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Editorial.

The Copper-Oxide Rectifier.

CONSIDERABLE interest was aroused at the National Radio Exhibition in the copper-oxide rectifier, or electronic rectifier, as it is called in the article by Grondahl and Geiger describing its construction and properties in the March number of the *Journal of the American Institute of Electrical Engineers*. The phenomenon upon which the rectifier is based was reported to the American Physical Society by Grondahl in April, 1926. It was found that if a layer of oxide was formed on a sheet of copper and contact made by a piece of lead pressed

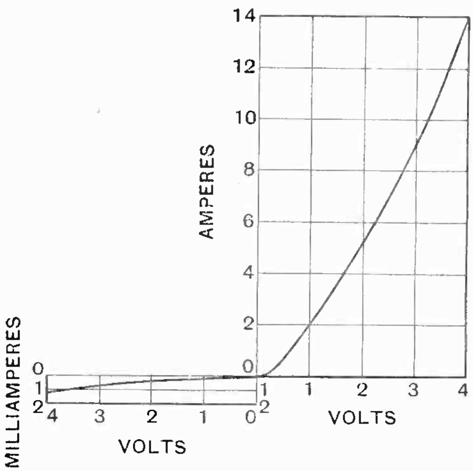


Fig. 1. *Characteristic curve of the rectifier.*

against the oxide, the resistance to current passing from the lead to the copper was less than that to current flowing in the other direction. This is shown in the characteristic curve reproduced in Fig. 1, in which it will be noted that the current scale in one direction is in amperes and in the other in milliamperes. The reverse current is very small, but the low resistance does not set in until about half a volt is applied. For an applied voltage of 4 or 5 volts the resistance in one direction is about 12,000 times that in the other. The efficiency of rectification is very poor for small currents but rises rapidly as the current is increased; the lower limit of the current for efficient rectification can be reduced by reducing the cross-section of the rectifier.

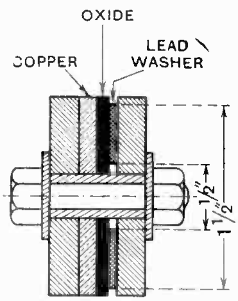
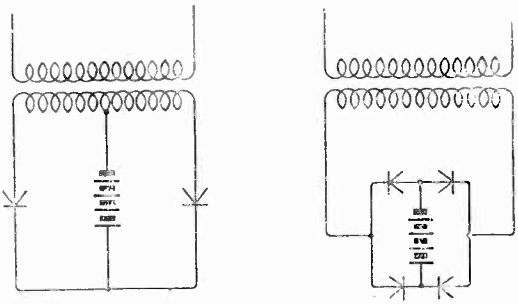


Fig. 2. *Method of clamping the electrodes of the rectifier.*

In practice, the rectifier is built up in a very robust and simple form by threading the copper disc with oxidised face on a bolt and clamping a leaden ring against the oxide face by means of a nut with suitable insulating tubes and washers. Such a unit is shown in Fig. 2. Two of these can be used in conjunction with a tapped secondary transformer, as shown in Fig. 3 (a). Another arrangement is shown in Fig. 3 (b), the four rectifiers for which can be assembled as a single unit, as shown in Figs. 4 (a) and (b).



Figs. 3 (a) and (b). *Circuits showing how the units can be used in conjunction with transformers.*

The unit shown in Fig. 2 is suitable for about 6 volts and a current depending on the area of cross-section and the cooling facilities. If the current density exceeds 2 amperes per square inch forced ventilation or oil immersion is necessary. A unit with ventilating

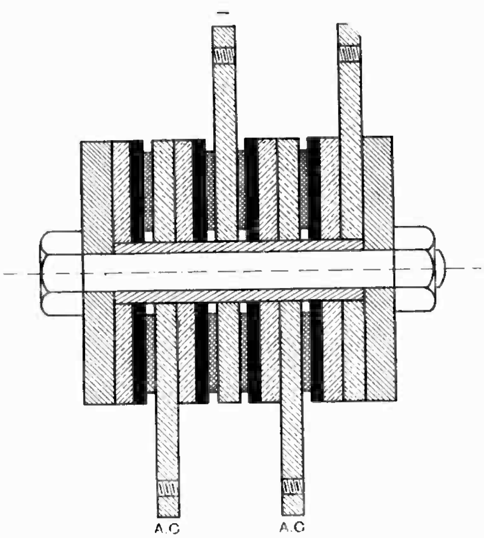


Fig. 4 (a). *Sectional drawing.*

fins and immersed in oil can carry $3\frac{1}{2}$ amperes per square inch.

If properly designed for the output required, efficiencies of 80 per cent. and over can be obtained but efficiencies between 50 and 70 per cent. are more common.

No satisfactory explanation has been found for the rectifying action which appears to occur at the junction of the copper and the thin film of oxide which is usually only about 0.001 inch thick.

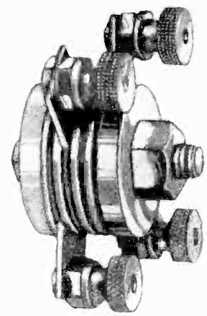


Fig. 4 (b).

Photograph of the unit shown in section in Fig. 4 (a).

This type of rectifier has obvious advantages over other types in the absence of liquid to spill or evaporate, in the absence of moving parts to get out of order or of valves to burn out. It may be that the copper oxide rectifier has troubles of its own, however; if so we shall doubtless hear of them. It

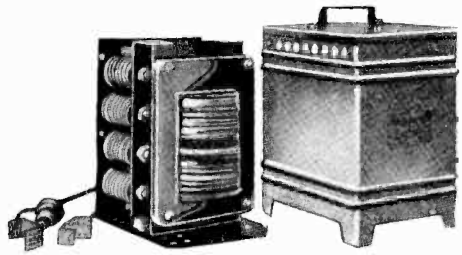


Fig. 5. *Battery charging unit removed from its case, showing the transformer mounted with it.*

is being made for many purposes; Fig. 5 shows a 2-ampere, 6-volt battery charging

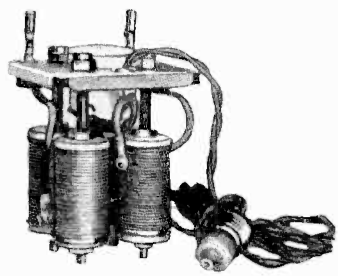


Fig. 6. *Columns of discs for a H.T. battery charger.*

unit in which the rectifying units can be seen on the side of the transformer; Fig. 6 shows the columns of discs constituting the rectifier for a H.T. battery charger.

The Stability of the Tuned-Grid Tuned-Plate H.F. Amplifier.

By R. T. Beatty, M.A., B.E., D.Sc.

HIGH-FREQUENCY reaction, the mainspring of the great majority of receiving sets, an agent which can exalt a whisper to loud-speaker level, which can conceal losses due to unworthy components and unskilled construction, and which can confer high selectivity on the flattest of resonance curves, is yet a quantity to which a numerical value can seldom be attached.

Otherwise the constituents which contribute to the total amplification are known tolerably well. The voltage gain due to a tuned grid circuit, the gain from grid to plate of a valve, the step-up of a transformer are confidently given in figures, but reaction, which is itself a gain exceeding any of these, remains vague.

The reason is simple enough. When a reaction coil is brought from the plate circuit to transfer energy to the grid coil, the transference depends on the mutual inductance between these two coils, which itself depends on the geometry of each coil and on their relative positions. *Mutual inductance is a quantity which the experimenter finds intolerably tedious to calculate and difficult to measure.*

But when tuned-grid tuned-plate circuits are used and reaction is due to capacity, either introduced between grid and plate or already existing there between the valve electrodes, the matter becomes much more simple. Such a capacity is not difficult to measure and is easy to guess and a numerical value for the extra gain due to reaction can readily be assigned. It is true that with three-electrode valves an unneutralised amplifier of this kind can be relied on to do one thing only, that is to oscillate continuously and mercilessly, but the advent of the shielded-plate valve, with its very low residual plate-grid capacity, has altered the situation completely and high frequency amplifiers can now be built with perfect stability and with reaction which is under control and calculable.*

1. Conductance is Preferable to Resistance.

At this point some readers will say: "These calculations are not as easy as you think: we have seen some before, and they have depressed our spirits considerably." Quite so, I have seen a formula for voltage amplification with capacity reaction which extended over several lines of a radio journal: it was stately and agonising.† But there is a rule for avoiding complicated formulæ and it is this:—

In the case of an amplifier with tuned circuits never allow a resistance to appear in a formula. Replace it by the corresponding conductance.

Conductance = 1/resistance or $\sigma = 1/R$.

Further, when a series resistance appears in a tuned circuit replace it by a parallel conductance. Thus r in series with $L\omega$ is equivalent to a resistance $L^2\omega^2/r$ in parallel with $L\omega$ and this should be expressed as a conductance $\sigma = r/L^2\omega^2$.

Ohm's law will now appear in the form $i = e\sigma$ instead of the usual form $e = iR$.

2. A Typical Parallel Circuit.

This is shown in Fig. 1. An E.M.F. e is placed in parallel with a coil, condenser, and conductance. The current i is equal to the sum of the three currents flowing downwards through these three elements. Hence

$$i = e[\sigma + jC\omega - j/L\omega] \quad .. \quad (1)$$

In Fig. 1 σ is drawn horizontally and $C\omega - 1/L\omega$ vertically.

* A list of the symbols employed is given at the end of the article.

† But neither grateful nor comforting.

Then $\tan\theta = t = [C\omega - 1/L\omega]/\sigma$
and equation (1) becomes

$$i = e\cdot\sigma[1 + jt] \quad .. \quad (2)$$

t is the tangent of the phase angle θ by which the current leads the E.M.F. When $t = 0$ the circuit is tuned to the incoming frequency, the LC circuit forms a barrier of infinite impedance and there remains only a pure

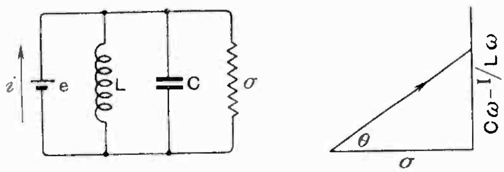


Fig. 1. *A typical parallel circuit.*

conductance σ so that $i = e\sigma$ as is evident from equation (2).

The coefficient of e in equation (1) is a vector operator and Fig. 1 shows that it is represented in magnitude and direction by the sloping side of the triangle. It is called the admittance of the circuit.

3. The Tuned-grid, Tuned-plate Circuit.

This is shown diagrammatically in Fig. 2, e is the high frequency signal voltage injected in series with the grid coil L_1, we

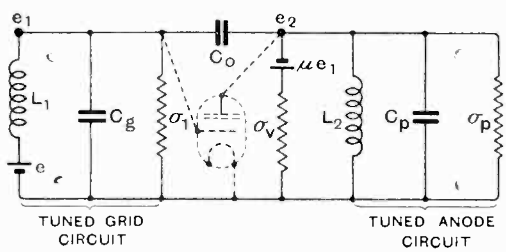


Fig. 2. *A high-frequency tuned-grid tuned-plate amplifier, showing ~ voltages. The valve is replaced by a generator of ~ E.M.F. μe_1 with series conductance σ_v.*

suppose that it is produced by a loosely coupled untuned aerial coil; e_1 and e_2 are the alternating grid and plate voltages; the valve is represented by a generator of E.M.F. μe_1 where μ is the valve amplification factor, in series with a conductance σ_v, the reciprocal of the valve differential resistance. C_0 is the grid-plate valve capacity. The tuned grid circuit is $L_1 C_g \sigma_1$; the tuned plate circuit is $L_2 C_p \sigma_p$. As emphasised in section (2) parallel conductances are used instead of series resistances.

We will now derive a single expression giving the ratio of e_2 to e, that is the overall amplification produced by this single stage set. To do this we dissect Fig. 2 into two parts as in Figs. 3 and 4: each part will

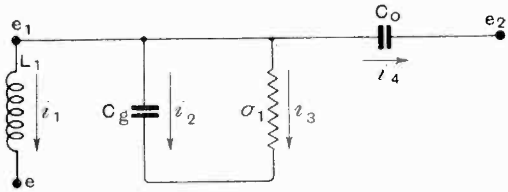


Fig. 3. *Component parts of Fig. 2.*

supply an equation connecting e_1 e_2 and e and on eliminating e_1 from these two equations the ratio of e_2 to e will emerge as a fairly simple quantity.

