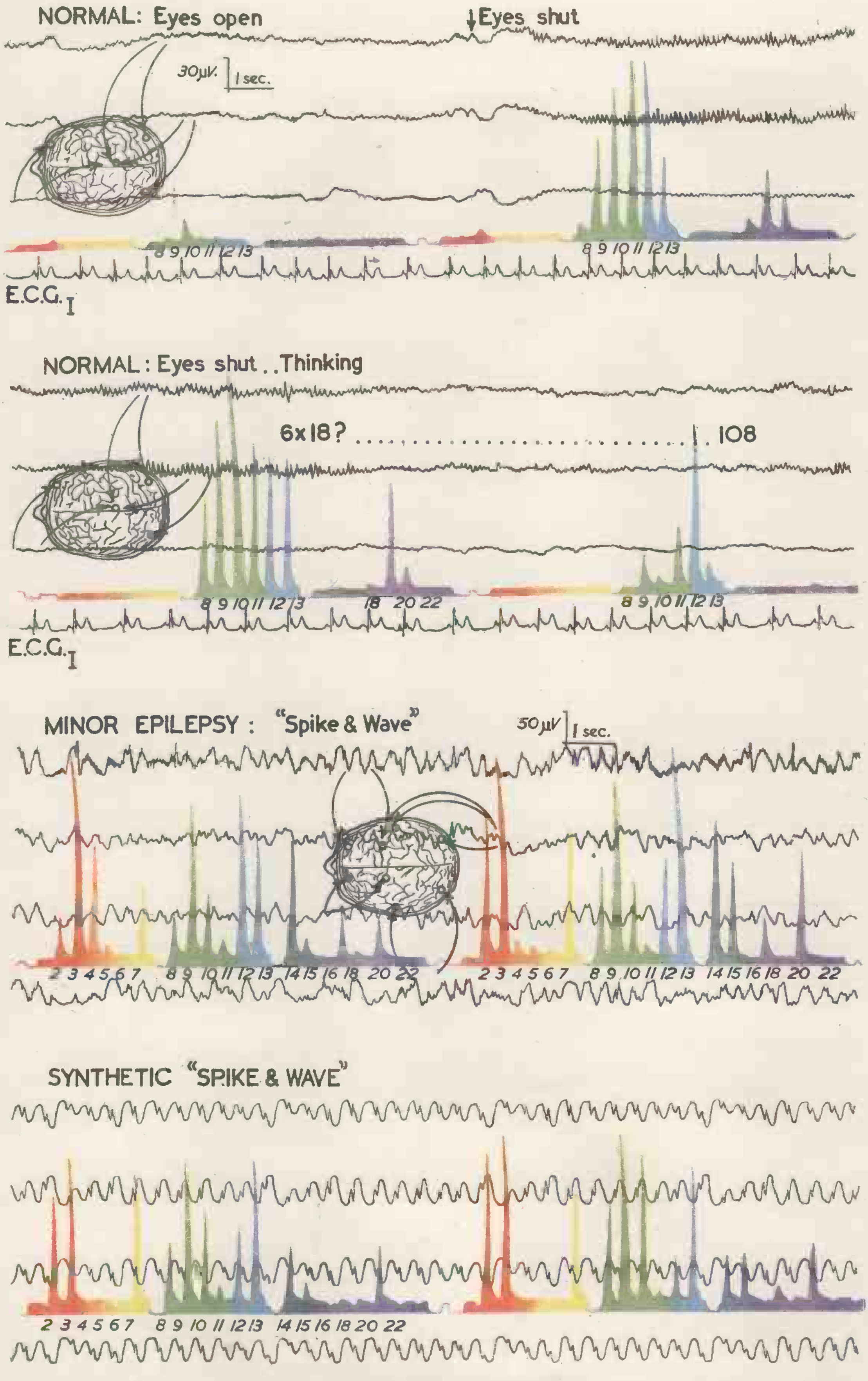
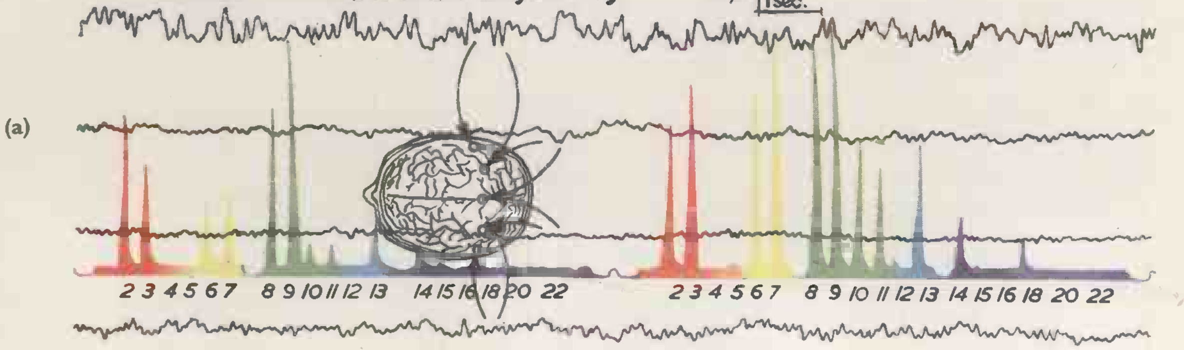
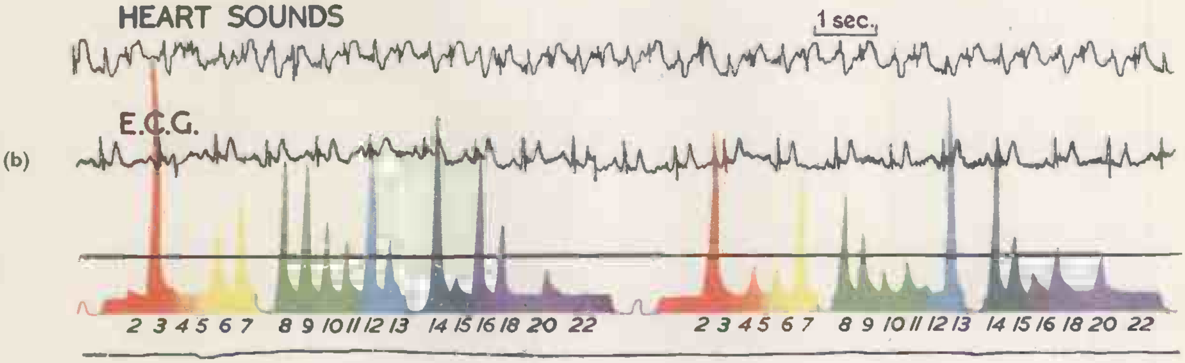


Fig. 4. Analysis of typical Electroencephalograms. The brain diagrams show the points from which the records are taken. The analysis is of the upper record in each case.

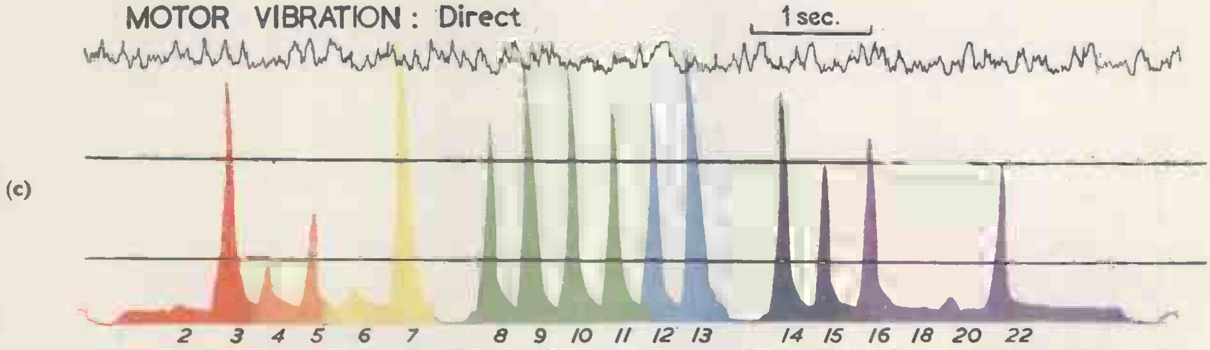
CHRONIC HEAD INJURY : Asymmetry



HEART SOUNDS



MOTOR VIBRATION : Direct



MOTOR VIBRATION : Rubber Mounting

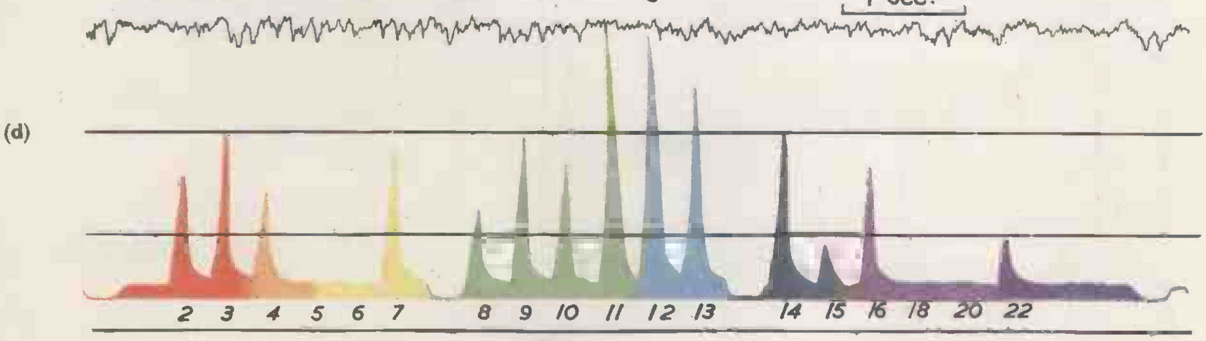


Fig. 5. Further analyses. (a) analysis of EEG—left, lower record, and right—upper record. (b) Heart sounds—left, upper record—right, lower record. (c) and (d) Motor Vibration. Note introduction of low frequency component with rubber mounting.

DATA SHEETS 54 & 55

Aerial Characteristics—III

Effect of Ground Losses on Polar Characteristics

IN last month's Data Sheet No. 53 the field strength relations and polar diagrams of several aerials located over a perfectly conducting ground were discussed.

The results given were derived from simple "optical plane-ray theory" by which the resultant field strength at a distant point can be considered as due to the addition of a direct ray from the aerial in free space plus a ray reflected from the ground. The latter may be considered as coming from the image of the aerial in the ground, just as in the case of a mirror in normal optical theory (*see* Fig. 1).

The resultant field at a long distance is obtained by the addition of the vector components of the two rays which have a time difference of

$$t_1 = (2h \cos \Theta)/c$$

or a difference in phase angle of

$$\omega t_1 = (4\pi h \cos \Theta)/\lambda$$

radians.

The image in the ground may be represented by the mirror image of the actual aerial. The currents in the corresponding parts of the actual and image aerials flow in the same directions for vertical portions of the aerial and in opposite directions in the case of the horizontal portions. This is illustrated for a few configurations in Fig. 2.

The effect of a perfect ground can therefore be obtained by multiplying the free-space vertical radiation characteristic of a given aerial (with plane polarisation assumed) by the Ground Reflection Factor *M*, where

$$M = \sqrt{2 \pm 2 \cos (2H \cos \Theta)} \quad \ldots \quad (27)$$

where $H = 2\pi h/\lambda$

The positive sign is taken for vertical polarisation (||) and the negative sign for the case of horizontal polarisation (⊤) to allow for the 180° phase difference in the currents of the aerial and the image in the latter case.

Simplifying, we have:

$$M_v = 2 \cos (H \cos \Theta) \quad \ldots\ldots\ldots \quad (28a)$$

$$M_h = 2 \sin (H \cos \Theta) \quad \ldots\ldots\ldots \quad (28b)$$

For the case of propagation along the ground ($\Theta = 90°$), $M_v = 2$ and $M_h = 0$. The field strength in the horizontal direction is therefore doubled for a vertical aerial and reduced to zero for the case of a horizontal aerial in the median plane by the presence of a perfect ground (*see* equations (13) and (14) Data Sheet 53, October issue.

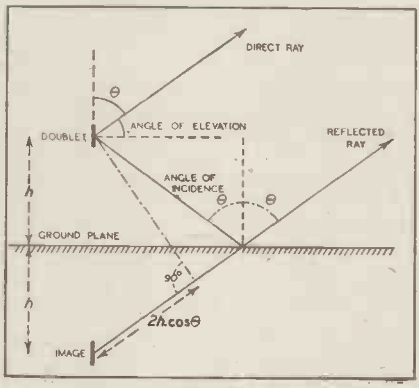


Fig. 1. Diagram to illustrate the optical plane-ray theory of radiation.

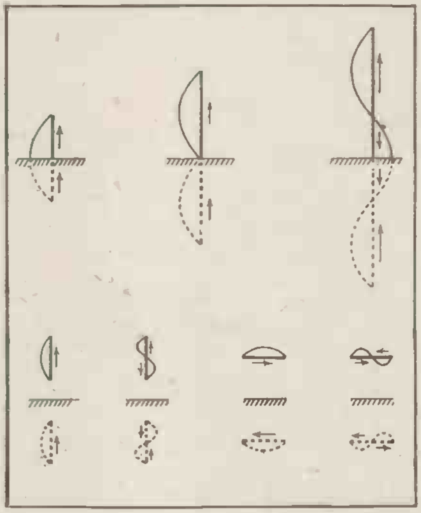


Fig. 2. Showing directions of current flow in aerials and images.

In the case of actual soil the ground acts as a dielectric of finite conductivity. For plane-polarised waves reflexion from the ground may be obtained from Fresnel equations provided we replace the usual index of refraction by a complex index of refraction $\sqrt{K'}$ where K' is the Complex Dielectric Constant, given by:

$$K' = K + j\,6 \times 10^{10}\sigma\lambda \quad \ldots\ldots\ldots \quad (29a)$$

$$= K + j\,2\sigma/f \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (29b)$$

where *K* is the dielectric constant in E.S.U. and σ the conductivity of the ground at the frequency of measurement, $j = \sqrt{-1}$. The conductivity σ is in E.M.U. units in equation (29a) and in E.S.U. units in equation (29b). The wavelength λ is in cms. and the frequency *f* is in c/s. If we designate the amplitude of the incident wave and reflected waves by E_1 and E_r respectively then

$$E_r = E_1 . A . \exp j(\omega t - \Psi) \quad \ldots\ldots \quad (30)$$

where ***A*** is the absolute amplitude of the reflexion coefficient and Ψ the phase shift accompanying reflexion. Curves of A and Ψ for both vertical and horizontal polarisation are given on Data Sheets No. 54 and No. 55 which are representative of bad, medium, and good ground ($K = 4$, 10 and 30 respectively) as well as sea water ($K = 80$). Such curves have been given by the Bell System Engineers, the three chain curves are from Feldman, *Proc. I.R.E.*, June, 1933, and are representative in the case of $K' = 7 + j3$ of rocky ground at Netgong N.J. with a conductivity of 3.3×10^{-14} while the curve of $K' = 25 + j\,19.2$ corresponds to a conductivity of 2×10^{-13} e.m.u.

Further curves will be found in the *Proc. I.R.E.*, Dec., 1936, by Hansen and Beckerley, and also McPetrie, *J.I.E.E.*, p. 214, 1938, and p. 135, 1940.

The characteristics of soils with intermediate dielectric constants can be obtained by interpolation.

The sense of the phase angle Ψ is that of a lag such as would occur if reflexion occurred without phase change Ψ, at some depth below the surface of the soil.

In Table I are given typical dielectric constants and conductivities of different types of soils. As the ground constants depend not only on the type of soil, but on its stratification, depth below the surface, moisture content, temperature and frequency of measurement only typical values of the order of magnitude can be quoted. In general the dielectric constant falls and the conductivity rises slightly with increase in frequency. The moisture content of the soil has, however, a much greater effect on the soil constants, both the dielectric constant and soil conductivity increasing with moisture content. The conductivity can increase a thousandfold by increasing the moisture content from 1% to, say, 20%. For further information on English soil constants the reader is referred to an article by Smith-Rose, *Jour., I.E.E.*, August, 1934.

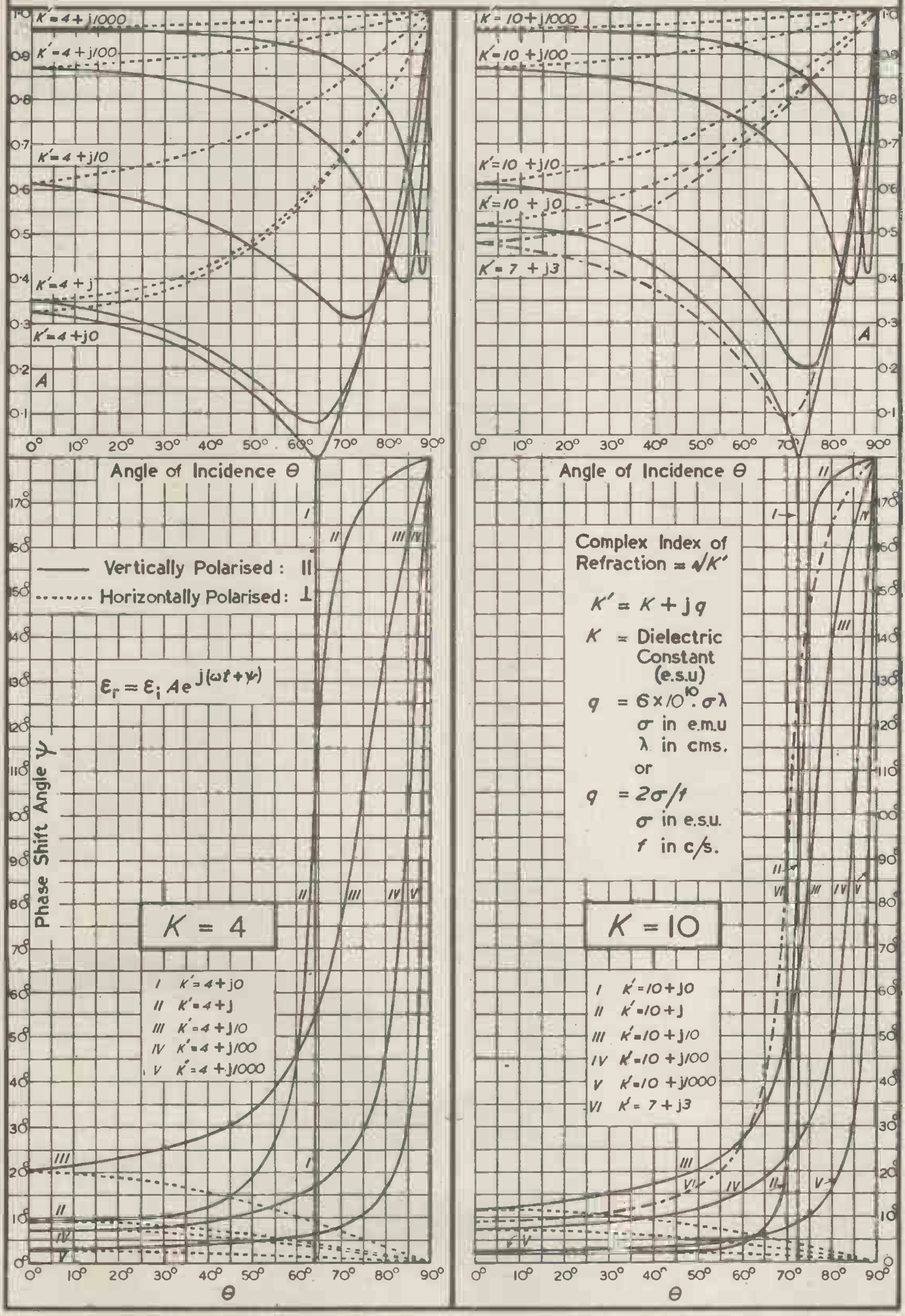
With the reflexion coefficient *A* less than unity and with the phase angle Ψ other than zero, equation (27) is modified to

$$M = \sqrt{1 + A^2 \pm 2A \cos (2H \cos \Theta + \Psi)} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (31)$$

where, as before, the positive and negative signs are taken for vertical and horizontal polarisation respec-

(*Continued on back page of Data Sheet.*)

DATA SHEET No. 54 GROUND REFLEXION COEFFICIENTS



$$\varepsilon_r = \varepsilon_i A e^{j(\omega t + \psi)}$$

Complex Index of Refraction $= \sqrt{K'}$

$K' = K + jq$

K = Dielectric Constant (e.s.u)

$q = 6 \times 10^{10} \cdot \sigma\lambda$

σ in e.m.u

λ in cms.

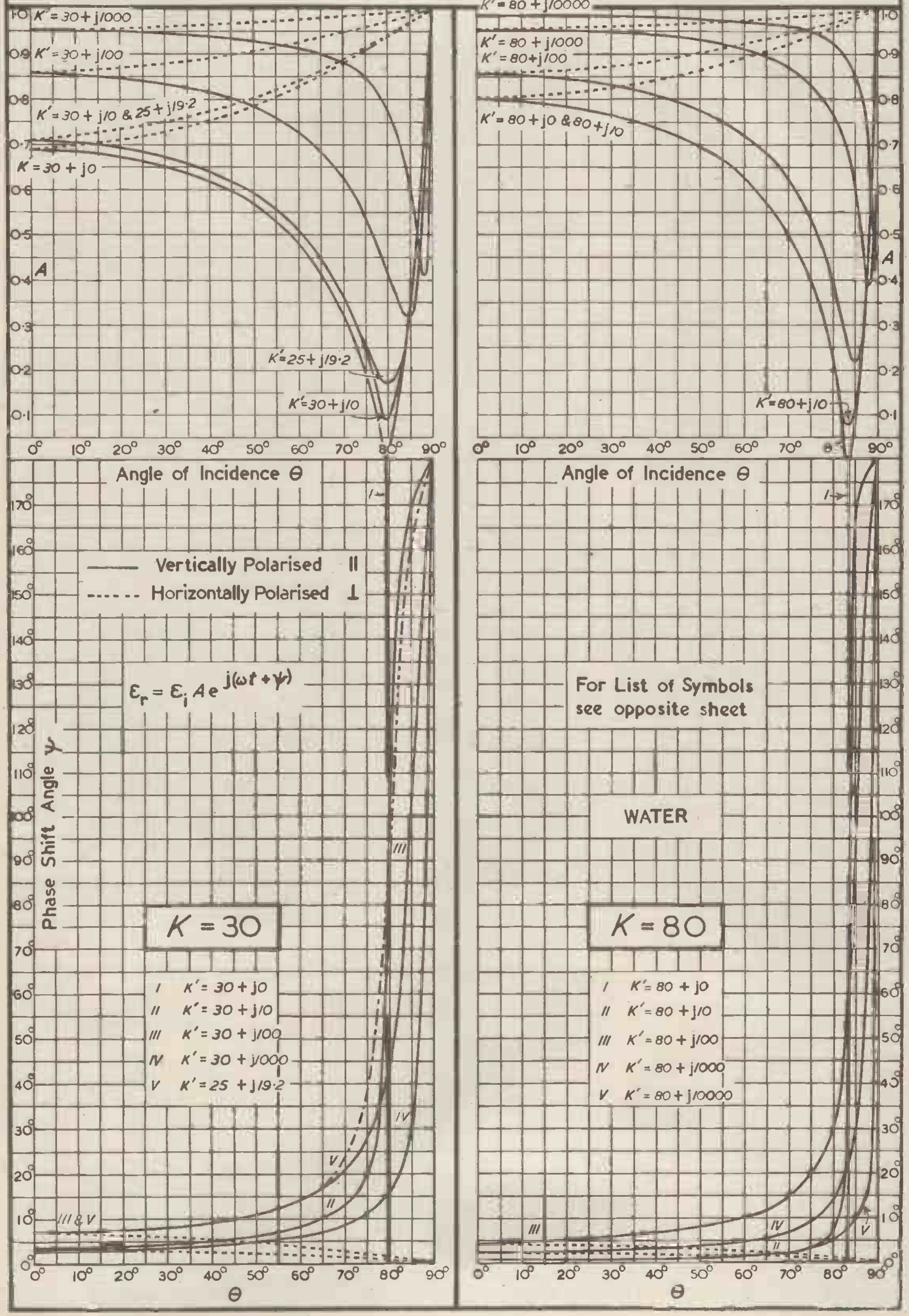
or

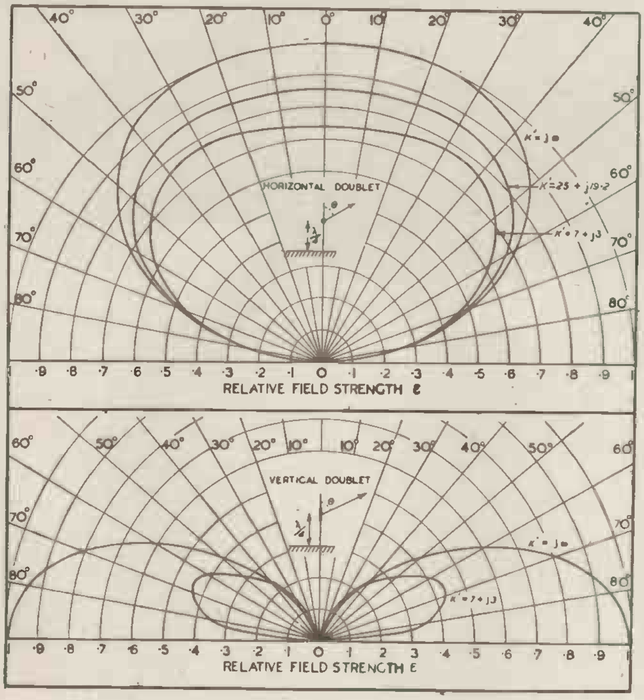
$q = 2\sigma/f$

σ in e.s.u.

f in c/s.