4. The Equations of the Amplifiers.

We know that in any circuit the sum of all the currents flowing away from any point must be zero. In Fig. 3 the sum of the currents flowing away from the point e_1 is $i_1 + i_2 + i_3 + i_4 = 0$. Replacing each current

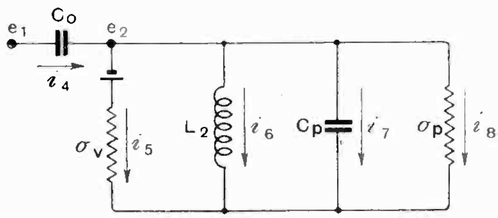


Fig. 4.

by its corresponding P.D. multiplied by an admittance we get

$$[e_1 - e]/j\cdot L_1\omega + e_1\cdot j\cdot C_g\omega + e_1\cdot\sigma_1 + [e_1 - e_2]j\cdot C_0\omega = 0 \quad (3)$$

which may be written

$$e_1[\sigma_1 + (C_g + C_0)j\omega - j/L_1\omega] - e_2\cdot j\cdot C_0\omega = -e\cdot j/L_1\omega \quad (4)$$

Evidently C_g and C_0 can be lumped together: put $C_g + C_0 = C_1$, then the expression in square brackets is of the same form as that in equation (1) and so can be expressed as in equation (2).

Hence

$$e_1 \cdot \sigma_1[1+jt_1] - e_2 \cdot j \cdot C_0\omega = -e \cdot j/L_1\omega \quad (5)$$

where $\quad t_1 = [C_1\omega - 1/L_1\omega]/\sigma_1 \quad .. \quad (6)$

Similarly in Fig. 4 the sum of all the currents flowing away from the point e_2 is

$$-i_4 + i_5 + i_6 + i_7 + i_8 = 0.$$

Replacing each of these by its corresponding P.D. multiplied by an admittance we get

$$-[e_1 - e_2]\, j \cdot C_0\omega + [e_2 + \mu e_1]\sigma_v + e_2 [1/j \cdot L_2\omega + j \cdot C_p\omega + \sigma_p] = 0 \quad (7)$$

which may be re-written as

$$e_2[\sigma_p + \sigma_v + (C_p + C_0)j\omega - j/L_2\omega] + e_1[\mu\sigma_v - j \cdot C_0\omega] = 0 \quad (8)$$

σ_p and σ_v can be lumped together, also C_p and C_0; put $\sigma_p + \sigma_v = \sigma_2$, $C_p + C_0 = C_2$. Then the coefficient of e_2 is of the same form

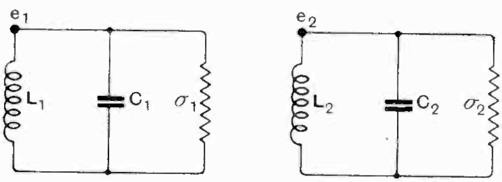


Fig. 5. *The equivalent grid and plate circuits.*

as that in equation (1) and so can be expressed as in equation (2). Accordingly it may be written as $e_2 \cdot \sigma_2[1+jt_2]$.

Again, considering the coefficient of e_1 in equation (8) $\mu\sigma_v$ is the mutual conductance g of the valve, while the term $C_0\omega$ is negligible compared with g.*

Hence when these substitutions are made equation (8) becomes

$$e_2 \cdot \sigma_2[1+jt_2] + e_1 \cdot g = 0 \quad .. \quad (9)$$

where $\quad t_2 = [C_2\omega - 1/L_2\omega]/\sigma_2 \quad .. \quad (10)$

In equations (6) and (10) C_1 C_2 σ_2 are lumped quantities so that we are dealing with equivalent circuits (Fig. 5) which represent the grid and anode circuits somewhat modified. The inductances remain unaltered in Fig. 5, but each capacity has been slightly increased by the amount C_0 while the conductance of the plate circuit has been considerably increased by the addition of the valve differential conductance.

Equations (5) and (9) with their auxiliary equations (6) and (10) are the fundamental equations of the amplifier. They refer to two equivalent circuits shown in Fig. 5, from which the valve has disappeared. The mutual action between these two circuits is completely specified by equations (5) and (9). The tangents of the phase angles of the circuits are t_1 t_2.

6. The Overall Amplification.

Write down equations (5) and (9) together, *i.e.*,

$$e_1 \cdot \sigma_1[1+jt_1] - e_2 \cdot j \cdot C_0\omega = -e \cdot j/L_1\omega$$
$$e_1 \cdot g + e_2 \cdot \sigma_2[1+jt_2] = 0.$$

multiply the upper by g and the lower by $\sigma_1[1+jt_1]$ and subtract; e_1 will disappear and we have

$$e_2[\sigma_1\sigma_2(1+jt_1)(1+jt_2) + j \cdot g \cdot C_0\omega] = e \cdot j \cdot g/L_1\omega \quad .. \quad (11)$$

This may be written as

$$e_2/e = j \cdot A \cdot F \quad .. \quad .. \quad (13)$$

where $\quad 1/F = (1+jt_1)(1+jt_2) + j \cdot H \quad .. \quad (14)$

$$H = g \cdot C_0\omega/\sigma_1\sigma_2 \quad .. \quad .. \quad (15)$$

$$A = g/L_1\omega \cdot \sigma_1\sigma_2 \quad .. \quad .. \quad (16)$$

A and H are numbers whose values are fixed by the constants of the circuits. F is a vector whose magnitude and direction are fixed partly by H, which depends only on circuit constants, and partly by t_1 and t_2 which depend on the tuning of the circuits due to moving the grid and plate condensers.

Equation (13) with its auxiliary equations (14, 15, 16) gives the overall amplification of the receiver shown in Fig. 2, expressed as a vector operator. It will be shown in the following sections that A is the amplification which would exist if back coupling were absent and the circuits tuned to the incoming signal, while F is the extra gain due to reaction. It will also appear that F and H can be represented on a parabola, from which the gain due to reaction can be read off by inspection.

* Thus taking
$C_0 = 1\mu\mu\text{F}$, $\omega = 10^7$, $g = 10^{-3}$ amps./volt.,
we have $C_0\omega = 10^{-12} \times 10^7 = 10^{-5}$ which is only 1 per cent. of g.

7. The Geometrical Meaning of F.

The expression $(1 + jt_1)\ (1 + jt_2) + j \cdot H$ which occurs in equation (14) can be put on a diagram as follows: $1 + jt_1$ is the vector ST (Fig. 6) obtained by rotating a unit vector SV in an anti-clockwise direction through an angle θ_1 where $t_1 = tan\ \theta_1$ and producing it till it meets the vertical line VT.

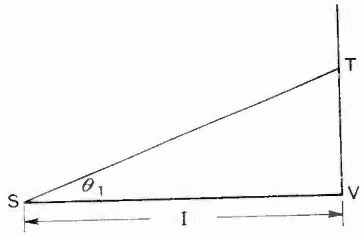


Fig. 6.

The next step is to multiply this vector ST by $1 + jt_2$. This is done (Fig. 7) by rotating ST through an angle $\theta_2\ (t_2 = tan\ \theta_2)$, and producing it till it meets TR, the line drawn from T at right angles to ST. Hence SR represents $(1 + jt_1)\ (1 + jt_2)$. jH is a vertical vector PS (Fig. 8).

Accordingly $(1 + jt_1)\ (1 + jt_2) + j \cdot H$ is the vector sum of PS and SR, *i.e.*, PR. Hence $1/F$ is the vector PR.

Now, considering Fig. 8 more closely, we see that while H is fixed by the circuit

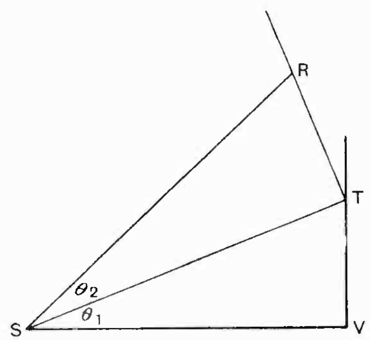


Fig. 7.

constants, as equation (15) shows, SR depends on the values of t_1 and t_2: that is on the settings of the grid and plate equivalent condensers. If t_1 is fixed, then as t_2 is varied R will move along the line TR; if t_1 is varied the line TR itself will assume different positions as shown in Fig. 9.

So when we try to draw the vector PR we find that although one end P is fixed and definite the other end R may lie on any one of a maze of lines $T_1R_1\ T_2R_2$, etc., according to the settings of the tuning condensers.

The situation now seems desperate till we recollect that this maze of lines has an important property: every line touches a fixed parabola whose focus is at S and which is shown in Fig. 9, so that the point R, though it may lie *outside* or *on* the parabola, can never get *inside*.

We are only concerned with setting the tuning condensers to make F as *large* as

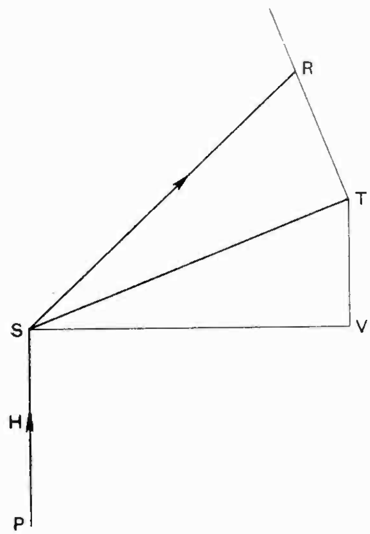


Fig. 8.

possible, or, since the vector PR equals $1/F$, to make PR as *small* as possible. Accordingly R should lie on the parabola in any case, and should be pushed along the parabola till it gets as close as it can to P. It is evident that we could get closer by using the other half of the parabola, as in Fig. 10, that is the phase angles θ_1 and θ_2 should both be negative and hence from equations (6) and (10) the tuned circuits should be on the inductive side of resonance—the condenser values should be smaller than the resonance values.

PR is smallest when it is the normal from P to the parabola. This smallest value of $1/F$ will be called $1/F_0$.

8. The Geometrical Meaning of H and F_0.

When the constants of the circuits are given so that H and A may be calculated from equations (15) and (16) the maximum

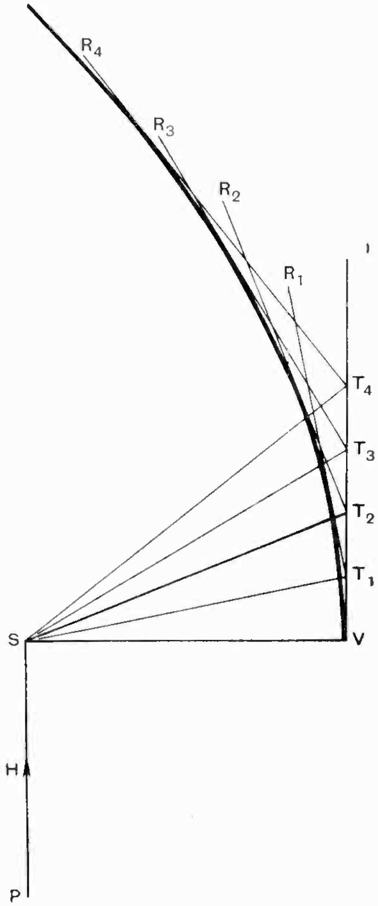


Fig. 9.

gain F_0 due to reaction is found as follows: In the parabola $y^2=4x$ (Fig. 10) draw a vertical line PS to the focus equal to H and from P draw the normal PR. Then $F_0=1/PR$.

When no feedback exists, *i.e.*, when C_0 is zero, H is zero (equation 15), so that the point P coincides with S (Fig. 10). The normal from S is the line SV and its length is unity, so that $F_0=1$ and the phase angles θ_1 and θ_2 are zero. That is the tuning condensers should be set for resonance in this case. Also since $F_0=1$ the overall amplification (equation 13) is A.

A is the maximum amplification which can be obtained without the help of reaction. Its value is given by equation (16). F_0 is the extra gain due to reaction. Its value is found by the geometrical construction of Fig. 10. The overall amplification has the arithmetical value AF_0.

9. A Numerical Example.

Let the incoming signal be of frequency 2,070 kilocycles and assume that in Fig. 2 the grid and plate circuits are identical, with the values $\sigma_g=\sigma_p=3.2\times10^{-5}$ mhos* and $L_1\omega=L_2\omega=1{,}000$ ohms. The constants of the valve are taken as $g=8\times10^{-4}$ amps/volt. $\sigma_v=8\times10^{-6}$ mhos.