DATA SHEET No. 55 GROUND REFLEXION COEFFICIENTS





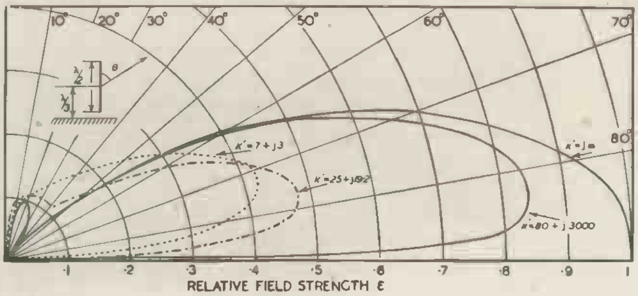


Fig. 3 and 4. Calculated effect of different ground constants on the relative field intensity and at different angles of incidence. At a wavelength of the order of 16 metres the curves are representative of ground conductivities of $\sigma = \infty$, $\sigma = 2 \times 10^{-13}$ e.m.u. and $\sigma \approx 3 \times 10^{-14}$ e.m.u. *(After Feldman, Proc. I.R.E., June.* 1933).

Fig. 5. Calculated effect of ground constants on the relative field strength ε (for different angles of incidence) from a vertical half wave dipole elevated a third of a wavelength above ground. At a wavelength of the order of 16 metres the curves are representative of (a) perfect ground, (b) salt marsh ($\sigma \approx 3 \times 10^{-11}$ e.m.u.), (c) fertile farm land ($\sigma \approx 2 \times 10^{-13}$ e.m.u.), and (d) rocky ground ($\sigma \approx 3 \times 10^{-4}$).

tively. (Cases of elliptical polarisation can be treated by resolving the incident wave into vertically (||) and horizontally (⊥) polarised components, treating the two separately by equation 31) and then recombining.)

Fig. 3 illustrates the application of the above methods to the calculation of the vertical polar diagram in the median plane of a horizontal doublet elevated a quarter of a wavelength above three types of ground, while Fig. 4 shows a similar set of curves for a vertical doublet with its centre elevated a quarter wavelength above ground. Ground conductivity values of infinity, $\sigma = 2 \times 10^{-13}$ E.M.U. and $\sigma = 3.3 \times 10^{-14}$ E.M.U. are assumed with a wavelength of the order of 15 metres.

Similar curves for a vertical half-wave aerial with its centre at a height 0.33 λ above ground level is shown in Fig. 5. Here in addition to the previous ground constants the case of a salt marsh near the ocean with $\sigma = 3.3 \times 10^{-11}$ E.M.U. is included.

From the above results it will be seen that with horizontal aerials the field strength ε is not appreciably affected by the ground constants at large angles Θ of incidence (*i.e.*, low angles of elevation), on the other hand, the conductivity of the ground has a very pronounced effect on the field strength at large angles Θ of incidence with vertical aerials and in the case of the half wave aerial only with infinite conductivity is the maximum signal strength in the horizontal direction Θ = 90°.

In this connexion it is important to remember that the above theory has been developed on the assumption that the transmitted wave could be represented by a plane-wave. While this is sensibly true for the direct ray at a sufficiently great distance, it can only be true for the ray reflected from the ground if the aerial is at a sufficient height above the ground. The theory is reasonably accurate for short aerials provided the doublet is at a sufficient height for the radiation field at the ground to be large compared to the induction and static fields, that is, a distance of at least a wavelength. With longer aerials the applicability of Fresnel's equations, necessitates that the rate of change of the reflexion coefficient with angle of incidence be reasonably small.

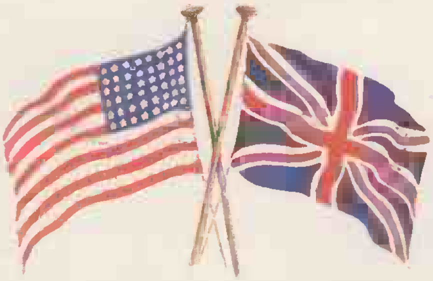
With finite ground conductivity the discrepancy between the simple plane-ray theory and practice occurs mainly at large angles of incidence. McPetrie and Stickland (*Jour., I.E.E.*, p. 135, 1940) have shown that the simple plane-ray theory is approximately applicable at short waves provided the field due to the Sommerfeld "surface wave" is added to the result.

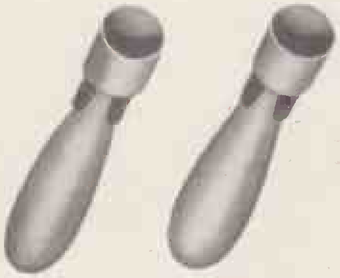
The "surface wave" will have a negligible effect with horizontal polarisation, it will, however, increase the field at large angles of incidence with vertical polarisation. The next Data Sheet will deal with the effect of ground conductivity on the radiation resistance and dissipation losses of an aerial.

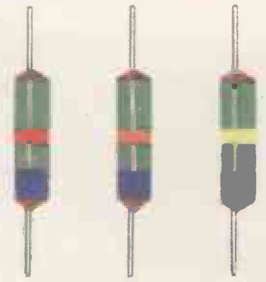
CHARACTERISTICS OF DIFFERENT SOILS. TABLE I.

Type of Soil	Dielectric Constant K in E.S.U.	Conductivity		
		E.M.U.	E.S.U.	mho/cm³
Salt Marsh (near ocean)...	80	3×10^{-11}	3×10^{10}	3×10^{-2}
Wet Soil	30—40	$2—3 \times 10^{-13}$	$2—3 \times 10^{8}$	$2—3 \times 10^{-4}$
Fertile Farm Soil ...	10—30	$1—3 \times 10^{-13}$	$1—3 \times 10^{8}$	$1—3 \times 10^{-4}$
Average European Inland Soil	15	1×10^{-13}	1×10^{8}	1×10^{-4}
Dry Clay with rocks ...	5—10	$1—3 \times 10^{-14}$	$1—3 \times 10^{7}$	$1—3 \times 10^{-5}$
Dry Sandy Rocky Soil ...	5	1×10^{-14}	1×10^{7}	1×10^{-5}
Granite	6—9	$1—10 \times 10^{-15}$	$1—10 \times 10^{6}$	$1—10 \times 10^{-6}$
Ocean Water	80	$4—5 \times 10^{-11}$	$4—5 \times 10^{10}$	$4—5 \times 10^{-2}$
River Water (fresh) ...	80	$1—10 \times 10^{-14}$	$1—10 \times 10^{7}$	$1—10 \times 10^{-5}$
Distilled Water	80	2×10^{-15}	2×10^{6}	2×10^{-6}

As the conductivity and dielectric constant of soil depends on a large number of factors such as composition, depth, moisture content and temperature as well as frequency of measurement, the above figures can only be taken as a rough guide. In converting to different units, figures have been given to the nearest whole number.








NOTICE.

Fluorescent Lamps

A Survey of Old and Recent Developments—Part III

By R. NEUMANN, Dipl. Ing.

A TYPICAL modern fluorescent lamp is in tubular form, with a length of 60" and a diameter of 1½". It is rated at 80 watts to operate on a supply voltage of 200-250 A.C.

Lamps of this type are manufactured by the G.E.C. (Osram), B.T.-H. (Mazda), Edison Swan, Philips, and others.[6]*

The length of the fluorescent coating is about the same as the total arc length, and the activated electrodes at either end are connected to two-pin bayonet caps. The operating voltage of the tube is 115 v., the remainder of the voltage being dropped by means of a choke connected in series with the tube. The initial luminous efficiency is 35 lumens per watt, and the brightness about 0.5 candles per sq. cm.

Fig. 3 shows the connexions to such a tube. T is the tube itself with the electrodes E_1 and E_2, L is the choke, S_1 the main switch, S_2 the starting switch, C_1 is a condenser of 7.5 μF. for raising the power factor from 0.5 to 0.9, and C_2 a 0.05 condenser in series with a resistance of 100 ohms serves to suppress radio interference. The series resistance is necessary to prevent welding of the starter contacts.

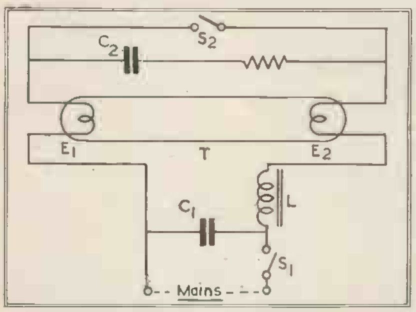
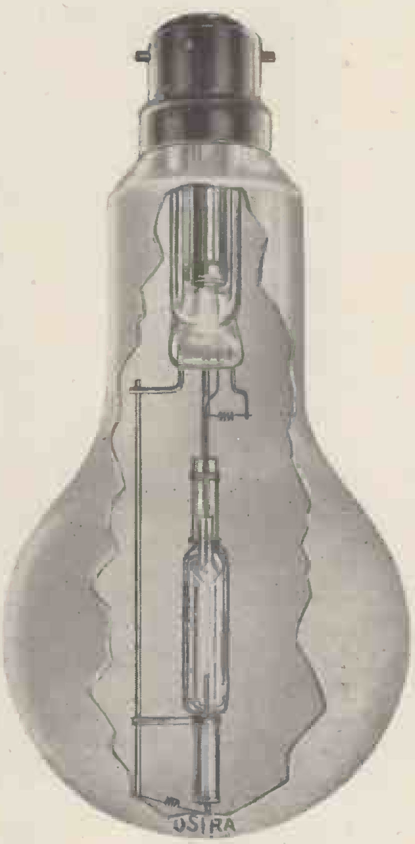


Fig. 3. Diagram of connexions of fluorescent lamp using two switches for starting.



'Osira' High Pressure Mercury Vapour Lamp. of 80 or 125 watt rating. The efficiency is 38 and 40 lumens per watt for the respective wattage ratings, and the bulb brightness 60 candles/sq. cm.

(By courtesy of the G.E.C.)

In the manufacture of these lamps special precautions are taken to ensure an appropriate and uniform distribution of the various luminescent powders used for obtaining the colour quality required. The procedure, as described by A. Claude[12], is as follows: "The purity of the chemicals is constantly tested under the arc spectrum. After a suitable treatment in an electric furnace the powder is inspected with regard to size of grain and outside appearance by microphotographic methods. Its interior structure is determined by X-rays in a Debye-Scherrer apparatus. Test tubes are then coated on their inside with a very thin film of the luminescent material and, as the conditions of distribution play an important part for obtaining the maximum emission of luminescence, the best distribution is controlled by microphotography after having been established by experiment. Then the electrodes are inserted and the tubes are given their final shape. For testing the spectral energy distribution a Beaudoin spectrograph with Ilford's Astra III plates is used the latter having a very constant sensibility over the whole range of visibility. The spectra thus obtained are registered with a microphotometer. Then the test tubes are submitted to an endurance test in which the value of the luminescent efficiency in the course of time has the last word to say."

Performance of Lamps.—Regarding the luminous efficiency and brightness of the various lamps described the following comparative figures indicate the progress made:

	Lumen/Watt	Candles/cm²
Carbon filament lamp	3.3	71
Tungsten filament lamp	10—15	600—900
Sodium vapour lamp	50—70	14
High pressure mercury vapour lamp	50—70	180
Low pressure fluorescent lamp	35	0.5—2

Development in U.S.A. and Great Britain.—While in this country the first 80 w fluorescent lamps were available to the general public since early in 1940, in U.S.A. the modern lamp was introduced in April, 1938. The rapid development of this source of light in U.S.A. may be judged from the following quotation[22]: †

> "From a lamp and fixture market that did not exist four years ago, fluorescent lighting has grown to an estimated $250,000,000 business for 1941. Few, if any, industries have grown at a comparable rate."

Of course, it must be considered that the development in U.S.A. was then not hampered by the war. A large impetus was given to the development there by the New York World's Fair of 1938, while in this country the settlement of standardisation questions between the manufacturers concerned required some considerable time. But it should be mentioned that by the close collaboration of the Research Laboratories of the different British lamp makers com-

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* *See* Bibliography to Part I, p. 205.

† *See* Bibliography, Part II, p. 205.

paratively soon the initial advantage gained by American enterprise could be made up for.

A further difference between the development in U.S.A. and this country is caused by the difference in the supply voltages. Thus with 110-120 v as usual in U.S.A. the tubes are shorter and are also built for smaller wattages while in this country so far mainly the 220-240 v 80 w type is being manufactured to a large extent.

Although the light installations in new built factories in this country have contributed considerably to increasing the demand for fluorescent lamps, the development in other respects is unfavourably influenced by the present situation. For instance, the choice of wattage and of dimensions was largely decided by the desirability of using chokes already in production for high pressure mercury vapour lamps in order to avoid the development of new designs during the war. The introduction of the lamp for domestic lighting is, of course, very much retarded. So far also in America its use has been more confined to industrial lighting, to merchandising, display and entertainment and to the lighting of offices, draughtsmen's rooms, schools, public buildings and the like.

Starting Switches.—In starting the tube the main switch is closed and then the starting switch is closed and opened again for striking the arc. This operation serves a dual purpose: When the starting switch is closed current flows through the tungsten coils of the electrodes and starts the thermionic emission. When it is opened a voltage "kick" is generated by the choke and the arc is struck. Two separate switches may be used for the purpose or they may be combined in the manner of group switches. But, especially if more than one tube is to be controlled by one main switch, or in order to make the outfit foolproof it was found desirable to develop automatically acting starting switches.

For instance, a glow starting switch (British Patent 521618, B.T.H. and W. J. Scott of 1938) may be used for this purpose with bimetallic strips carrying the electrodes inside a bulb of 20mm. diam., 70mm. long. On closing the main switch these electrodes and the strips are heated by the glow discharge. The electrodes are thus brought into contact and the current increases from 100mA. to about 1.3A. By the closing of the contacts the glow discharge is short-circuited and the strips are cooled down again and open the contacts within a few seconds which suffice for starting the main discharge in the fluorescent tube (Fig. 4).

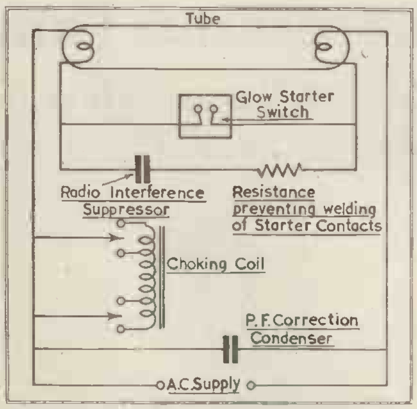


Fig. 4. Connexions of lamp with glow starter switch.

Other kinds of automatic switches have also been proposed, *e.g.*, switches with a heating coil or magnetic switches. While with the glow discharge switch the contacts are normally open and the glow discharge causes their closing, the contacts of the thermal starter switch are normally closed and the heating causes their opening.[16] Due to the thermal inertia of this switch a time of about four second is required for restriking the lamp after it has been switched off while with the glow starter switch only two seconds are required. Fig. 5 shows the connexions for the thermal starter switch. The energy consumption of the heater coil is not more than about 1 w.

The starting of the main discharge is effected by the voltage kick of some 1,000 v., produced by opening the circuit of the choking coil. If the arc in the main discharge tube is once started no further outside heating of the activated electrodes is required as they act alternately as cathodes and anodes and are heated sufficiently by the anode drop during the half period in which they are working as anodes.[8]

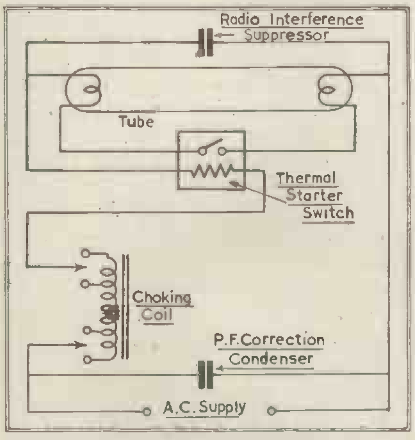


Fig. 5. Connexions of lamp with thermal starting switch.

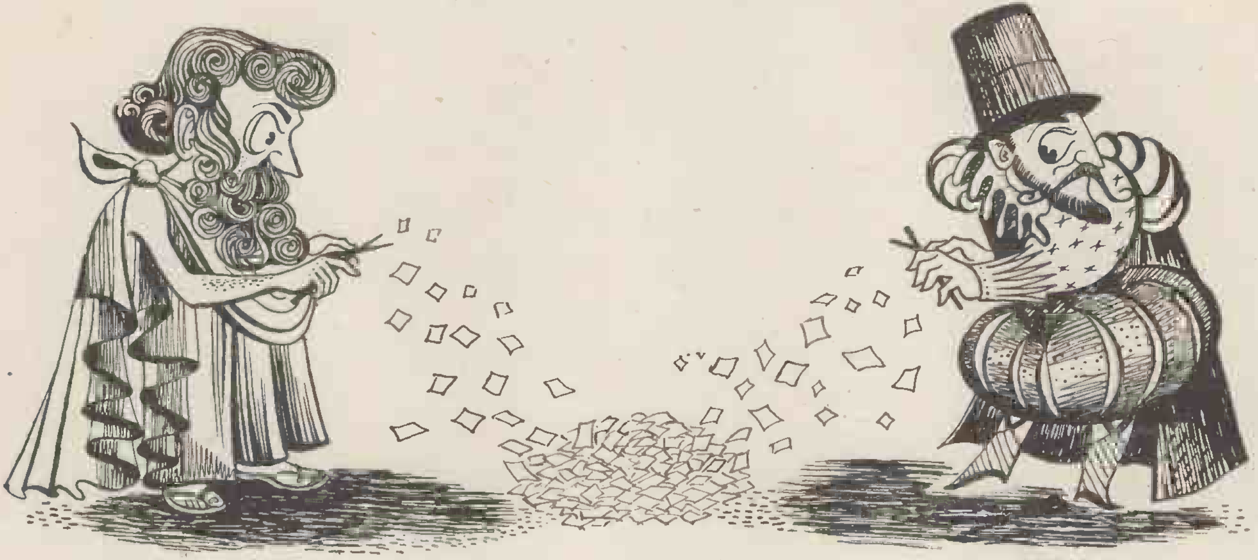
The operation of these lamps from a d.c. supply is not recommended although it is possible with some safeguards to prevent the effects of electrophoresis which seriously reduce the light radiation from the anode.

Choking Coils. Some remarks should be made here on the choking coils connected in series with the lamps.[21] Their function is not only that of stabilising the arc discharge, but also of reducing the effect of fluctuations in the supply voltage and of providing the voltage kick necessary for starting the arc. They are usually fitted with different tappings for adjusting the lamp to different supply voltages.

As previously mentioned, and as was the case with the old arc lamp the voltage decreases with increasing current and so, due to this negative characteristic of the arc, the current would increase to enormous amounts and would ruin the lamp if it were connected without a stabilising device. As a means of stabilising, inductance, capacitance, or resistance or combinations of these may be used, but in most cases choking coils are used in practice. In those exceptional cases where the lamp voltage is much in excess of the supply voltage, step-up transformers in series with chokes may be applied or an autotransformer with a magnetic shunt causing a high leakage reactance. With the usual series connexion of lamp and choke the current lags behind the line voltage by an angle depending on the ratio of lamp voltage to line voltage. In normal service the restriking voltage is near the peak of the line voltage. If the ratio of lamp voltage to line voltage is increased the phase position of current and lamp voltage is advanced, but if this increase is too large the instantaneous value of the line voltage is not sufficient for striking the arc. Thus the lamp efficiency is reduced, the life of the lamp is shortened and the flicker is highly increased. By these considerations a critical ratio of lamp voltage to line voltage is determined which fixes the power factor at about 0.55 lagging.

The actual dimensioning of the choke is usually done empirically as the non-linearity of the lamp characteristic and of the iron-cored choke prevent a successful calculation. Hays and Gustin give an equation for the impedance of the choke based on some simplifying assumptions.[21]

The low power factor is usually corrected by a condenser connected across the line. With a larger number of lamps burning on the same premises a common condenser may be arranged at some convenient place if this should prove more economical than having a separate condenser for each unit.



If instead of the choke a condenser is connected in series or in parallel to the lamp the whole energy of the a.c. wave is stored in the condenser immediately when the ignition voltage is reached. The current reaches peak values several times in excess of its normal value and falls down to zero immediately afterwards. By these heavy surges the electrode emission material is sputtered from the cathodes, an unbearable flicker is produced and the life of the lamp is considerably shortened.

Also, with ohmic resistance in series with the lamp the flicker is increased, the power consumption is prohibitive and the current waveform is poor.

The undesirable current surges produced when the lamp is connected to a condenser may only be avoided if a condenser and a choke are connected in series to the lamp. This results in a circuit with a leading power factor and with good stabilising qualities. In combining a leading and a lagging circuit in a two-lamp arrangement an outfit may be obtained which operates at a power factor of 0.99 and at the same time reduces the flicker considerably as the currents for the two lamps are working under a phase shift of 120°.

(To be continued.)

The Institution of Electrical Engineers

Admission of Non-Members to Meetings

The Council of the I.E.E. have had under consideration for some time the question of making the technical meetings of the Institution accessible to those who may be interested in the proceedings, but who may consider that their technical experience and educational attainments do not suffice to admit them to any form of the Institution membership.

With this end in view, the Council have decided that a person who is interested in the proceedings at ordinary meetings, section meetings, local centre meetings, and informal meetings, may apply for admission as a visitor. On the completion of the application form and on payment of a fee of 7s. 6d. to cover administration costs, he may receive notices of meetings and an invitation card which will serve as a title of admission.

The possession of the invitation card will not confer upon the holder any status within the framework of the Institution, nor will he have the right to join in the discussions without special permission from the chair.

Those interested in this new facility, whether they reside in London or in the provinces, should apply to the Secretary of the Institution, Savoy Place, London, W.C.2.

Emission-Type Photoelectric Cells

Notes taken from an article by **A. C. Lynch** and **J. R. Tillman** in the **P. O. E. E. Journal,** July 1943.

An emission-type photo-electric cell is equivalent to a high-impedance (and therefore constant-current) source, shunted by the inter-electrode capacitance of the cell, of the order of 5 μμF in a typical commercial cell. It would be possible to reduce this capacitance by increasing the separation of the electrodes; but in general this process would not improve the performance of the cell at high frequencies owing to transit-time effects.

Sensitivity

The sensitivity of a cell is expressed in μA per lumen. (1 lumen is the total amount of light falling on a surface of 1 sq. ft. at a distance of 1 ft. from a source of 1 candle-power.) This figure for the rating of the cell does not depend on the size of the sensitised cathode, for an increase of cathode area will increase the amount of light (measured in lumens) collected. The sensitivity of a "caesium" cathode, the commonest in commercial use, is about 15 μA per lumen; most others are less sensitive, but a cathode has recently been produced for which a sensitivity of 50 μA per lumen is claimed. Owing to the selective colour-response of cathodes it is necessary to specify the colour-characteristics of the light with which the measurement is made; this is equivalent to fixing the temperature of the lamp-filament used. The generally adopted standard is an incandescent lamp at a temperature of 2,850° K.; this is advantageous in being the type of source with which photo-electric cells are frequently used. The sensitivity of an ordinary "caesium" cathode is from 4 to 8 μA per lumen of daylight instead of the 15 μA per lumen of the light from an incandescent lamp.

In gas-filled and secondary-emission cells the sensitivity is greater; for example, using the above-mentioned cathode giving 15 μA per lumen in a gas-filled cell, a sensitivity of 75 μA per lumen is obtained. A one-stage secondary emission cell using this cathode will give 200 μA lumen, and sensitivities up to 2A per lumen are obtainable in experimental multi-stage electron-multipliers.

In practice, damage to the cell may result from attempts to draw currents corresponding to illuminations greater than, say, 1/20 lumen.

The vacuum cell, when used under saturation conditions, gives an accurately linear response over a wide range of values (10,000 : 1) of incident illumination. The secondary-emission cell, being essentially a vacuum cell, is nearly as good. The gas-filled cell, though inferior, gives a substantially linear response except when used with high polarising voltages or high illuminations.

The cathode material usually emits electrons at a small rate even in the dark; this is simply thermionic emission. This dark-current is largest in caesium cells; a better ratio of sensitivity to dark-current is obtained with other cathodes (e.g., potassium) which are therefore used, in spite of their lower sensitivity, for some precision measurements.

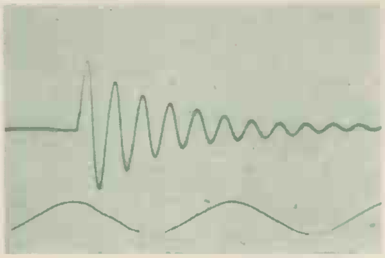
Unless, however, a guard-ring is used between anode and cathode there will be a leakage current over the insulation which greatly exceeds the thermionic dark-current; e.g., 10^{-9} A leakage current compared with thermionic currents of 10^{-11} A in a caesium cell and 10^{-13} A in a potassium cell.