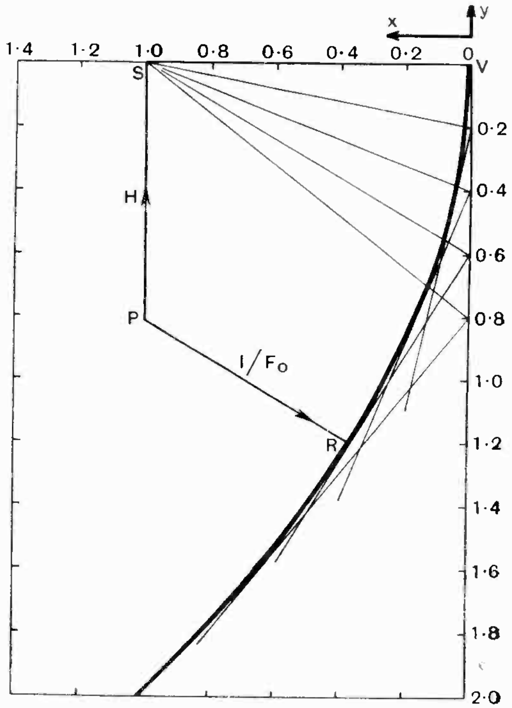


Fig. 10. *By means of a parabola* F_0 *can be found when* H *has been calculated.*

$C_0=0.1\mu\mu$F: we are using a shielded plate valve which accounts for the low value of C_0.

* If the shunt conductance in each tuned circuit in Fig. 2 is actually due to a resistance r in series with the coil then $\sigma=r/L^2\omega^2$ (see section 2). If $r=32$ ohms, $\sigma_g=\sigma_p=32/10^6=3.2\times10^{-5}$ mhos.

The tabulated values are

$\omega = 2\pi \times 2.07 \times 10^6$ *radians/sec.*

$\sigma_1 = 3.2 \times 10^{-5}$ mhos.

$\sigma_2 = \sigma_p + \sigma_v = 4 \times 10^{-5}$ mhos.

$g = 8 \times 10^{-4}$ amps/volt.

$C_0 = 10^{-13}$ farad.

$L_1\omega = 1{,}000$ ohms.

Equation (15) gives

$$H = \frac{8 \times 10^{-4} \times 10^{-13} \times 2\pi \times 2.07 \times 10^6}{3.2 \times 4 \times 10^{-10}} = 0.816.$$

making $H = 0.816$ on the parabola in Fig. 10, and drawing the corresponding normal, we find

$F_0 = 1/\text{length of normal} = 1.31.$

From equation (16)

$A = 8 \times 10^{-4}/10^3 \times 3.2 \times 4 \times 10^{-10} = 625.$

Hence the overall amplification AF_0 is $625 \times 1.31 = 819$.

9. The Threshold of Instability.

As H increases, PR diminishes (Fig. 10) and as H approaches 2, PR approaches zero and therefore F_0 approaches infinity. When P has travelled downwards till it lies on the parabola the amplifier is on the threshold of instability, and for values of H greater than 2, self-oscillation will occur. Thus, in the numerical example just given, if C_0 were $0.3\mu\mu F$ instead of $0.1\mu\mu F$, H would be equal to 2.4 and instability would result. Stability could be regained by reducing g to about one-third its value by dimming the filament or by increasing the shunt conductance of the grid and anode circuits to make $\sigma_g = \sigma_p = 5.5 \times 10^{-5}$ mhos. The reader can easily verify these results for himself.

10. The Voltage Gain from Grid to Plate without Reaction (stage gain).

The gain A from injected signal to plate may be split up into two parts, the gain from signal to grid and the gain from grid to plate. Equation (9) shows that this latter gain e_2/e_1 is equal to $g/\sigma_2[1 + jt_2]$ which has its maximum value g/σ_2 when the plate condenser is set at resonance. In the numerical example given above, the gain from grid to plate is $8 \times 10^{-4}/4 \times 10^{-5} = 20$.

From the value for A given by equation (16) it is evident that since g/σ_2 represents the gain from grid to plate, the gain from signal to grid must be $1/L_1\omega \cdot \sigma_1$ or (if the resistance is r in series with $L_1\omega$) the more familiar expression $L_1\omega/r$.

In the example, where $L_1 = 1{,}000$ ohms, $r = 32$ ohms, the gain $= 1{,}000/32 = 31.25$ and hence $A = 31.25 \times 20 = 625$ as given above.

The overall amplification AF_0 can be divided into three parts. (1) The gain from injected signal to grid $1/L_1\omega.\sigma_1$ or $L_1\omega/r$; (2) the gain from grid to plate g/σ_2, (3) the gain F_0 due to reaction calculated from equation (15) and the construction shown in Fig. 10.

11. How to find F_0 when the Stage Gain is Specified.

We are now in a position to answer an important question. *What gain due to reaction do we get at any particular frequency when the stage gain e_2/e_1 is specified?* For example, if, as in section (11), the stage gain is 20, how do we find the value of F_0?

Equation (15) gives $H = g \cdot C_0\omega/\sigma_1\sigma_2$. Let us call the stage gain G then as in section (11) $G = g/\sigma_2$ so that we can eliminate σ_2 by replacing it by g/G. Again, as in the example in section (9) $\sigma_2 = \sigma_1 + \sigma_v = g/G$, so that σ_1 can be replaced by $g/G - \sigma_v$.

Hence $$H = \frac{G \cdot C_0\omega}{\frac{g}{G} - \sigma_v} \quad .. \quad (17)$$

Equation (17) *gives H when G the stage gain and ω are specified.* F_0 can then be read off from Fig. 10. The reader may work out a numerical example using the data given in section (9). $G = 20$ from this data and H will prove to be 0.816, leading to $F_0 = 1.31$.

12. Curves of Constant Reaction for the Standard Valve.

Equation (17) enables us to plot curves of constant F_0 on a logarithmic diagram where the abscissa is frequency and the ordinate is the stage gain. It is convenient to plot the frequency k in megacycles (millions of cycles): that is, we put

$$\omega = k\Omega \quad .. \quad .. \quad (18)$$

where $\Omega = 2\pi \times 10^6$

If now we rearrange equation (17) for ease in calculation and replace ω by $k\Omega$ we get

$$k/H = g[1 - G \cdot \sigma_v/g]/G \cdot C_0 \cdot \Omega \quad ... \quad (19)$$

With the valve which is taken as standard and whose constants are given in the list of symbols at the end of this paper, this becomes

$$k/H = 1.27 \times 10^3[1 - G/100]/G^2 \quad \ldots \quad (20)$$

Equation (20) gives the relation between G, the stage gain, and k, the frequency in megacycles, for any fixed value of H. In Fig. 11 two curves of constant reaction are show how this can be done. All that is necessary is to make a slight re-arrangement in equation (19) as follows :—

$$[k/H]\,[C_0 \cdot \Omega \cdot g/\sigma_v^2] = [1 - G \cdot \sigma_v/g]\,g/G \cdot \sigma_v \quad (21)$$

Observe that on the right-hand side $G\sigma_v$ and g only occur as the quantity $G \cdot \sigma_v/g$ so that if, for example, g and G are each doubled the right-hand side will be unchanged. Similarly, if on the left-hand side g is doubled

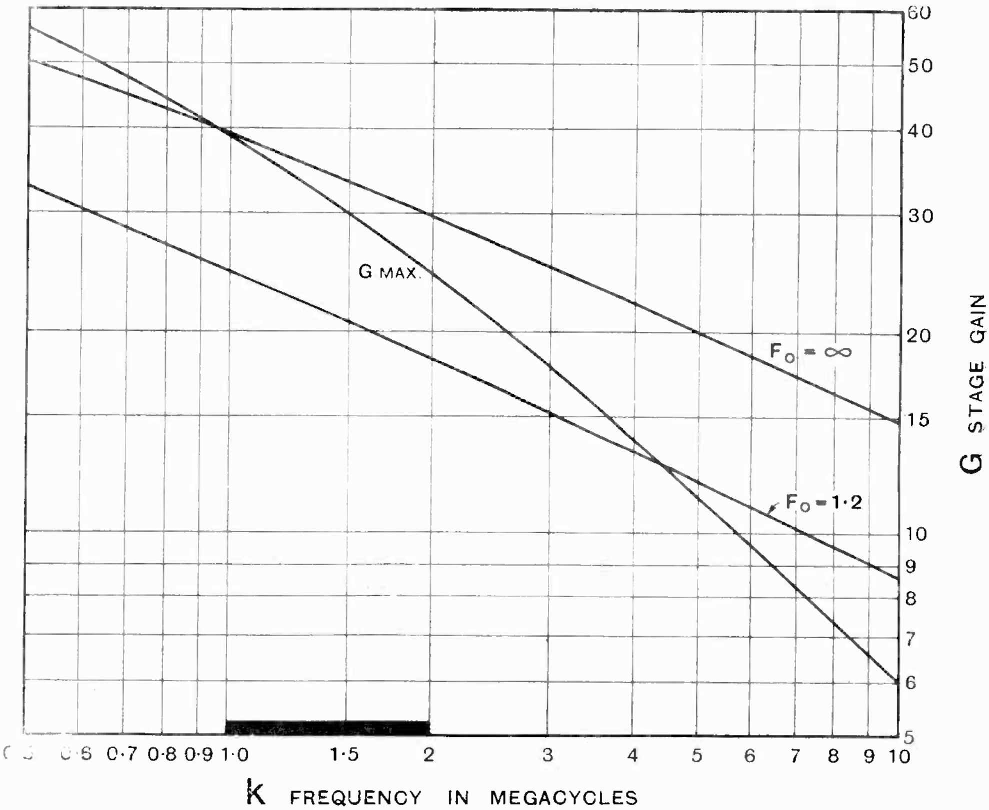


Fig. 11.

plotted one for $H=2$ (F_0=infinity) and one for $H=.625$ ($F_0=1.2$). These curves refer to the valve which is taken as standard in this paper.

13. Curves of Constant Reaction for any Valve.

Fig. 11 would be enormously more useful if the curves could be easily altered to suit *any* valve, whether of the 3-electrode or the shielded-plate type, and we will now and k is halved no change will be produced. Accordingly, if we take the point $k=2$, $G=30$ in Fig. 11 and then replace the valve used by one whose mutual conductance is twice as great, the point will shift to one where $k=1$ $G=60$.

Now, on a logarithmic diagram an ordinate is doubled by raising the point by an amount equal to the distance from 1 to 2 (or the equal distance 10 to 20). Similarly an abscissa is halved by displacing the point to the left by an amount equal to the distance from 1 to 0.5 (or the equal distance 10 to 5). Thus every point on the curve $F_0=\infty$ must be raised an amount equal to the length of the bar shown at the bottom of Fig. 11 and simultaneously moved to the left by an equal amount. That is, as shown in Fig. 12, the curve must be displaced to the north-west by the amount shown by the arrow g. Again, if σ_v is doubled equation (21) shows that the right-hand side will be unaltered if G is halved, the left-hand side if k is increased four times. Thus the curve must be shifted as shown by arrow σ_v (Fig. 12). All possible shifts are shown in Table I.

TABLE I.

Change from standard valve where $g=8\times10^{-4}$ amps/volt, $\sigma_v=8\times10^{-6}$ mhos, $C_0=0.1\mu\mu$F	Factors by which k and G must be multiplied.	
	k	G
g doubled	½	2
σ_v doubled	4	½
C_0 doubled	½	1
H doubled	2	1

Fig. 11 does not extend far enough since if at $k=10$ megacycles we wish to move a curve to the left there will be no curve left at this point. Accordingly Fig. 13 has been drawn giving a greater range of k and G.

Further, since we are not interested in H so much as in F_0 a scale of F_0 has been drawn below Fig. 13. To pass from the curve $F_0=\infty$ to, say, $F_0=2$, displace the former curve to the left by an amount equal to the distance between ∞ and 2 on this scale.

Fig. 13 shows the curves of constant reaction for the valve whose constants are given in Table I. For any other valve slide the curve in question parallel to itself according to the rules given in Table I and indicated n Fig. 12. To pass from any F_0 curve to any other use the F_0 scale below Fig. 13.

Discussion of Curves of Constant Reaction.

Let us consider a valve in which the designer has succeeded in reducing C_0 to .01$\mu\mu$F. From Table I or Fig. 12 we see that since C_0 is diminished 10 times k must be increased 10 times; each F_0 curve must slide to the right over a distance equal to the interval from $k=1$ to $k=10$. This can be easily done by placing tracing paper on Fig. 13 and marking the point $k=1$ $G=10$. Then slide the paper to the *left* till the mark is on $k=0.1$; draw the curve $F_0=\infty$ and slide the tracing back to its original position; it will be found that the new threshold curve is almost clear of the diagram so that the set would remain stable even if $G_{max.}$ could be raised to 50 at frequencies up to $k=5$.

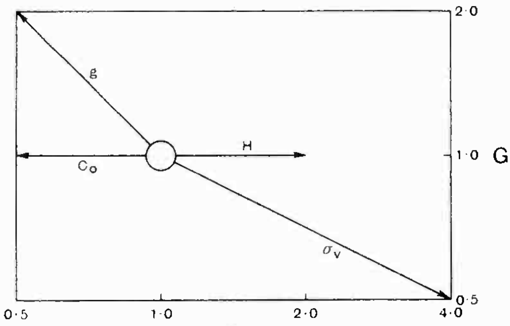


Fig. 12. *Shift of curves of constant reaction when any constant is doubled.*

Again, suppose g σ_v and C_0 each trebled: we must multiply k in succession by 1/3, 9, and 1/3, while the multipliers for G are 3, 1/3, and 1. The result is that k and G are unchanged, no shift of the F_0 curves results. Fig. 12 shows the same thing: each vector must be increased by 50 per cent. and the vector sum of the three adds up to zero showing that no displacement of the curve is to be made.