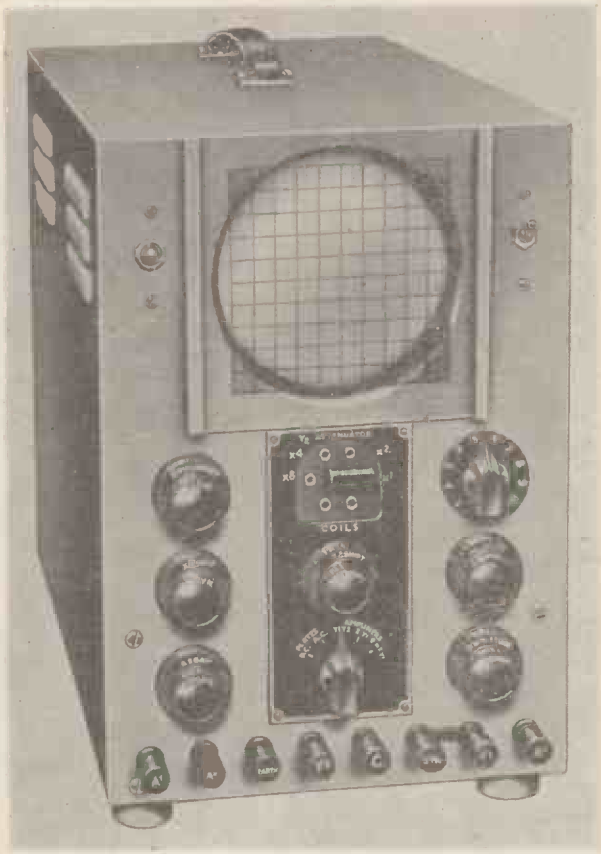
Frequency response to Interrupted Light

Vacuum and secondary-emission cells respond satisfactorily to the variations in light interrupted at frequencies up to about 1 Mc/s, above which the inter-electrode capacitance limits the load impedance which can be used. In a gas-filled cell, however, the comparatively slowly-moving ions require a time of the order of 10^{-5} sec. to reach the electrodes. For this reason the response to frequencies higher than about 5,000 c/s is progressively reduced. In cells using the high gas-pressures which are necessary to obtain high gas-magnification, this effect occurs most strongly.

Notes on Intensity of Sources

In calculations of the response to be expected from a photo-electric cell, it should be noted that a conventional condenser lens rarely collects more than one-sixteenth of the light from a lamp. A deep parabolic reflector can collect nearly half the light; but such reflectors are rare. Of the 4π lumens emitted per candle-power, therefore, less than 1 is likely to be useful in an optical system.

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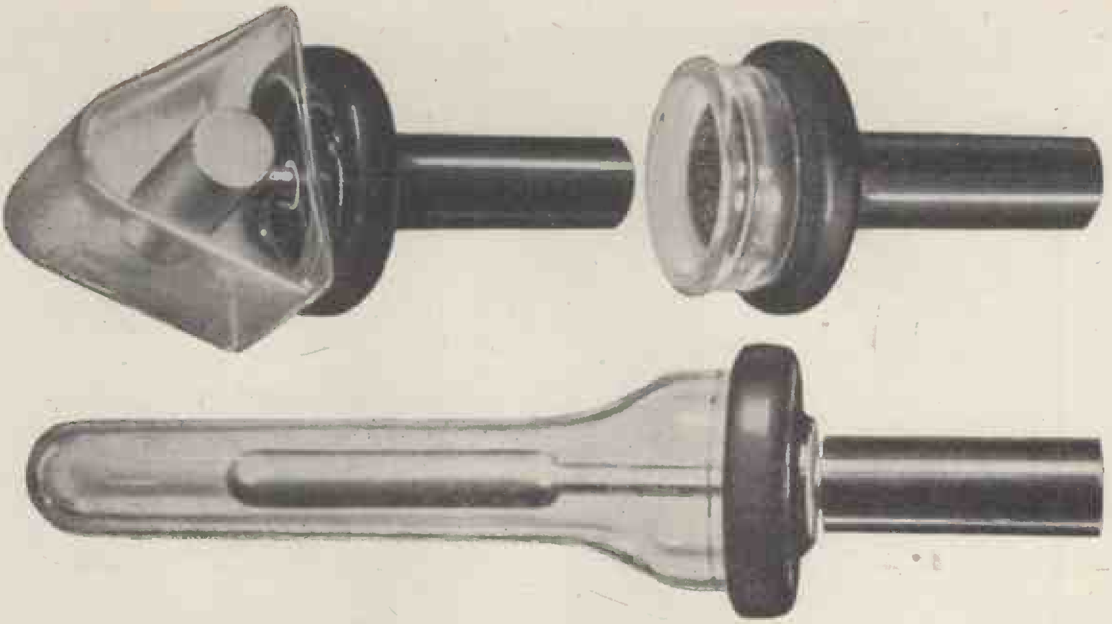

The photograph at the head of this page shows a typical set of shaped electrodes for special purposes.
(By courtesy of General Radiological, Ltd.)

High Frequency Therapy

Part III—Electrode Theory and Design

by W. D. OLIPHANT, B.Sc., F.Inst.P.*

IT has already been shown how use can be made either of conduction (and convection) currents or of displacement currents to produce a thermal effect in a substance. In the former case direct electrical contact would be made with a pair of electrodes, while in the latter the substance would form part of the dielectric system of a condenser made up of specially designed electrodes. It is the object of this section to consider in some detail the theoretical principles underlying electrode design and operation.

Development of the Condenser Field

In general, the electrode system with the associated biological substance (hereafter for brevity simply referred to as the "body") forms part of the secondary or output circuit of a high frequency oscillation generator, and as such will contribute in a very marked manner to the circuit constants. The generator is usually adjusted to run at some fixed frequency while the body circuit is suitably tuned to resonance. Let us examine the effect of inserting the body into such a resonant system as that shown in Fig. 1 (a).

The output circuit is here a very simple tuned circuit comprising inductance L and capacitance C, which latter quantity is contributed to by the electrodes A and B themselves. We will assume that this circuit is in resonance to the required frequency. On inserting the body in direct contact with the electrodes as shown in Fig. 1 (b), two drastic changes immediately occur. As most biological substances possess a very high dielectric constant (usually of the order of about 75), the capacitance C is very considerably increased thus throwing the circuit right out of tune. The second effect is brought about by the severe damping introduced into the circuit by the presence of the body as part of the conduction path. In short, the body has completely destroyed the essential qualities of an efficient output circuit.

In order to restore the circuit to resonance with the generator frequency it would be necessary to reduce considerably the effective capacitance, in other words, to insert a suitable series capacitor C_s as shown in Fig. 1 (c). Now this condition could equally well have been attained simply by separating the electrodes; in fact, by placing the body between A and B without actually being in contact with one or both of them. The body thus becomes *part* of the dielectric system of the electrode arrangement AB. In practice, the body is not placed in contact with either electrode and this has the additional advantage that the patient is not in direct electrical contact with any part of the circuit, and it thus affords a very necessary safety precaution. (*See* Fig. 1 (d).)

We have thus passed naturally from conduction to displacement current operation. The resulting equivalent electrode circuit is shown in Fig. 2.

This arrangement is usually referred to as the "condenser field" method, a method of unique importance for successful short wave therapy treatment. In therapeutic work where we are dealing with a very large range of possible bodies, it is customary to retain the condenser C_s of Fig. 1 (c) besides employing the air-spaced electrodes. This condenser affords the means for tuning the body circuit to resonance with the drive oscillator, and what is perhaps of as great importance, it provides a means for controlling the actual current flowing through the body circuit by the simple process of detuning.

In the above we have developed the condenser field method from the conduction method by a logical argument based on electrical principles, and we have seen how the former method is the better for short wave technique

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* University of St. Andrews.

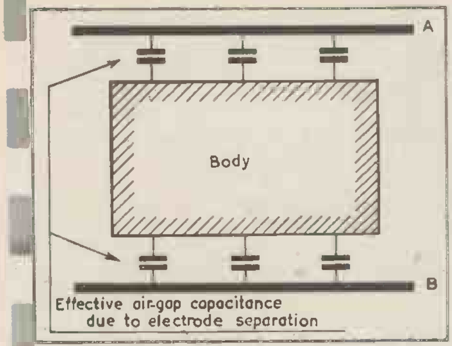


Fig. 2 (left). Equivalent electrode circuit in "condenser field" arrangement.

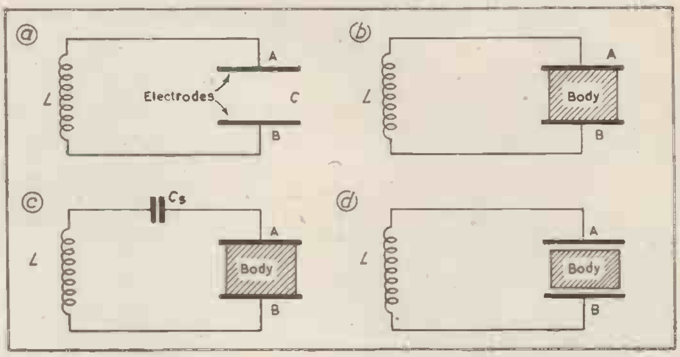


Fig. 1 (right). Showing effect of insertion of body in the oscillatory circuit.

It is a matter of good fortune that it also happens to be the better method from the therapeutic point of view. We will now consider a very simple case.

We are presented with some abnormal condition in an internal organ, and it is known that short wave therapy would prove beneficial in restoring the organ to its normal condition. This organ is found to be surrounded by a substantial layer of fat which in its turn is encased in a thick layer of tissue. (This example is very common.) We will examine first of all what happens when conduction electrodes are applied as shown in Fig. 3 (a).

We are here dealing with a composite conductor wherein the tissue is of good conductivity and the fat is of bad conductivity. The result is that the current will distribute itself across the section in such a manner that the tissue will conduct most of it, while only a very small proportion indeed will traverse the internal organ. This condition is depicted in the diagram. The organ is, in fact, effectively screened by the fat layer in conjunction with the tissue. In order to bring about the desired effect in the internal organ it would be necessary to increase the potential difference across the electrodes, but long before that point was reached serious damage would most probably have been inflicted in the tissue sheath. In our attempt to cure one ailment, we may have brought about a much more serious condition in the tissue.

If, however, we had introduced an air-gap between the electrodes and the body as shown in Fig. 3 (b), we would have created a distribution of lines of force as shown. It will be seen that a considerable concentration is present in the organ as compared with that in the rest of the body and so we have, so to speak, focused the effect where we want it. A more detailed discussion of these effects will be given later in the series when we are considering the electrical properties of biological substances and the effects of different frequencies.

Electric Field Theory

In using the condenser field method we are primarily concerned with the properties of an electric field which is characterised by both electrical and geometrical conditions; in other words the field configuration is governed by the shape and size of the electrodes as well as by the shape, size and electrical properties of the interposed dielectric body.

By way of introduction, consider a simple parallel plate condenser made up with two planar electrodes A and B which are suitably spaced and suspended in a homogeneous dielectric medium such as air. The arrange- is shown in section in Fig. 4.

Plate A is earthed and is thus maintained at zero potential, while for the sake of illustration plate B is charged to 100 E.S.U. of potential, thus creating an electric field. In studying the nature of such a field it is customary to consider the lines of electric force which are present in it. A line of electric force may be defined as a line whose direction at any point gives the direction of the electric intensity at that point. The electric intensity (E) at any point in an electric field is the mechanical force in dynes which would be experienced by a unit positive charge placed at that point, and it is a vector quantity. As like electric charges repel each other, it follows that the direction of a line of force must be *away* from its parent positive charge. In other words, a line of force may be looked upon as the path which would be traversed by a positive point charge which was entirely free to move way from the seat of the main positive charge.