15. Practical Limitations to the Stage Gain G.

The maximum possible stage gain is determined by the maximum plate load which can be built up: at resonance this is a pure resistance of magnitude $L^2\omega^2/r$. For any given coil in a given copper screen box, the ratio $L\omega/r$ remains fairly constant at different frequencies, the increase in the H.F. resistance r keeping pace with the increase in ω, and may have some value from 50 to 100 according to the coil and screen used. Since the coil possesses self-capacity its $L\omega$ cannot be made greater than that which will make it resonate at the desired frequency without any condenser, but we cannot attain this value in practice on account of the difficulty which would be found in tuning. Thus, if the stray capacity is $5\mu\mu F$ and at 1,000 kilocycles we wish to tune to a station 10 kilocycles away we must add a capacity of only $0.1\mu\mu F$. *Such a razor-edged set would be impossible to work.* Accordingly we must add ballast capacity for the sake of uniform and easy tuning. In constructing a set to deal with the *total*

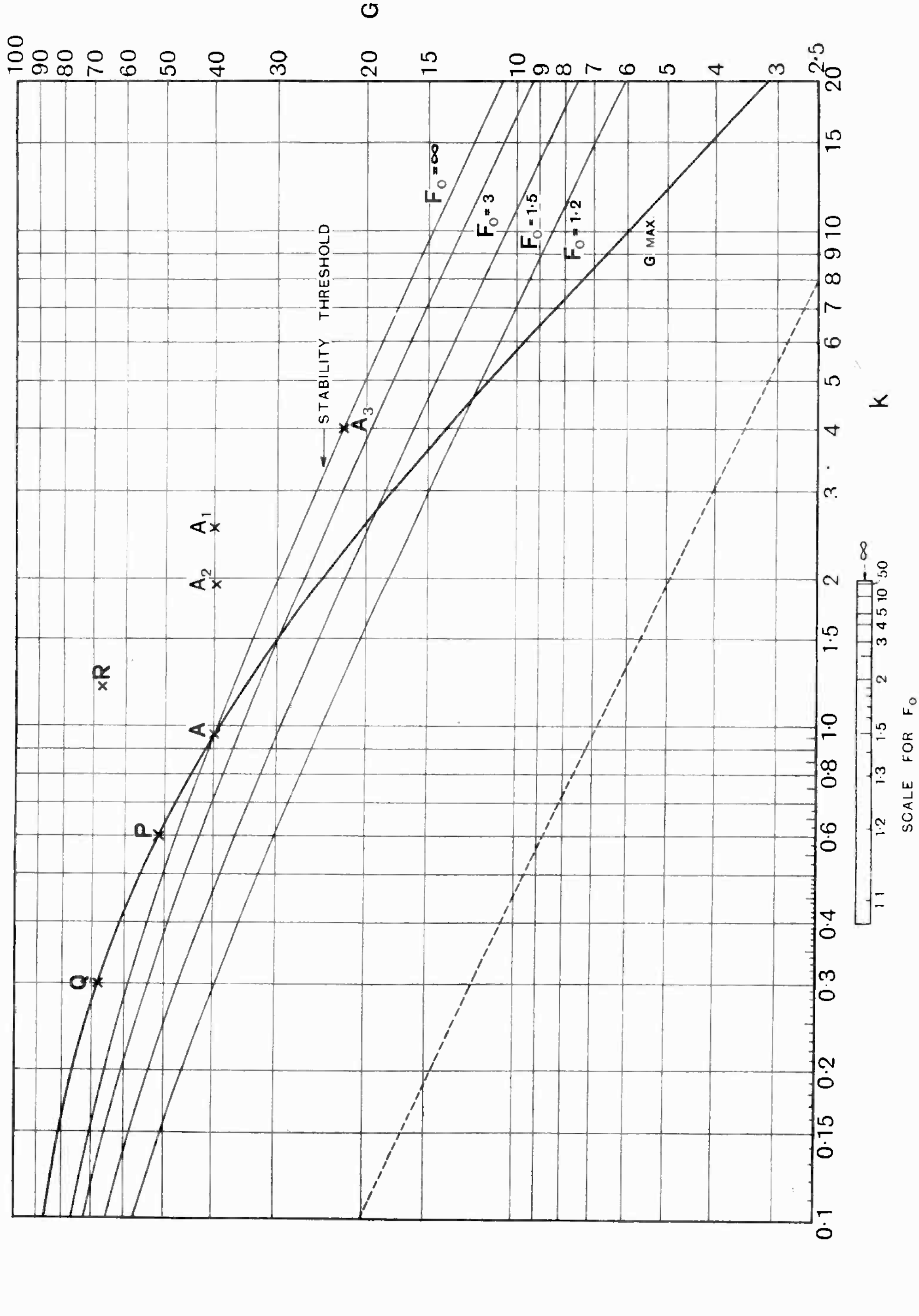


Fig. 13.

H.F. broadcast range from $k=0.5$ to $k=10$ we invariably have a set of coils each of which covers a portion of the range with the help of a variable condenser. The range covered by one coil will be called the *coil range.* The curve giving the maximum G plotted against k will be continuous as the condenser is varied, but on putting in a new coil the curve will jump to a new position so that *we shall have a ladder-like curve with discontinuous rungs.* This curve will be discussed later on, but it will simplify our ideas if in the meantime we assume that in tuning over the *total range* the condenser is fixed and the change from coil to coil is made continuous as with a variometer. In the next section the results will be given under this assumption.

16. Maximum G with Fixed Condensers and Variable Coils using the Standard Valve.

$G=g/\sigma_2$ and if we use identical coils and condensers in the grid and plate circuits, $\sigma_1 = r/L^2\omega^2 = C\omega \cdot r/L\omega$ when the coil is tuned to resonance: putting $\omega = k\Omega$ we finally get

$$\sigma_2=\sigma_1+\sigma_v=[k+\sigma_v \cdot L\omega/r \cdot C\Omega]C\Omega \cdot r/L\omega \quad (22)$$

and so

$$G = \frac{g \cdot L\omega/r \cdot C\Omega}{k + \sigma_v \cdot L\omega/r \cdot C\Omega} \quad .. \quad (23)$$

In the case of single layer coils screened by cylindrical copper pots we have found experimentally that $L\omega/r=80$ over a wide range of frequencies. Taking this value, choosing $C=160\mu\mu F$ and using the standard data given in the list of symbols, equation (23) becomes the working formula

$$G_{max.} = 64/k+0{\cdot}64 \quad .. \quad (24)$$

This curve is plotted in Fig. 11. It has been deduced theoretically and practically coincides with the experimental curve published in a previous paper.*

When $k=0$ $G_{max.}=100$ showing that at low frequencies the plate load can be made so great that the full valve amplification ($\mu=g/\sigma_v=8\times10^{-4}/8\times10^{-6}=100$) is attained; at frequencies below 970 kilocycles the curve lies in the unstable region above $F_0=\infty$; at higher frequencies stability is assured, but $G_{max.}$ rapidly drops since the plate load is decreasing, and falls to 6 at 10,000 kilocycles ($k=10$).

When the grid and plate circuits are identical, fixed condensers of value 160$\mu\mu$F being used, and tuning over the total range is effected by continuous variation of the coils, the value of $L\omega/r$ remaining fixed at the value 80, equation (24) and Fig. 11 give the maximum stage gain $G_{max.}$ obtainable at any frequency k using the standard valve. The set is unstable at low, stable at high frequencies.

17. Maximum G with Fixed Condensers and Variable Coils using any Valve.

In section (13) it was shown how the F_0 curves (Fig. 11) could be displaced to suit any valve, and we shall now see that the $G_{max.}$ curve can be similarly treated. By a slight re-arrangement equation (23) can be written as follows:—

$$g/G \cdot \sigma_v = 1 + k \cdot C\Omega \cdot r/L\omega \cdot \sigma_v \quad (25)$$

Now, as in section (13) we can see how any point Gk on the $G_{max.}$ curve (Fig. 11) will change due to alteration of any constant in the circuit. If g is doubled G must be doubled and k unchanged, so that equation (25) may still hold; if σ_v is doubled G must be halved and k doubled, and so on. Table II shows all the possible displacements of the $G_{max.}$ curve due to circuit alterations, and the arrows in Fig. 14 show these displacements graphically.

TABLE II.

Change from standard circuit where $g=8\times10^{-4}$ amps/volt, $\sigma_v=8\times10^{-6}$ mhos, $C_0=0.1\mu\mu F$, $C=166\mu\mu F$, $L\omega/r=80$	Factors by which k and G must be multiplied.	
	k	G
g doubled	1	2
σ_v doubled	2	$\frac{1}{2}$
C_0 doubled	1	1
C doubled	$\frac{1}{2}$	1
$L\omega/r$ doubled	2	1

Since the $G_{max.}$ curve in Fig. 11 may, when shifted, move out of the field of view it is redrawn over a greater range in Fig. 13.

* *E.W. & W.E.*, Oct., 1927, p. 625, Fig. 10, curve 3.

Fig. 13 shows the maximum stage gain $G_{max.}$ for the standard valve and standard circuit with fixed condensers and continuously variable coils. For any other valve or circuit, provided that identical circuits are used for grid and plate, slide the $G_{max.}$ curve parallel to itself according to the rules given in Table II and indicated in Fig. 14.

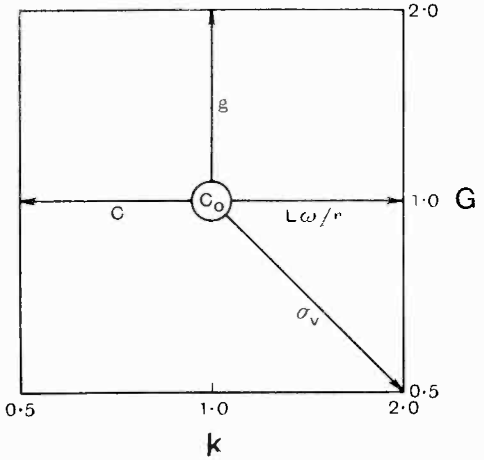


Fig. 14. *Shift of $G_{max.}$ curve when any constant is doubled.*

18. Discussion of Fig. 13.

The most striking features shown by the curves are that at low frequencies ($k=0.5$), although high amplification from grid to plate is possible experimentally, only part of it is available on account of instability, and that at high frequencies ($k=10$) the stage gain is low, its value being about 6, and the set is well within the stable region.

A study of Figs. 12 and 14 will enable us to foretell the behaviour of the set when changes are made in the design of the valve or circuit. Thus if g is doubled, the $G_{max.}$ curve rises by one unit (all values of $G_{max.}$ doubled), while Fig. 12 shows that all the F_0 curves take one pace upwards and one to the left. If the reader will carry out this operation with the help of tracing paper he will find that the point A (Fig. 13) where the G curve crosses the threshold curve has been shifted to A_1 ($k=2.55$) and that for frequencies higher than this stability is assured, with the advantage that the stage gain is doubled, while at lower frequencies the increased stage gain is largely useless owing to the stability threshold having risen.

If C_0 is halved, all other constants remaining the same, we find from Fig. 12 that all the F_0 curves take one pace to the right while Fig. 14 shows that the $G_{max.}$ curve is unaltered. Our tracing paper will now show that stability is assured at all frequencies so that we utilise all of the large stage gain at low frequencies but that at high frequencies no improvement results.

These results are not of much moment for single stage amplifiers but are of great importance for multi-stage sets since the stability threshold keeps dropping as the number of stages increases.

Anyhow, the problem of reducing C_0 in a shielded valve below $0.1\mu\mu F$ is not easy and is probably keeping valve designers awake at night.

Incidentally, the substitution of a 3-electrode valve with $C_0=5\mu\mu F$ will shift the stability boundary to the position shown by the broken curve in Fig. 13. The possible stage gain is now very small: at 8,000 kilocycles it is only 2.5.

19. Further Progress in Valve Design.

The alteration of one valve constant at a time, as considered in section 19, is probably impracticable, but there are two lines of progress which seem possible. Taking as an example a valve in which all electrodes are in parallel planes, we might in the first place put twice the length of filament into the same area, leaving the other electrodes unchanged in size and position, thus doubling the emission per unit area; this would result in doubling g and σ_v leaving C_0 unchanged. Secondly we might double the area of each electrode and also double the filament length, leaving the spacing between the electrodes unchanged. This would result in doubling g, σ_v and C_0. The first method may be called *doubling the filament packing*, and the second, *doubling the valve diameter.*

Figs. 12 and 14 show that the first of these changes would cause all curves in Fig. 13 to move one pace to the right, the stability boundary and maximum stage gain would be raised everywhere, and the frequency below which instability is possible would move from A to A_2. Accordingly, above frequencies of 2 megacycles increased stable amplification would ensue, at lower frequencies the improvement would be partly nullified by instability.

The second type of valve in which the diameter is doubled would leave the F_0 curves unchanged, while the $G_{max.}$ curve would move one pace to the right. The intersection of the $G_{max.}$ curve and the curve $F_0 = \infty$ would now be at A_3. At frequencies above 4 megacycles the possible gain would be doubled, at lower frequencies the improvement would be less.

this special assumption. In practice, however, we use a set of coils and tune over each coil range with variable condensers. If, for example, nine sets of coils were used over the total range $k=0.5$ to $k=10$ we should only be on the $G_{max.}$ curve on the nine occasions when the condensers are set at our standard value of 160$\mu\mu$F and each pair of coils is inserted in turn. At all other condenser settings we should be on a completely new set of curves.

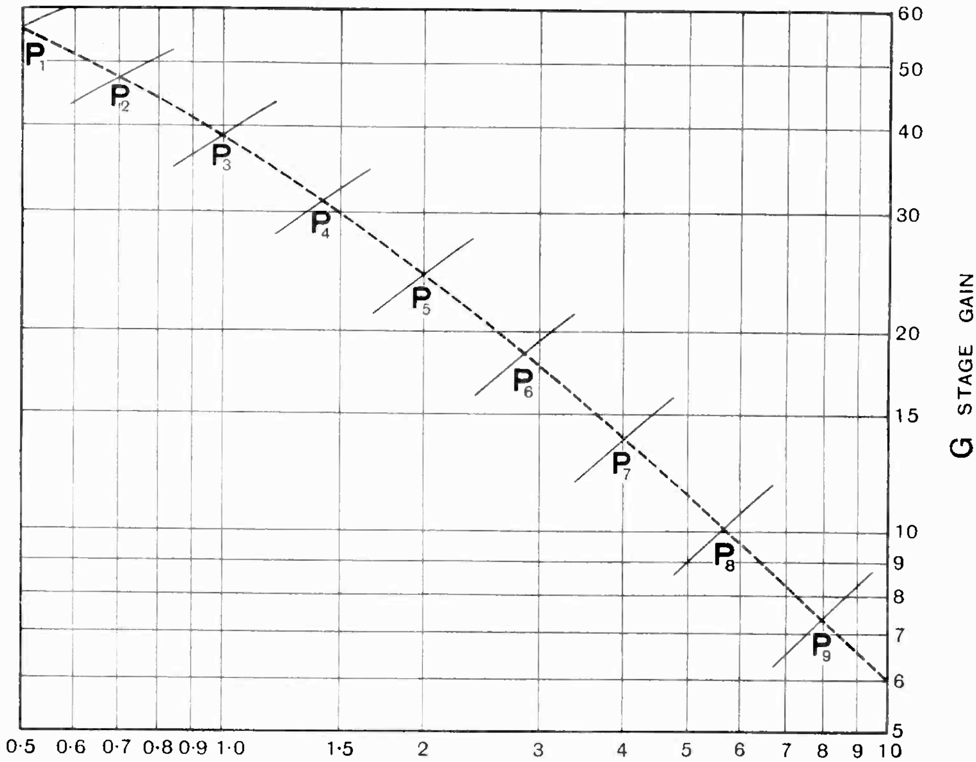


Fig. 15.

We see that valves of either of the two types discussed would enable higher amplification to be obtained at and below about 70 metres.

The Ladder Curves.

So far it has been assumed that the grid and plate condensers have fixed values and that variometer tuning has been employed: the $G_{max.}$ curve in Fig. 13 is only true for

We will now investigate the $G_{max.}$ curves obtained by varying the condensers.

Equation (25) gives the relation between $G_{max.}$ and k on the assumption that C is fixed: the variable L does not appear except in the form $r/L\omega$ which is treated as a constant. Our task is to remove C, which has become a variable quantity, and replace it by its equivalent in L which is now fixed as long as the same coil is used.

$C\omega = 1/L\omega$ at the tuning point, hence, putting $\omega = k\Omega$, $C \cdot k \cdot \Omega = 1/L \cdot k \cdot \Omega$ that is $C\Omega$ can be replaced by $1/k^2 \cdot L\Omega$. Accordingly equation (25) becomes

$$g/G \cdot \sigma_v = 1 + [1/k \cdot L\Omega]\,[r/L\omega \cdot \sigma_v] \quad \ldots \quad (26)$$

k appears in the denominator whereas in equation (25) it appeared in the numerator. Thus when k is *halved* in equation (25) a certain change in G is produced; when k is *doubled* in equation (26) the same change in G is produced. Thus in Fig. 13, if we travel from P where $k=0.6$ to Q where $k=0.3$ by variometer tuning, the result of increasing G the same amount by condenser tuning will bring us to R, where $k=1.2$.

Evidently our new path from P to R is the mirror image of our former variometer path PQ as reflected in a vertical line through P.

In Fig. 15 the old G_{max}. curve due to variometer tuning is shown as a broken line. If nine pairs of coils are provided for the total range we shall be on this curve at the nine points P_1 to P_9 as the coils are changed, provided that the condenser settings are fixed at $160\mu\mu$F. On tuning by the condenser we move along one of the rungs of the ladder, the length of the rung depending on the condenser limits.

In Fig. 15 each rung gives the relation between stage gain and signal frequency when condenser tuning is used. Each rung corresponds to a particular pair of equal coils. Upward movement along a rung corresponds to decreasing condenser settings. The broken curve corresponds to variometer tuning with $C = 160\mu\mu$F. For any other standard C the whole ladder must be displaced horizontally according to the rule given in Table 2.

The ladder curves are capable of giving an enormous amount of information as to the design and behaviour of a set, but the limitations of space allotted to this paper do not allow further discussion of them at present.

LIST OF SYMBOLS.

C σ	Capacity of	any tuned circuit.
C_g σ_g	- —— -	grid circuit.
C_p σ_p	Conductance in	plate circuit.
C_1 σ_1	parallel with	equivalent grid circuit.
C_2 σ_2		equivalent plate circuit.
σ_v	Differential conductance of valve.	
C_0	Grid-plate capacity of valve.	
L	Inductance of any circuit.	
L_1	Inductance of grid circuit.	
L_2	Inductance of plate circuit.	
r	Resistance in series.	
R	Resistance in parallel.	
e	A.C. E.M.F. injected in series with grid coil.	
e_1	A.C. voltage of grid.	
e_2	A.C. voltage of plate.	
i	Any A.C. current.	
ω	$2\pi \times$ signal frequency in cycles.	
Ω	$2\pi \times 10^6$ cycles.	
k	Signal frequency in megacycles ($=$ cycles $\times 10^6$)	
μ	Voltage amplification of valve.	
g	Mutual conductance of valve: amps/volt.	
θt	Phase angle in	any tuned circuit.
$\theta_1 t_1$	- —— -	equivalent grid circuit.
$\theta_2 t_2$	Tangent of phase angle in	equivalent plate circuit.
H	$g \cdot C_0\omega/\sigma_1\sigma_2$.	
$1/F$	$(1+jt_1)(1+jt_2)+j \cdot H$.	
F_0	Max. value of F obtained by tuning: voltage gain from signal to plate on tune due to reaction.	
A	Voltage gain from signal to plate on tune without reaction.	
G	Voltage gain from grid to plate without reaction: stage gain.	
G_{max}.	Largest G obtainable experimentally.	

Constants of Standard Valve.

g	8×10^{-4} amps/volt.
σ_v	8×10^{-6} mhos.
C_0	$0.1\mu\mu$F.

Constants of Standard Grid and Plate Circuits.

$L\omega/r$	80.
C	$160\mu\mu$F.

The Power Factor and Capacity of the Electrodes and Base of Triode Valves.

With special reference to their use in Thermionic Voltmeters.

A PAPER with this title was read by Mr. G. W. Sutton, B.Sc., at a recent meeting of the Physical Society. The requirements for a valve voltmeter for H.F. resistance measurements are (1) that it puts the smallest possible load on the circuit to which it is connected, (2) that its readings should be proportional to the square of the voltage, and (3) that it should be rapid in indication.

Unlike a thermo-junction a voltmeter must be connected across points differing in P.D., thus increasing the capacity by 5 to 10$\mu\mu$F, but unlike an electrostatic voltmeter the capacity does not vary with the reading. More serious are the losses in the voltmeter, which, using the anode bend, may double or treble the decrement of the circuit under investigation. The valve holder and base may introduce considerable additional losses. Measurements by Hartshorn and Jones suggested that the glass pinch was a worse offender than the compound base but this is not borne out by Mr. Sutton's measurements, the results of which are given in the following table.

These results indicate the importance of removing the cap before using a valve in a valve-voltmeter. By adopting this device and carefully arranging the leads and by applying —4.2 volts grid bias, the increase of the circuit decrement due to the voltmeter was reduced from 18 to 1.8 per cent. in a given example.

With regard to the attainment of the square law, Mr. Sutton shows that for a given valve it is possible to find values of anode voltage and grid bias such that the departure from the average value of the constant $V/\sqrt{\theta}$ does not exceed 0.4 per cent. A method is described whereby the best values can be determined experimentally.

To obtain rapidity of reading Mr. Sutton recommends the use of a pivoted and critically damped moving-coil galvanometer of short period.

	(f=650kC)	$C(\mu\mu F)$.	P.F.
(*a*)	Modern "low-loss" valve-holder (sockets mounted on narrow insulating ring of large diameter)	1.4_8	0.04
(*b*)	French D.E. valve	7.0_0	0.02_1
(*c*)	Ditto base alone	1.1_0	0.1_0
(*d*)	Valve base found previously to have very low insulation resistance	2.4_2	0.37
(*e*)	English D.E. valve	4.9_6	0.03_4
	Ditto base alone	1.5_8	0.05_5
	Ditto remainder alone—*i.e.*, pinch, electrodes and leads	3.0_6	0.02_0
	(f=545kC)		
(*f*)	"R" valve. Metal ring on cap...	5.0_5	0.06_3
	Ditto base alone	1.8_3	0.17
	Ditto remainder alone	2.9_0	0.00_3
(*g*)	"R" valve. Another manufacturer	4.6_2	0.04_9
	Ditto base alone	1.7_2	0.09_6
	Ditto remainder alone	2.5_8	0.02_8*
(*h*)	D.E.R. valve. Bakelite cap	4.4_1	0.01_5
	Ditto base alone	0.7_5	0.05_4
	Ditto remainder alone	3.2_2	0.00_{15}
(*i*)	D.E.R. Old pattern, before the use of "gettering" ...	5.1_1	0.03_5
	Ditto base alone	1.6_1	0.05_4
	Ditto remainder alone	3.2_3	0.02_7

* It was noticed that the under surface of the glass pinch was oily. This may have accounted for the comparatively high value of the P.F. in this case as compared with the others.

The Accuracy and Calibration Permanence of Variable Air Condensers for Precision Wavemeters.

By W. H. F. Griffiths, A.M.I.E.E., Mem.I.R.E.

Introduction.

THE accuracy of a substandard wavemeter is always limited by the constancy and degree of law conformity of its variable air condenser, so much so, in fact, that it is almost impossible, for this reason, to construct a substandard instrument having an overall inaccuracy of less than 5 parts in 10,000 for an appreciable range of frequency and continuously variable.

For reasons of "stray" capacity variabilities and circuit capacity inconstancy the minimum capacity of such a wavemeter is usually not less than 500 or 1,000$\mu\mu$F for moderate frequencies although it may be somewhat lower for ultra high frequency bands. Even so, since capacity variations with age of the order 1 or 2$\mu\mu$F are generally expected even in variable condensers of the highest quality, uncertainties to the extent of 1 or 2 parts in 1,000 in capacity are always possible and introduce frequency uncertainties of the order of 1 part in 1,000 if a considerable period of time has elapsed since the calibration of the substandard against a *standard* of frequency.

These capacity uncertainties are discussed in the first part of the article and in the second part is described an entirely new design of variable air condenser by the use of which it is hoped to fill, more effectively, the gap which exists between good commercial heterodyne wavemeters having an overall accuracy of, say, 2 parts in 1,000 and the modern multivibrator standard of radio frequencies. The standard multivibrator wavemeter,* due to Dr. Dye of the National Physical Laboratory, may be relied upon to within 1 or 2 parts in 100,000, the elinvar tuning fork, with which the frequency of the Abraham Bloch harmonic producing multivibrator is controlled, being standardised for frequency with great accuracy against a standard clock using a specially constructed phonic wheel as a means of effecting the comparison. Moreover, the temperature coefficient of the fork is of a very low order—of the order of 1 part in 100,000 per degree Centigrade.