Having established the meaning of electric intensity as applied to an electric field, we might for a moment consider what we mean by electric potential. The electric potential (V) at any point in an electric field is the potential energy of a unit positive charge placed at that point. In order to acquire this energy work must be done and so the electric potential at any point is the work in ergs which must be done to bring the unit positive charge from infinity to that point *against the electric intensity.* At infinity the potential is zero, but for

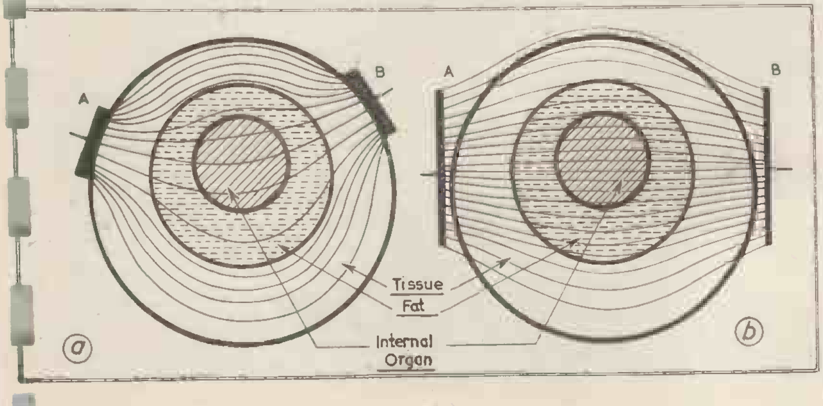
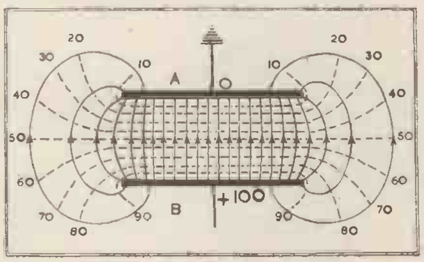


Fig. 3 (left). The effect of body tissues on field distribution.

Fig. 4 (below). Potential field in a flat plate condenser.



practical purposes an earthed conductor is taken to be at zero potential. The potential difference between any two points, by the above formal definition, is simply the work done in conveying the unit positive charge from one point to the other against the electric intensity. Electric potential, like work and energy, is not a vector quantity.

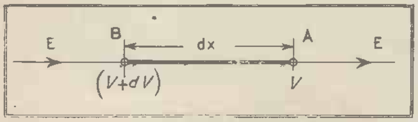


Fig. 5.

It is now obvious that potential and intensity must be rigorously related to each other and such a relation is not difficult to find. Consider any two points A and B in an electric field distant dx apart as shown in Fig. 5.

Let the component of electric intensity in the direction $\overrightarrow{BA}$ be of magnitude E and let the potentials at A and B be respectively V and $(V+dV)$. Then the force which will be experienced by a unit positive charge placed anywhere along the line BA (or BA produced) will be E dynes. Now in order to move the unit charge from A to B against the electric intensity, the amount of work which must be done is simply $-E.dx$ ergs. This is the product of force and distance, the distance here being taken with the minus sign since it is opposite to the positive direction of the intensity and therefore of the force.

Now the potential difference between A and B is dV, and so we have

$$dV = -E.dx,$$

or $$E = -dV/dx \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

In other words, the electric intensity at a point in any given direction in an electric field is the negative potential gradient at the point in the given direction. The electric intensity, or, as it is sometimes called, the field strength, is thus expressed as so many units of potential difference per unit of length; in other words, in E.S.U. per centimetre or in volts per centimetre. (1 E.S.U. of potential = 300 volts.)

Returning now to our simple condenser in Fig. 4, we have a system of lines of force as shown by the solid directed lines. As the plates of the condenser provide equipotential surfaces, these lines must everywhere be normal to the electrode surfaces and they must never intersect each other—in fact, they may be regarded as suffering mutual repulsion between themselves.

In the centre of the electrode system the field strength is uniform, but as we approach the edge of the plates the field becomes non-uniform and we have wide curvature of the lines of force. This is technically known as "fringing" and is dependent on the size and separation of the electrodes. The potential distribution between the electrodes is examined with the aid of equipotential lines (or surfaces, if we are not merely confining our attention to a sectional view of the electrode system). These lines join together all points which are at the same potential and they must everywhere be normal to the lines of force, otherwise there would be a component of electric intensity along an equipotential line indicating a potential difference which, by definition, cannot exist. The lines, shown dotted in the diagram, are drawn for every 10 units of potential.

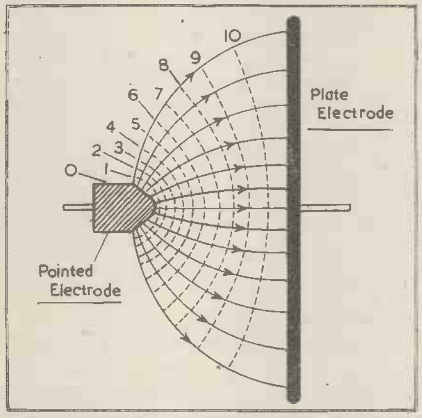


Fig. 6. Field distribution between plane and pointed electrode.

The field strength in the uniform part of the field is given by

$$E = V/d \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

where V = potential difference between A and B

d = separation between A and B.

The theory of the point effect of small electrodes is of some importance not only from the point of view of understanding their action but also to enable one to appreciate the potential danger which might exist in their use. Let us examine the field and potential distributions between a plate electrode and a pointed electrode as shown in Fig. 6.

Lines of force must leave the point electrode normal to the surface and arrive normal to the surface of the plate electrode, so naturally we have a great concentration of the lines in the neighbourhood of the point. Arising out of this, the equipotential lines are also closer together at the point giving rise to a greater potential gradient. This is known as the "point effect" and it increases with increase in the curvature of the point; that is to say, the more pointed the electrode the greater is the effect.

The point effect is advantageously made use of in practice as a means for concentrating energy into a portion of a body near an electrode. In this mode of operation, the plate electrode can either be remotely placed on the body with respect to the pointed electrode, or it may be dispensed with entirely. In either case this form of treatment is known as the unipolar method. Careless choice of electrodes, on the other hand, might involve the use of a pointed electrode with resulting serious injury to the patient in the neighbourhood of the point. We shall see later that the point effect also occurs when points, such as the nose, are part of the form of the patient under treatment.

Electrodes Used in Practice

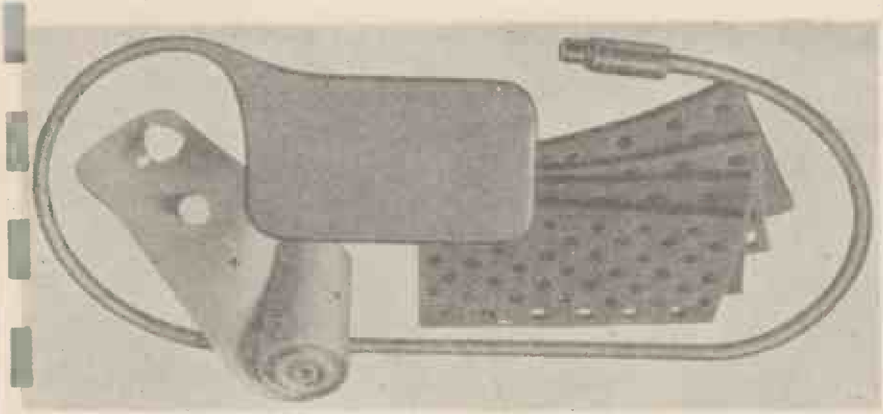
Without concerning ourselves for the moment with the precise effect which the body under treatment has on the field of configuration, we can, nevertheless, infer that the effect will be such as to call for specially-shaped electrodes in a large number of cases. In order to meet these varying requirements, the manufacturers of therapy equipment have provided a number of types of electrodes which can be classified according to three main types, namely (1) pliable electrodes; (2) rigid electrodes; and (3) special electrodes suitably fashioned for insertion into body cavities and so on.

1. Pliable Electrodes

These are made up of sheets of metal foil encased in specially-treated rubber sheaths. The electrodes are designed so that in general practice they do not in themselves become too hot and can be shaped and strapped to any part of the body by means of rubber bandages. They are generally supplied in a selection of sizes and can be plugged direct into the generator unit. To provide for variable separation between the electrode and the body, layers of perforated felt may be inserted, the perforations being essential to reduce heat insulation and unwanted dielectric loss. Pliable electrodes give a fairly even field distribution, and facilitate the nearest approach to the body surface when this is desired. Their use, however is limited on very short wavelength of operation and their place is more advantageously taken by the rigid type.

2. Rigid Electrodes

For shorter wave operation the pl able electrodes are not so effective and in general the electrodes take the form of suitably shaped metal con ductors which are assembled on high grade insulating base, and the electrode proper is enclosed in a glass



(By courtesy of General Radiological, Ltd.)

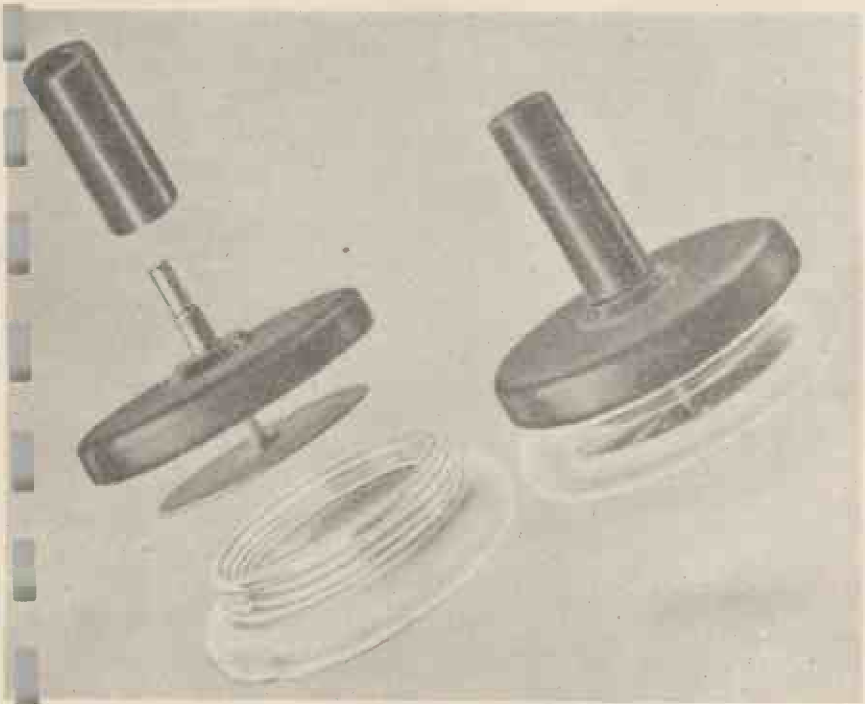
g. 7. Flexible condenser electrode of metal foil embedded in pliable insulating material. The perforated pads are for adjustment of air-gap between electrode and skin surface.

cover or "shoe." Such electrode assemblies have come to be known as Schliephake glass-shoe electrodes after their inventor. The metal electrode is capable of adjustment within the shoe to provide for separation adjustment, while the glass shoe itself provides protection for the patient. Since very high potentials are applied to the electrodes it is necessary to ensure that the patient does not come into contact with them or indeed to approach them to within such a distance as to start a spark discharge, and so the shoes afford this protection. These shoes further augment the available field strength in the treatment or body air space provided the material used in their construction possesses a high dielectric constant and incurs low loss. The glass shoes are further constructed so as to be larger than the electrode which they enclose and this to some considerable extent overcomes the effect of fringing.

3. Special Electrodes

In order to treat organs or diseased areas which could not easily be done by means of electrodes applied on the outside of the body, special electrodes have been constructed. These electrodes are specially suited to the body cavities such as the mouth, vagina, rectum, and so on, and are usually specialised versions of the simple glass shoe already described. Specimens of these are shown at the head of this article.

(*To be continued.*)



(By courtesy of General Radiological, Ltd.)

Fig. 8. Pyrex enclosed condenser electrode with adjustment for plate distance.

The I.E.E. Wireless Section's 25th Anniversary

Mr. T. E. Goldup's Inaugural Address

At the meeting of the Wireless Section of the I.E.E. on October 13th, Mr. T. E. Goldup (Mullard Radio Valve Co.), the new Chairman, reviewed the progress in radio valve and receiver manufacture during the past 25 years and pointed out the growing importance of the industrial applications of thermionics. We have only space to reproduce his remarks on the growth of the Radio Industry and the Wireless Section, which will be read with interest by newcomers to the field.

TONIGHT, at the commencement of a new Session, the Wireless Section is entering upon the year of its 25th anniversary, in circumstances unfortunately surrounded by war conditions. Those arrangements which normally would have been made to celebrate this important anniversary will of necessity be much curtailed, but nevertheless this will not prevent us from reflecting with considerable pride and satisfaction on the immense contribution made towards the war effort by members of this Section engaged in research, development, and manufacture, and last but not least in the use of wireless equipment of all types for the Armed Forces of the Crown.