Full use cannot be made of the high degree of accuracy now obtainable in frequency determinations by a standard such as this if really good substandards of greater accuracy than 1 part in 1,000, of great conformity to law and having continuously variable and extensive ranges of adjustment, are not available. In such a variable substandard the new design of variable air condenser would be employed.

PART I.

The necessity for a high degree of calibration accuracy and permanence of variable air condensers of good quality substandard wavemeters is generally appreciated. It is, however, not always realised how difficult it is to obtain these essential qualities even in condensers of the highest precision.

The oscillatory circuit of a wavemeter usually comprises a reactance the value of which is fixed at any given frequency and one of opposite sign which is adjustable, and for still greater convenience the adjustable reactance is usually made continuously variable. If the L/C ratio of the circuit is correctly chosen it matters not which of the two reactances is made variable, but in multi-range wavemeters it is convenient to make the capacity reactance continuously variable by using a variable air condenser, so that a number of inductances may be selected for association with it. It would be

* D. W. Dye, *Phil. Trans. Roy. Soc.*, Ser. A, 224 (1924), 259; also W. H. F. Griffiths, *The Wireless World and Radio Review*, Vol. XVI., No. 296.

unwise to employ a single variable inductance in conjunction with a number of fixed capacities for range extension for several reasons.

Reasons for using Variable Condensers.

The capacity of a wavemeter circuit cannot have any value to suit a variable inductance of a definite limited range, because of the difficulty of obtaining high value capacities (of convenient bulk) having negligibly low temperature coefficients and constancy of value generally and also because of the fact that "stray" capacities which augment the circuit capacity are of a more or less constant order and not proportional to the value of the latter and therefore impair seriously the accuracy when it is of a low order. Slight changes of position of conducting masses of the wavemeter or of neighbouring conductors, changes of wiring and changes of so-called "earth capacities" introduced by the body during operation, all produce serious inaccuracies when the circuit capacity is small. The capacity of a precision wavemeter is, for these reasons, limited therefore to a range of about 300$\mu\mu$F to 3,000$\mu\mu$F.

It is convenient to make the capacity variable and to use this in conjunction with a number of interchangeable inductances for yet another reason.

In order to keep the "sharpness of tuning" of the same order throughout a wide range of wavelength, the decrement of the wavemeter circuit must be maintained roughly constant, and this cannot be so if the capacity is varied throughout wide limits. The ideal resonant circuits are those, perhaps, in which the ratio of L/C is maintained approximately constant, but since this is impracticable, it is better that this ratio shall increase with wavelength rather than decrease, as the following tables will show.

TABLE I.

Variable *inductance* mean values $L=100\mu$H $R=1.0\Omega$.

C μF	$\frac{L}{C}$	λ metres	f	ω	ωL Ω	R Ω	$\delta=\frac{R}{2fL}$
0.0001	10^6	188	1.6×10^6	10×10^6	1,000	1.0	0.003
0.001	10^5	592	0.5×10^6	3.2×10^6	320	1.0	0.010
0.01	10^4	1,885	0.16×10^6	1.0×10^6	100	1.0	0.032

TABLE II.

Variable *capacity* mean value $C=0.001\mu$F.

L μH	$\frac{L}{C}$	λ metres	f	ω	ωL Ω	R Ω	$\delta=\frac{R}{2fL}$
10	10^4	188	1.6×10^6	10×10^6	100	0.32	0.01
100	10^5	592	0.5×10^6	3.2×10^6	320	1.0	0.01
1,000	10^6	1,885	0.16×10^6	1.0×10^6	1,000	3.2	0.01

Table I illustrates, as an example, a resonant circuit having a total wavelength range of 10 to 1 obtained by a variable *inductance*, of mean value 100μH and mean resistance 1.0Ω, and a number of fixed capacities ranging from 0.0001μF to 0.01μF. The three capacity values given in the tabulation are, of course, not intended to be the actual number of ranges required to cover the total wavelength range—many more would be required in practice. The capacities are assumed to be of air dielectric and to have, in consequence, negligibly low equivalent series resistance values. It is assumed also that the effective resistance of the inductance remains approximately constant throughout the whole range of frequency; although there will, in practice, be an increase of resistance with frequency, it need not be great over a limited range in a well-designed coil when the applied E.M.F. is induced into the whole coil.

It will be seen that while the resistance of the circuit remains constant the reactances *decrease* proportionally with frequency, resulting in a rapidly increasing decrement.

If, however, the *capacity* is made variable about a mean value of, say, 0.001μF and a number of fixed value inductances ranging from 10μH to 1,000μH are employed (as indicated in Table II), the resistance of the coils will increase, as a crude approximation, proportionally to the root of the inductance, and, since the reactances of the circuit will *increase* proportionally with frequency in this case, the decrement remains of a constant order.

The resonant circuit in which the condition of constant ratio of resistance to reactance can be maintained throughout its range, is the ideal from the tuning sharpness point of view and these tables merely serve to illustrate the fact that this condition is best obtained by keeping the capacity of a more or less constant *order* and by associating it with a series of fixed inductances of widely differing values, because the resistance of any resonant circuit resides almost entirely in its inductance.

For all these reasons, therefore, it is more convenient to follow the usual practice of employing a variable condenser and fixed inductances, but, unfortunately, a more permanent arrangement would be that of a variable inductance and a number of fixed air condensers. Fixed inductances and fixed *air* condensers have roughly the same order of permanence of value, but it is much more difficult to obtain a high order of calibration permanence in a variable condenser than in a variable inductance due to the fact that small changes in the geometry of the former are of much greater importance than are changes of similar magnitude in the case of the latter.

The Difficulties of Variable Condenser Construction.

A variable condenser which will "hold" its accuracy of calibration over a period of time can only therefore be obtained by the most careful design and construction. This particularly applies to the initial setting of the two sets of plate conductors to ensure uniformity of dielectric air gaps.

It is not only necessary for the plates of each system to be set perfectly parallel and for the moving plates to rotate truly in relation to the fixed plates, but it is necessary also for each moving plate to rotate exactly midway between the pair of fixed plates with which it interleaves.*

The reason for this is that since the capacity between the adjacent moving and fixed plates is connected with the distance between them by an inverse law, it follows that the percentage change of capacity (for a given scale setting) due to a given change of position of one bank of plates, axially, relative to the other, will be a minimum when the distance between *all* adjacent plates is a maximum. This can only occur when the distances between all adjacent plates are equal, and in this condition the capacity of the condenser is, of course, a minimum for any given scale reading.

The Effect of Gap Equalisation on the Permanence of a Variable Air Condenser.

Let d_1 and d_2 be the distances of the dielectric gaps (of uniform dielectric constant) between a moving plate and adjacent upper and lower fixed plates respectively, then the capacity of this element of the plate assemblage is proportional to

$$\frac{1}{d_1} + \frac{1}{d_2}$$

$$\therefore \quad C \propto \frac{d_1 + d_2}{d_1 \, d_2} \quad \text{but } d_1 + d_2 \text{ is constant}$$

$$\therefore \quad C \propto \frac{1}{d_1 d_2}$$

Since the capacity is inversely proportional to two quantities the sum of which is constant, it is generally thought that for very small differences of gaps the resultant capacity change is negligible. This is far from being the case however even in modern condensers of precision, the effect upon both the permanence of calibration and upon the general conformity to law being very marked,

* Since the present article was written this necessity has been more concisely dealt with by Messrs. Braillard and Divoire in the June issue of *E.W. & W.E.*

the latter may generally be taken as a criterion of the former.

The curves of Fig. 1 show, for various displacements of plates from their exact mid-positions, the decrease of the product of

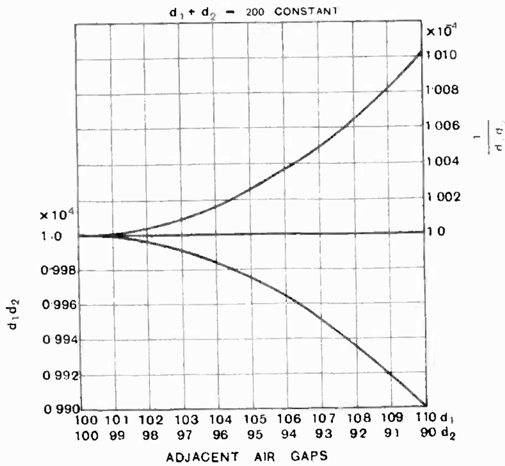


Fig. 1.

adjacent air gap distances and the consequent increase of the reciprocal of this quantity, $1/d_1d_2$, to which the resultant capacity is proportional.

Fig. 2 shows how the effect of any post-calibration mechanical changes in plate positions is magnified if the adjacent gaps are not initially *exactly* equalised. From this set of curves can be found the percentage change of capacity due to any *post-calibration* percentage axial displacement of one set of plates relative to the other for various percentages of *initial* axial displacement of that set of plates from the exact mid-positions between the others. The curves marked with positive percentages correspond with cases where the *error producing displacement* is in the same direction as the *initial displacement* and those marked with negative percentages where the initial and subsequent displacements are in opposite directions. The curve marked zero indicates the capacity change which occurs for various post-calibration changes when all dielectric gaps have been initially set equal.

These curves are not, however, as convincing as they should be owing to the fact that they are plotted to a scale which emphasises those portions of the curves for which the changes subsequent to calibration are of the same order as the initial plate displacement. The capacity changes produced are therefore, in this region, not much increased by the want of initial gap equalisation. The lower portions of these curves plotted for very small capacity changes are given in Fig. 3 and show well the importance of initial gap equalisation. It should be noted that these curves (Fig. 3) represent more nearly, quantitatively, the displacement and capacity change likely to be experienced in good quality condensers.

It will be observed that a 1 per cent. post-calibration displacement will have little effect on the capacity of a condenser if the gaps have been carefully equalised, but effects a 0.2 per cent. capacity change if there is an initial axial displacement of one set of plates relative to the other amounting to 10 per cent. of the mean gap, an error about twenty times greater than would have been the case had the gap equalisation been perfect.

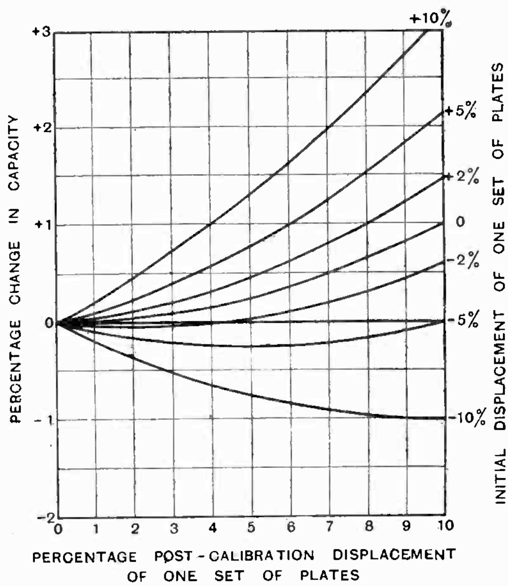


Fig. 2.

It is interesting to note that, as a safeguard against inaccuracies introduced by the sagging of the moving plates, if these plates could be set 2 per cent. *high* in the gaps between the fixed plates, a sagging up to 4 per cent. of the mean gap would produce very little effect on the capacity. The initial setting of the moving plates 2 per cent. from the mid-position is, however, a very difficult operation.

The curves of Fig. 4 show the percentage capacity change produced by 1 per cent.,

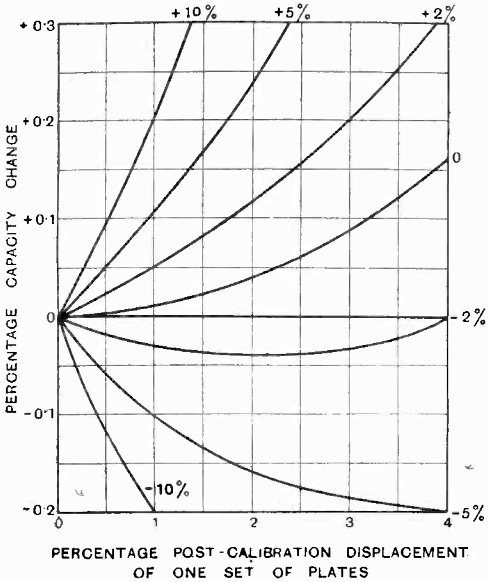


Fig. 3.

2 per cent. or 3 per cent. post-calibration gap changes for various values of initial plate displacement.

Gap Equalisation an Aid to Law Conformity.