The Radio Industry

In the early twenties the public interest in wireless broadcast reception was such that a rapid growth of valve and equipment manufacturing capacity was necessary to meet the demand for apparatus with which to receive the broadcast programmes. Some of the well-established electrical manufacturing companies, together with many newcomers, took steps towards setting up the necessary manufacturing facilities and made suggestions for the establishment of the original British Broadcasting Company and plans for the collective organisation of this new industry. Three manufacturers' Associations were formed, one dealing with receiving valves, another with broadcast receivers, and at a much later date an Association of Radio Component Manufacturers was formed. These Associations became known as the British Radio Valve Manufacturers' Association (B.V.A.), the Radio Manufacturers' Association (R.M.A.), and the Radio Component Manufacturers' Federation (R.C.M.F), their function being concerned with marketing of their products, the regulation of trading practices and liaison with Government Departments in addition to the B.B.C. and Post Office on general matters affecting the industry. The necessary technical guidance was provided for by the appointment of various technical committees.

Complete freedom regarding research, technical development and manufacturing technique is permitted, the view being taken that this is essential in order to progress towards the highest possible technical attainments and to encourage the initiative of the various research and development organisations.

There are advantages and disadvantages in this method of procedure. The net result is, however, fairly satisfactory, as is shown by the high technical quality and reliability of radio valves, equipment and components made in this country, together with the rapid progress in technical achievements in the field of television reception. Among the disadvantages of unrestricted research and development is a tendency towards non-standardisation of products and manufacturing methods. The work of the various technical committees in industry has therefore been devoted to a large extent to the problems of standardisation and the framing of recommendations on such questions as electrical interference, the preparation of test specifications and codes of practice, in addition to which assistance has been given to British Standards Institution Committees in the production of national standard specifications. The results of this technical work are often criticised, particularly that part concerned with standardisation. However, it must be appreciated that standardisation, even under ideal conditions of controlled and co-ordinated development, is always very difficult of attainment, by reason of the fact that so many conflicting interests are involved. The war naturally brought to light many deficiencies in the work formerly undertaken on standardisation, and it was soon realised that we were a long way from anything even approaching the ideal.

So far as receiving valves are concerned, there is some degree of standardisation in valve bases and connexions, although the types of bases in use still tend to be too numerous. The individuality of valve manufacturing technique among the various valve manufacturers constitutes a disadvantage during wartime, in that difficulties arise in attempting the manufacture of valves designed and made by another valve manufacturer. The problem is aggravated by the enormous expansion of production capacity necessary to meet war needs, but nevertheless the co-ordinated efforts of the B.V.A. valve manufacturers have largely overcome these inherent difficulties to a point where a very large increase in the output of valves has been achieved.

In pre-war years, the Technical Committees of the R.M.A. and R.C.M.F. were active in promoting standardisation of radio components from the point of view of physical interchangeability, performance specifications and methods of test, ultimately putting them forward for consideration by the B.S.I. when the work was sufficiently well advanced to warrant consideration from the point of view of a national standard. Later, the R.M.A. extended this work to embrace the electrical and acoustic test specifications of broadcast receivers, the latter, it is believed, being the first specification of its kind to be published. The basis of this specification formed the subject of an informal discussion in 1927 at a Wireless Section Meeting, resulting from which the R.M.A. published a revised specification, finally handing the work over to the B.S.I. for completion.

Manufacturers have always attached great importance to the training of suitable technical personnel for all branches of the industry, the rapid growth of which necessitated particular attention being given to this question. The larger manufacturers possess adequate training facilities, having in most cases their own schools. A co-ordinated effort was, however, thought to be necessary, and the R.M.A. interested itself in the problem, commencing in 1935 some discussions with the Board of Education. At that time the objectives were the recruitment of suitable technicians for manufacturers, the provision of technical training for radio service personnel and the improvement of the technical knowledge of existing service men whose technical training was considered to be insufficient. In consultation with the Board of Education a syllabus was agreed for a Radio Course, occupying three evenings per week over a period of three years. To meet the needs of improving the knowledge of existing radio service men

the R.M.A. published a Service Manual which had been drawn up in co-operation with their technical committee. With the assistance of the Board of Education a course for radio teachers was organised in 1937, which included lectures at manufacturers' works by experienced technicians. The experience gained through these training schemes proved of great value in organising large scale training to meet war needs when the problem of technical personnel for the armed Forces and research establishments became acute.

The growth of the radio industry is indicated by Board of Trade returns which show for 1924 a value of £4,000,000 as against £12,000,000 for 1935, these figures covering the sales of receiving sets and radio gramophones. The B.V.A. output for civilian purposes only, increased from three million valves in 1927 to eight million in 1939, with a peak output of approximately ten million in 1937.

Technical Press

No survey of the development of the Radio Industry could be complete without recording the contribution made by the technical and trade press. Through its columns the story of the progress of wireless and of the industry throughout its history is recorded.

To-day, the industry and the technical public are served well by two or three wireless papers of established repute, and their record during the years of war is excellent. They have kept all sections of the industry in touch with one another at a time when contacts have often been difficult if not impossible, and given information concerning Government Regulations and Orders affecting the radio trade, in addition to publishing explanatory details, a service which has earned the recognition of the Board of Trade and other Government Departments.

The trade journals have realised the necessity for an efficient technical service for traders. In peace time this has included test reports and reviews of new receivers, information on the general technical developments taking place in this country and overseas, and instructions for the repair of faulty receivers. The latter feature is of considerable help to-day. One weekly trade journal commenced in 1933 the publication of service sheets on current receivers; these included circuit diagrams, chassis layouts, values of components and other general instructions, produced in a standard form.

After the war the press will have an important part to play in gathering up the threads of the industry, and helping it in its changeover from wartime production to peacetime manufacture and distribution.

The Wireless Section

The Wireless Section, now 25 years of age, was the first section of the Institution to be formed. On February 17, 1919, the first Wireless Section Committee Meeting was held under the chairmanship of Dr. W. H. Eccles, and a few months later, on November 19, Prof. C. L. Fortescue read the first paper presented to the Section. During 1934 the Committee very wisely decided to include informal meetings in the Section's programme, the first such meeting being held on January 29, 1935. Recently, two local groups have been formed at Manchester and Birmingham. Our immediate past Chairman has recorded further details of the Section's history in his Inaugural Address last year, and I propose, in the concluding paragraphs of this address, to review the past activities of the Section and to discuss a possible extension of its usefulness.

The main task of the Section is to facilitate the exchange of technical information between members on those subjects coming within the scope of the Section. This is achieved by the reading and discussion and subsequent publication of papers presented to the Section, by the publication of communications relating to wireless or telecommunication subjects, and by informal discussions. It is agreed that the papers published in Part III of the *Journal*—Communication Engineering—and formerly in the *Proceedings* of the Wireless Section, constitute a very excellent record of technical progress, attaining a high technical standard and forming a source of authoritative information on the subjects concerned. However, the rapidly expanding field of high frequency engineering and allied subjects results in specialisation in specific groups of subject matter, and this is reflected in the papers published. Hence they tend to become very specialised, and as such are of immense value to those engaged in the particular field under review, while of passing interest only to others whose activities are confined to other specialised branches of high frequency engineering. Further, many readers may have only a superficial knowledge of the subject concerned, and may possibly lack a clear understanding of the fundamentals involved, so if we are to facilitate an extension of knowledge among ourselves these points need careful thought while a paper is in the course of preparation.

The war has focused our attention on the problems of education and training, and those of us in industry and elsewhere having the responsibility of controlling technical staffs are well aware of the present deficiencies. The war years have proved t be very difficult for engineering students, for they have continued their studies in circumstances that are not altogether conducive to good results, and this has aggravated an already unsatisfactory position. In the immediate post-war period we shall therefore be faced with the problem of completing the training of these engineers and deciding thei future sphere of engineering work. In addition, an overhaul of present methods of education and training will be necessary, and industry wil have to share in the responsibility o providing technological training; but what can the Wireless Section do in this connexion? I am personally o the opinion that we can contribut considerably towards the solution of this problem. We could promote a series of quite informal discussions on specific aspects of training, and pr gress them towards the preparatio of some definite recommendations for the guidance of educational bodies and industry. There are among ou number several who have detaile knowledge of the problem of training, and collectively the experience available is considerable, so let us exchange these experiences and arriv at some definite conclusions. I sha the view that there is no more important problem than that of training, and if our industrial undertakings a to be successful in home and overse markets, then it is essential for them to have well trained technicians continuously flowing into their organis tions.

Over the years a steady increase the membership of the Section has been maintained; in fact, during the past eleven years the membership h doubled, but having in mind the rap expansion of radio engineering and its allied subjects, the membership of our Section should be much large In my opinion it is incumbent up the trained engineers, physicists, a others having the necessary qualifications to become members of the Institution and of the Wireless Se tion, and so interest themselves in t recognised essential professional In stitution governing the general technical advancement and status of our profession.

The B.B.C. Bites It

(*From the Daily Telegraph.*)

SIR,—In reply to your corresp dent, Mr. Paul Nichols, who inqui s about the music which ends the B.B.C. early morning religious broadcasts in alternate weeks, it is not, s he supposes, played on a concerti , but by the B.B.C. Symphony Orch tra.—Yours, etc.,

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Director of Publicity,
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ABSTRACTS OF ELECTRONIC LITERATURE

THEORY

Vacuum Rectifiers Working with Condenser Input

(R. G. Mitchell)

Formulas are derived enabling curves to be drawn which give all the desired circuit data in terms of the known constants for vacuum rectifier circuits working with condenser input, in single-phase and bi-phase circuits.

Wireless Eng. Vol. 20 (1943), p. 414.

Coupled Circuit Filters

(K. R. Sturley)

Generalised selectivity curves developed by Beatty for identical coupled tuned circuits are shown to be applicable to dissimilar coupled tuned circuits of differing Q, L, and C valves, but having a common resonant frequency.

Generalised selectivity curves of loss in decibels and of phase shift are given in terms of a function of off-tune frequency for selected values of coupling coefficient, k, and the magnifications Q_1 and Q_2 of the primary and secondary circuits.

Shunt and series inductance and capacitance couplings are examined, and it is shown that the generalised curves are here applicable if certain terms, which are indicated, can be neglected. Generally, this is possible. The two special cases of a common resonant frequency are detailed and expressions for transfer impedance, mid-frequency and coupling coefficient are derived.

The effects of resistance in the coupling element and of mistuning of the primary and secondary circuits are considered, and in the latter instance it is shown that the generalised curves may be applied if certain conditions are fulfilled. The influence of a frequency ratio factor, which is assumed to be 1 when determining the generalised selectivity curves, is discussed.

Wireless Eng., Vol. 20 (1943), p. 420.

Standard Curves

(C. W. Hansel)

A method is proposed, using one standard curve to represent all functions of the same type, and adjusting the scales until this curve represents the cartesian plot of any selected function of that type. The curve $Y = X^2$ may be used as a standard to represent any quadratic function $y - ax^2 + bx + c$. Using the standard curves $Y = X^3 - 3X^2$, $Y =$ sine X, and $Y = e^x$, $Y = e^{-x^2}$, any cubic sine or exponential function may be represented without transformation of origin.

—*Phil. Mag.*, Vol. 34 (1943), p. 361.

CIRCUITS

An Automatic Frequency-Controlled Oscillator and Amplifier for Driving Mechanical Vibrators

(E. V. Potter)

An oscillator system has been developed for driving mechanical sound generators or other vibrating mechanical systems which require that the vibrating member be driven at its resonant frequency. The oscillator is a vacuum tube type in which an automatic frequency control, similar in principle to that employed in radio receivers, is used to keep the frequency at or very close to the resonant frequency of the vibrator. The change in phase of the vibrator motion relative to the driving force is used to supply a potential proportional to the difference between the driving frequency and the resonant frequency of the vibrating member, and having a polarity dependent on whether the driving frequency is less than or greater than the resonant frequency. This voltage is used to control a reactor tube which in turn controls the frequency of the oscillator circuit. The circuit is very effective, changes in either oscillator or vibrator frequency, or both, of approximately 500 cycles per second in 12 kilocycles, being followed automatically so that the oscillator frequency will not deviate from the resonant frequency of the vibrating member by more than 0.1 cycle per second.

—*Rev. Sci. Inst.* Vol. 14 (1943), p. 207.

CATHODE-RAY TUBES

A Synchronised Calibrator for Sweep and Gain in Cathode-Ray Recording

(S. A. Talbot)

A circuit is described comprising an R.C. oscillator and multivibrator which generate three timing scales suited to calibrate a wide range of sweep speeds. In addition, a square pulse with adjustable duration is provided to calibrate the gain and to record the frequency characteristics of an amplifier. Both calibrations are synchronised with the sweep.

—*Rev. Sci. Inst.*, Vol. 14, No. 6 (1943). p. 184.

The C.R.O. applied to Long-Time Switching Transients

(G. W. Dunlap and N. Rohats)

A simple inexpensive cathode ray oscillograph without the high-speed features of the all-purpose type is described, which is used for recording long-time transient switching voltages of the order of one or two seconds. Details of the camera unit, electrical circuit and operation are given and photographs are presented to show partial and complete assembly. The performance of the unit is given for measurements on 230 kV. and 15 kV. systems together with the procedure adopted when making tests.

—*El. Engg.*, May, 1943, p. 231.*

A New High-Speed Recurrent Surge Oscillograph

(E. L. White)

A description is given of the principal features of the E.R.A. recurrent surge oscillograph. The instrument incorporates a hot-cathode, low-voltage, cathode-ray tube with balanced electrostatic deflection, the deflecting voltages being produced by a thyratron-controlled time base with a wide range of sweep speeds. A single transient or recurrent transients from an external source can be recorded on this oscillograph and the case of the capacity spark of a magneto ignition system is given. Oscillograms obtained in the investigation of the transmission of surges through a transformer winding are shown.

—*Jour. Sci. Inst.*, Vol. 20 (1943), p. 125.*

INDUSTRY

Apparatus for the Detection of splits in Tungsten Wire

(D. T. O'Dell)

The paper describes an electrical apparatus for the detection of fine longitudinal splits in tungsten wire. It has proved to be much more rapid in operation than the usual method of examination under a low-power microscope.

—*Jour. Sci. Inst.*, Vol. 20, No. 9 (1943), p. 147.

Detecting Small Mechanical Movements

(J. C. Frommer)

An improved vacuum tube current for detecting mechanical movements as small as a millionth of an inch is described. These movements are converted into capacitance changes of the order of $0.01 \mu\mu F$. Accuracy is claimed to be high because variations in oscillator and cable characteristics are nullified by the insertion of a displacement unit between the R.F oscillator and amplifier. The amplifier is stated to have been used successfully for measuring blood pressure curves; various industrial uses are suggested.

—*Electronics*, July, 1943, p. 104.*

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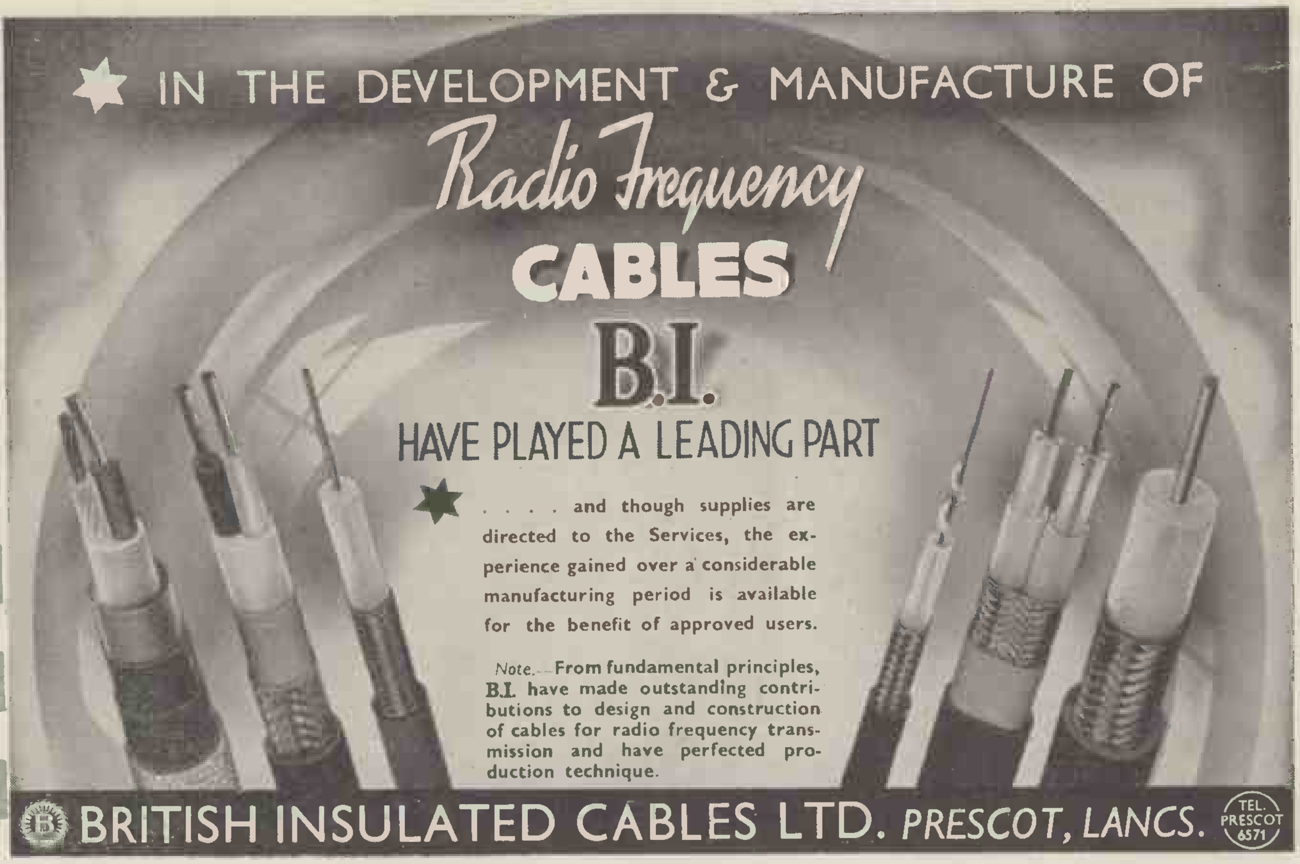
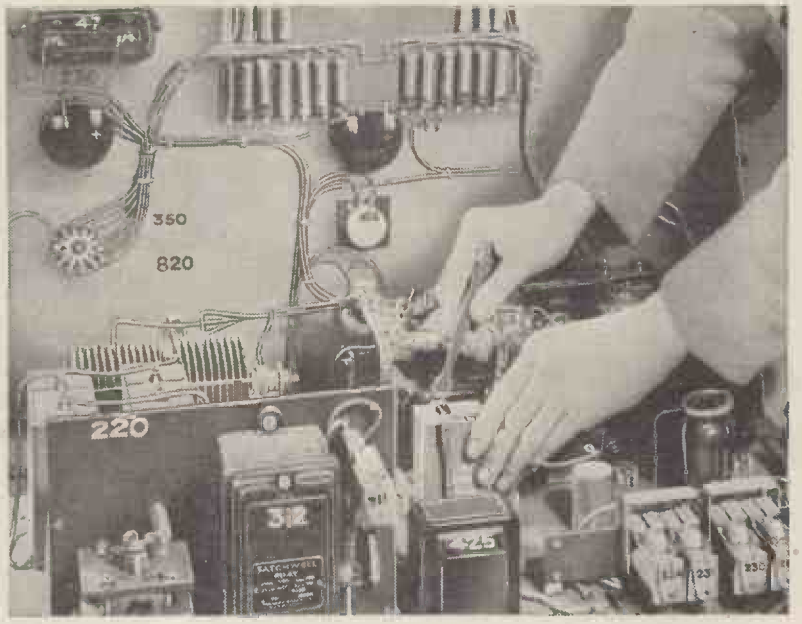
* Supplied by the courtesy of Metropolitan-Vicker Electrical Co. Ltd., Trafford Park, Manchester.

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BOOK REVIEWS

Synthetic Resins and Allied Plastics

(2nd. Edition) Edited by R. S. Morrell, Sc.D., F.I.C. 552 pp. 59 figs. (Sir Humphrey Milford — Oxford University Press; 35s. net.)

The first edition of this book appeared in 1937, and, as the editor says in the preface to the second edition, the range of the subject has now become so wide that it requires a number of contributors to do it justice.

The authoritative nature of this book is indicated by naming a few of the authors of the sections: Dr. Yarsley on protein and cellulosic plastics; Dr. Redfarn on phenol- and urea-formaldehyde resins; Dr. Rowland Hill on vinyl and acrylic acid resins; Mr. E. G. Couzens on testing and identification of plastics; and Mr. Langton has written a general introduction besides sections on ester gums and coumarone resins.

A separate chapter is devoted to the electrical testing of resins used for electrical work, including the various bituminous compounds, rubbers, and varnishes. Each section is followed by a full bibliography of references amounting to several hundred in some cases.

The section on the testing and identification of synthetic resins and raw materials is particularly useful and should enable any physicist or engineer to determine approximately the nature of an unknown plastic material without difficulty.

As a reference book for works libraries it is unreservedly recommended, and many users of plastics in industry will wish to possess a copy for themselves.

Worked Radio Calculations

A. T. Witts. 121 pp. (Sir Isaac Pitman & Sons. 6s. 6d. net.)

The author has set out three hundred graded worked-out examples in this book, commencing with Ohm's Law and concluding with gain of amplifiers and calculation of input capacitance.

Explanatory notes have not been given except where clarity demands them, as the book is intended to be an accompaniment to a course in radio theory in which the student will already have the principles explained.

Apart from its obvious value to training classes, this book should prove particularly useful to home-study workers and service engineers who may have a problem to solve in connexion with their everyday work.

Classified Radio Receiver Diagrams

E. M. Squire. 161 pp. 332 figs. (Sir Isaac Pitman & Sons, 10s. 6d. net.)

This might be considered a companion volume to the author's "Radio Receiver Circuits Handbook" which gave comprehensive notes on the theory of various basic circuits. In the present volume the aim has been to give a classified selection of practical circuits, all of which have been employed in actual receivers. Values of components are also given wherever possible.

Some useful chapters apart from the usual ones dealing with the stages in the receiver are: Volume Control circuit; Tone Control circuits; Push-button Tuning circuits; and Automatic Frequency control.

The diagrams are well drawn and the whole book provides a useful work of reference to the working of modern radio equipment.

Books reviewed on this page or advertised in this Journal, can be obtained from

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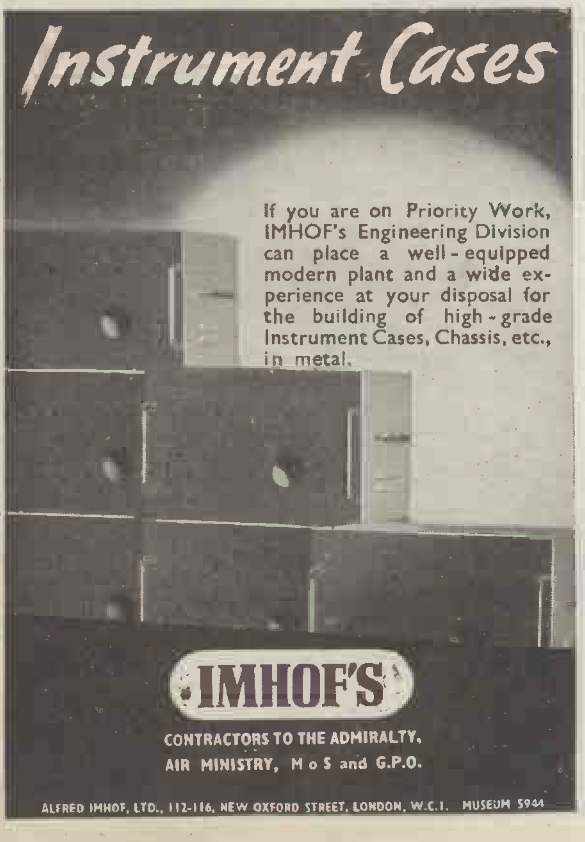

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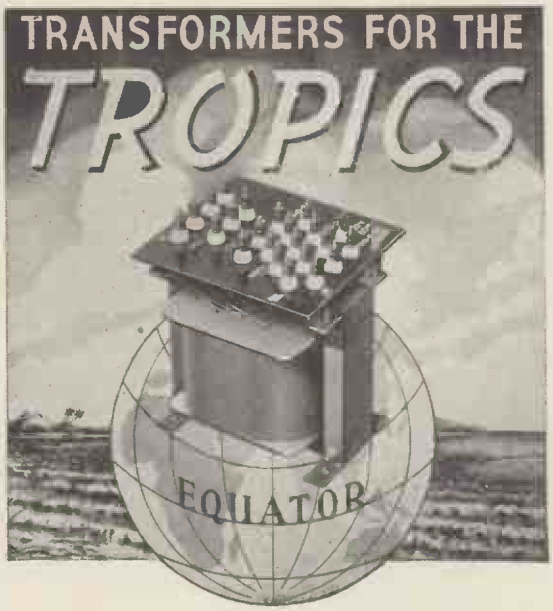
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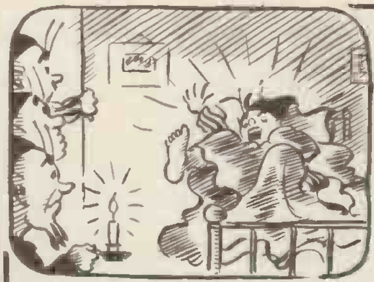

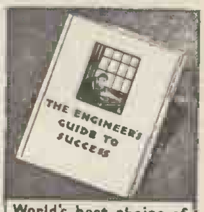
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