This important feature of construction affects not only the degree of calibration permanence but also the degree of conformity to the mean law connecting capacity with angular movement.

Small general and local irregularities which would produce only negligible departures from the mean law if the plates were absolutely equidistant will produce law departures by no means inconsiderable if this initial plate setting has not been effected or insufficient care exercised in this operation.

As an example of this effect the case of a condenser whose moving plates have a "wobble" of about 10 per cent. of the mean gap due to their revolving at an angle of about 8′ out of truth with the fixed plates, will be taken. The angle of 8′ corresponds to a 10 per cent. "wobble" with a plate radius of 4 inches and a dielectric gap of 0.1 inch. Let it be assumed that this wobble is such that the moving plates commence to enter the bank of fixed plates correctly in their mid-positions so that the rate of change of capacity, $dC/d\theta$, at the commencement of the scale is a minimum. As the angle θ of plate envelopment is increased, however, the moving plates become more and more displaced from their mid position at entrance to the fixed plates until, at $\theta = 90°$, the displacement is 10 per cent. and is gradually reduced again to zero at $\theta = 180°$. Such a wobble is, of course, small but may be very serious in its effect on the law.

In Fig. 5 is plotted (curve *A*) a curve giving the percentage departure from the correct calculated "slope," $dC/d\theta$, for a condenser having this imperfection, the slope increasing until the moving plates are half entered and then commencing to decrease until the *entering* portions of the

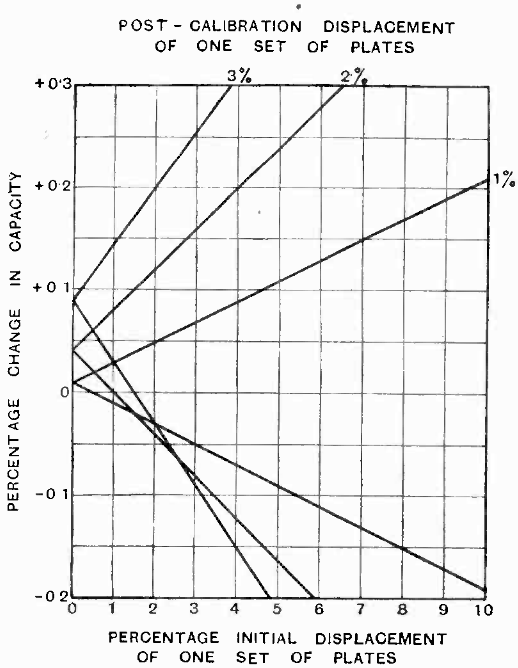


Fig. 4.

moving plates once more regain their mid-positions at the 180 degrees setting. Curve *B* shows the corresponding deviation from the law for the same degree of wobble when the moving plates are initially displaced, axially, *in the direction of the wobble,* by 10 per cent., and shows well the effect of such an initial displacement upon the law of the condenser.

An Example of Modern Precision Condenser Accuracy.

A modern precision condenser having a law departure not greater than that corresponding to curve *A* would be considered good and it is interesting to compare this calculated curve with one plotted from measurements on an actual condenser.

The curve *A*, since it is plotted from a computation of errors from the *ideal* law, appears as a wholly positive error, but in practice the average error would be reduced by calculating the deviations on either side of a *mean slope,* the corresponding percentage slope deviation being indicated by curve *C* of Fig. 5.

Curve *D* of this figure is plotted from actual National Physical Laboratory measurements on a large precision air condenser by

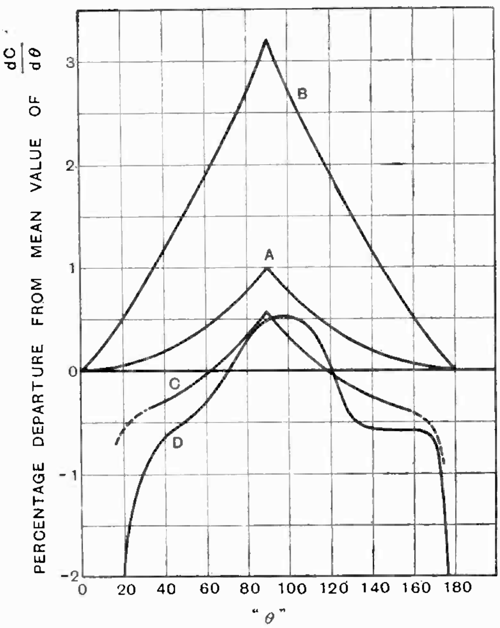


Fig. 5.

Messrs. H. W. Sullivan, Ltd., and shows remarkable similarity to the calculated curve *C* (although it is not suggested that the cause for the peculiar curve shape has thus been diagnosed). The average deviation from the law is seen to be very small over the useful range of the condenser. It is thought that a full statement of actual measured capacities and variously expressed

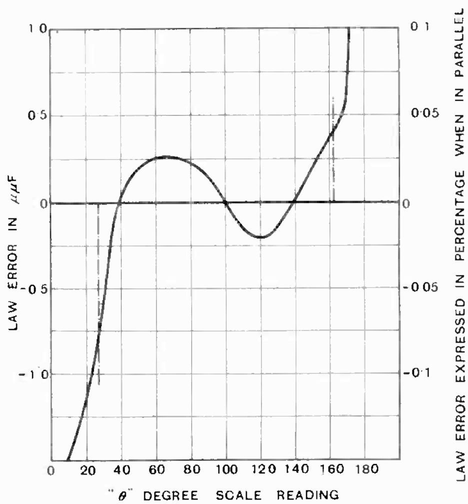


Fig. 6.

errors for this condenser will be of use in helping to form a clear idea of what one may expect from a good quality modern laboratory condenser and these are therefore tabulated below. The mean law of the condenser computed from all capacity values between 27 degrees and 144 degrees (inclusive) was found to be $C=3.0173\ \theta+59.80$, and the third column of Table 3 gives the values computed from this linear law.

The fourth column gives the error introduced by assuming the law to be correct at any point and in column 5 these errors are expressed as percentages of the correct capacity for the various settings.

In all precision wavemeters the "zero" of the variable condenser is "set-up" by paralleling with it a fixed condenser of great constancy of value and in column 6 therefore the percentage law inaccuracy is given when a fixed capacity of 500$\mu\mu$F is paralleled with the variable condenser under examination. Wavelength inaccuracies corresponding with these capacity departures are given in column 7.

In column 8 the actual slope, $dC/d\theta$, is given and in the final column the percentage departure from the mean value of $dC/d\theta$, the curve of which has already been plotted in Fig. 5 (*D*).

It will be seen that the departure from the law at any point throughout the range of the tabulation is almost within the accuracy of measurement of capacities of this order. In this connection it should be noted that the measured capacity values given in the second column originally had their fourth significant figures dropped showing that the accuracy of measurement was of the order of $\pm 0.1 \mu\mu$F.

TABLE III.

θ Degrees	C $\mu\mu$F	C Law value	Law Error $\mu\mu$F	Law Error %	Error of $C+500$ %	λ Error %	$\frac{dC}{d\theta}$	Slope Error %
27	141.6	141.27	—0.30	—0.20	—0.04	—0.020		
							2.990	—0.89
36	168.5	168.42	—0.08	—0.05	—0.01	—0.005		
							3.000	—0.56
54	222.5	222.74	+0.23	+0.10	+0.03	+0.015		
							3.010	—0.24
72	276.7	277.05	+0.25	+0.09	+0.03	+0.015		
							3.027	+0.33
90	331.2	331.36	+0.16	+0.05	+0.02	+0.010		
							3.033	+0.53
108	385.8	385.67	—0.13	—0.03	—0.015	—0.007		
							3.022	+0.16
126	440.2	439.98	—0.18	—0.04	—0.019	—0.009		
							3.000	—0.56
144	494.2	494.29	+0.10	+0.02	+0.01	+0.005		
							3.000	—0.56
153	521.2	521.45	+0.25	+0.05	+0.02	+0.010		
							3.000	—0.56
162	548.2	548.61	+0.41	+0.07	+0.04	+0.020		
	Measured values		See curve of Fig. 6		See curve of Fig. 6			See Curve D Fig. 5

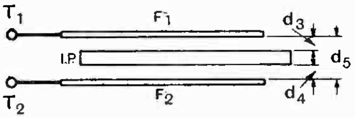


Fig. 7.

The curve of Fig. 6 shows the error of capacity value introduced at any scale setting by assuming the law to be obeyed perfectly and the same curve approximately represents the *percentage* capacity error with the fixed capacity in parallel if the right-hand scale is used.

PART II.

The necessity for "Series" Dielectric Gaps and the advantages of making adjacent Gaps complementary.

In order to eliminate largely errors of calibration due to want of permanence and non-conformity to law inherent in ordinary variable condensers of the rotary plate type, the author has recently devised a new variable air condenser* of the interleaved plate type. In this condenser not only are the adjacent dielectric gaps electrically in series instead of parallel but are also complementary.

If, in Fig. 7, F_1 and F_2 are adjacent fixed plates electrically insulated one from the other and connected to the terminals T_1 T_2 of the system and *IP* is an intermediate conducting plate (moving plate) inserted in the field between these plates and insulated from them, then the two gaps d_3 d_4 are electrically in series, so that, their

* Patent application made by H. W. Sullivan, Ltd., and the author.

reactances being added arithmetically, the resultant capacity of the combination will be, for any given scale setting, inversely proportional to the sum of the two gaps.

If C_3 is capacity of dielectric gap d_3,
C_4 ,, ,, ,, ,, ,, d_4
and C ,, the resultant of the two gaps in series.

$$\frac{1}{C} \propto \left(\frac{1}{C_3}+\frac{1}{C_4}\right) \propto \left(\frac{1}{1/d_3}+\frac{1}{1/d_4}\right)$$

$$\propto d_3 + d_4$$

$$\therefore \quad C \propto \frac{1}{d_3 + d_4}$$

which remains constant irrespective of changes of position of the intermediate conductor plate *IP* which is inserted between, but not connected electrically, to either terminal system.

The capacity variation of such a system with the intermediate plates *IP* inserted and withdrawn from the fixed plates will, of course, be proportional to the effective reduction of dielectric gap, *i.e.*,

$$\frac{C_{max.}}{C_{min.}} = \frac{d_5}{d_3 + d_4}$$

It is only necessary, therefore, to make the moving plates thick compared with the gaps $d_3 d_4$ in order to obtain an appreciable capacity variation.

It is relatively easy to ensure that two sets of interleaved plates to which are connected the two condenser terminals $T_1 T_2$ are fixed rigidly relatively even though they are insulated from each other, and so constancy is ensured by making the only moving part the system of intermediate conductors, as Fig. 8, in which all the intermediate plates *IP* must, of course, be insulated from one another by the insulating material collars $W_1 W_2$.

This arrangement, therefore, ensures that a want of truth of rotation of a moving plate does not cause a deviation from the general design law connecting capacity with angular position of moving plates and also that "end-play" of the spindle (carrying the moving plates) in its bearings will not produce, for any given angular position of moving plates relative to fixed plates, any change of capacity. Thus, even when such lateral movement of the moving plate system occurs at the time of, or subsequent to, calibration it is of no consequence.

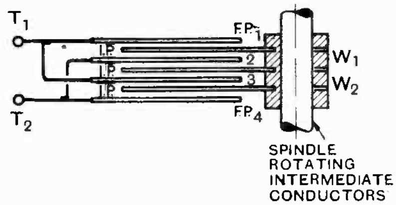


Fig. 8.

Moreover, whether the movable plate accurately travels in its own plane or not, any local permanent or varying deviations of its surfaces from that plane due to kinks or bends, will not, if the plate thickness is uniform, cause any local deviations from the general law of capacity increase with angular displacement of movable plate.

It is obvious that the two adjacent gaps on either side of a moving plate must be complementary in order that all the above advantages may be obtained in one instrument, *i.e.*, that one gap must be the complement of the other in order that at *all* points in the area over which the moving and fixed plates interleave, the sum of the two adjacent air gaps shall be constant.

(*To be continued.*)

The Attenuation of Wireless Waves Over Land.

Paper read by Mr. R. H. BARFIELD, M.Sc., A.M.I.E.E., before the Wireless Section, Institution of Electrical Engineers, on Wednesday, 7th December, 1927.

ABSTRACT.

THE paper gives an account of work by the author on the attenuation of wireless waves over land, in continuation of work on the attenuation due to the earth's surface previously described by the author in conjunction with Dr. R. L. Smith-Rose.*

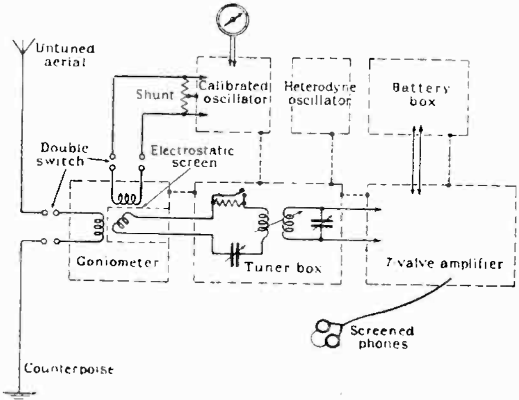


Fig. 1.

Theexperimental work described in the present paper was mainly confined to making intensity measurements with portable apparatus on the normal transmissions from the London Broadcasting Station (2LO, 364 m.) along seven different directions and at distances of from 5 to 100 miles. Within these ranges in daytime there is no appreciable reflection from the upper atmosphere, so that the intensity of the ground ray only was obtained.

The directions along which the measurements were made are set out in Table I, and are also shown in the contour map of Fig. 7.

TABLE I.

Approx. direction.	Length of run.	Town nearest end of run.	Date.
	km.		
N.	115	Huntingdon	Oct., 1926
N.E.	140	Norwich	Sept., ,,
E.	110	Deal	Aug., ,,
S.S.E.	90	Pevensey	Oct., ,,
S.S.W.	90	Chichester	Sept., ,,
W.	160	Bath	May, ,,
N.W.	160	Birmingham	June, ,,

The points at which measurements were made were selected so as to be as far away as possible from such objects as trees and telegraph wires likely to produce local variations in field strength. A fixed intensity measuring apparatus at the Radio Research Station, Slough, took check measurements as nearly as possible simultaneously with those of the portable set. These showed that the radiation from the transmitter remained sensibly constant, the variation over the whole period not being great enough to necessitate any correction.

The general scheme of the apparatus is shown in Figs. 1 and 2.* A radiogoniometer is used as a convenient coupling, a change-over switch enabling either the aerial circuit or the local reference circuit to be joined to the appropriate field-coil. The aerial circuit being first tuned to the signal, the switch is then thrown to apply the local source

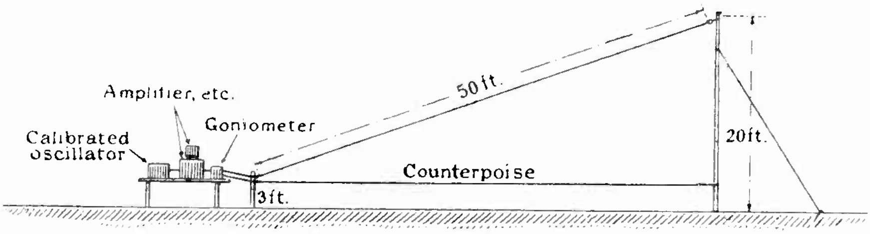


Fig. 2.

*J.I.E.E., 1926, Vol. 64, p. 786.

* The author's original figure numbers are adhered to throughout this Abstract.

which is tuned to exactly the same wavelength. The goniometer search coil is then rotated and the switch continuously reversed until a position is obtained for which the signal intensities are equal for both sides of the switch. The tangent of the angle made by the search coil axis with that of one of the local-source field coils then gives the ratio of the current in the aerial to that in the local-source output circuit. The method provides an accurate and easily controlled means of varying the relative effects of the two sources until they are equal. The fact that it obeys a tangent law makes it capable of embracing a large range of intensities.

The apparatus was calibrated by means of a local small-power transmitter over a range of intensities approximately equal to that covered by the experiments. The relative values of signal strength as measured on the portable apparatus were converted to absolute values in millivolts-per-metre by comparison with measurements of the absolute value at one site (Slough).

The curves of Fig. 6 show the whole of the data obtained and utilised to construct the contour map of Fig. 7.

In order to ascertain the attenuating effect of the earth's surface, it is necessary to separate this effect from the normal attenuation due to the spreading out of the waves. This separation can be effected by deriving a series of curves in which the product of field strength and distance is plotted against distance, this being the accepted method of treating the problem as first introduced by Duddell and Taylor.

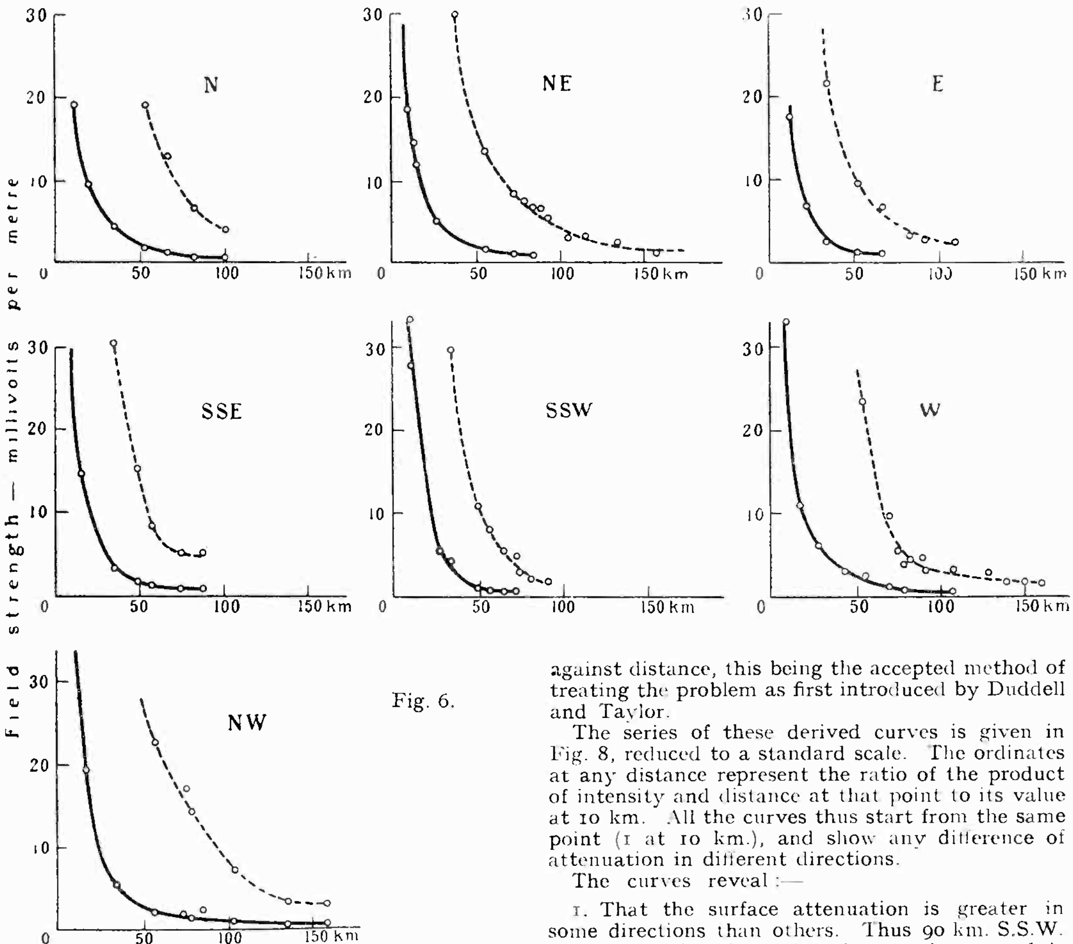


Fig. 6.

The series of these derived curves is given in Fig. 8, reduced to a standard scale. The ordinates at any distance represent the ratio of the product of intensity and distance at that point to its value at 10 km. All the curves thus start from the same point (1 at 10 km.), and show any difference of attenuation in different directions.

The curves reveal :—

1. That the surface attenuation is greater in some directions than others. Thus 90 km. S.S.W. of London the absorption due to the ground is nearly five times as much as in the N.W. direction. The directions may be classified in order of increasing attenuation :—

(*a*) Directions from London, N., N.W., N.E.
(*b*) Directions from London, E., W.
(*c*) Directions from London, S.S.E., S.S.W.

2. Curves in the same group agree very well.

3. The N. curve has an unexpected shape.

4. No trace of any effect due to hills can be seen in the curves, although many of the directions passed over low hills, *e.g.*, South Downs, Chilterns and Cotswolds.

The author then proceeds to consider the theoretical value of attenuation deduced in accordance with Sommerfeld's work on the theory of attenuation. Theoretical values are shown in Fig. 9 for various values of σ, the conductivity of the earth's surface, and by comparison with these curves a value for apparent conductivity can be found for each of the experimental curves of Fig. 8. In

It is suggested that the theory does not fit the facts because it assumes a flat surface, and does not take account of objects such as trees, houses and other erections which occur in practice. Messrs. Round, Eckersley, Tremellen and Lunnon have, in fact, already concluded that this was the sole cause of the land attenuation which they observed on longer waves (10—25 km.).

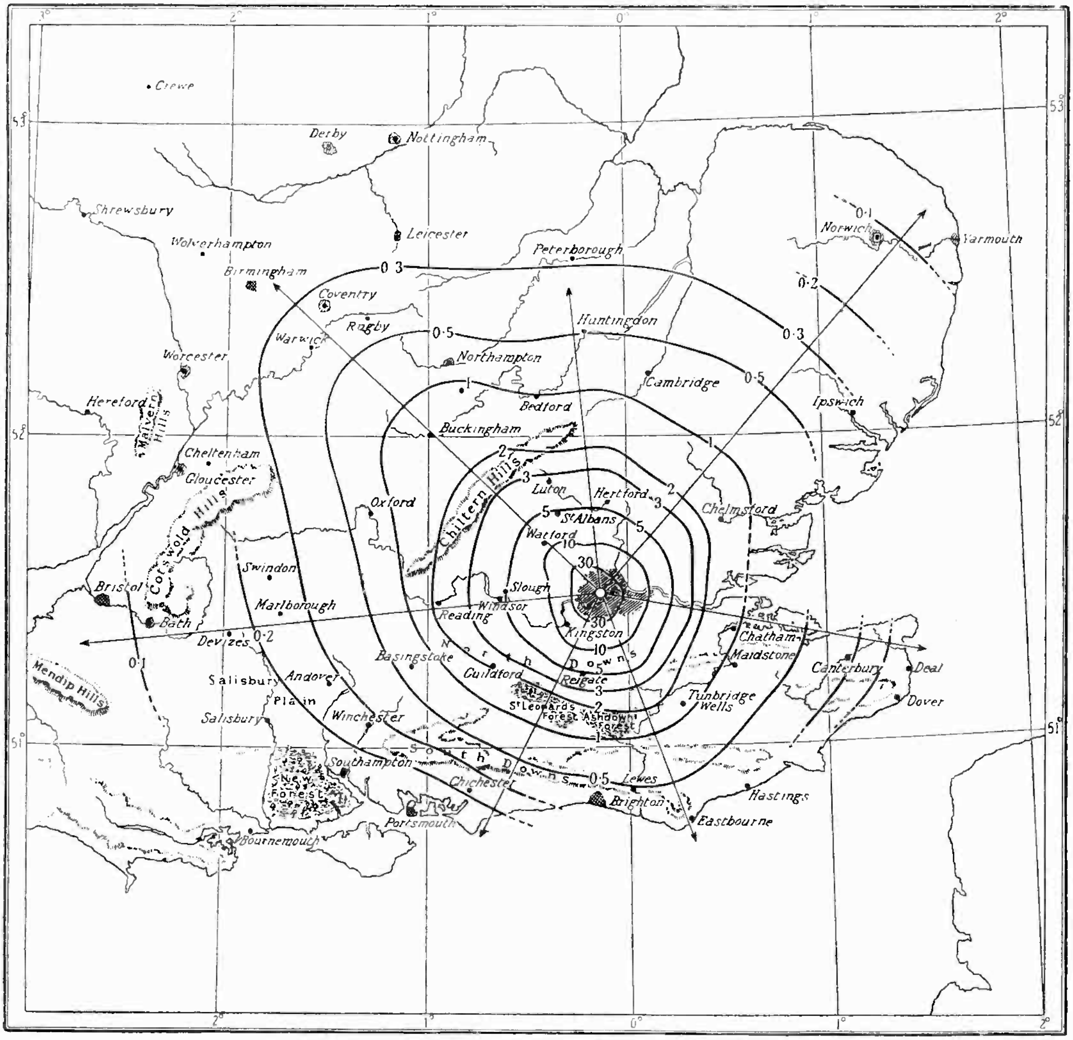


Fig. 7.

Fig. 10 experimental and theoretical curves are superimposed, the two cases selected being the best and worst "fits."

While the experimental curves agree well in shape with the theoretical, there still remains to be explained the difference of attenuation with direction and the fact that in all directions attenuation is greater than theory predicts.

The English countryside is mostly thickly wooded, and trees must contribute an appreciable amount to the surface absorption.

The author then discusses the amount of energy absorbed from a wave by a given tree. The effect of the tree is as shown in Fig. 11, where in (*a*) the magnetic field of the wave is shown by the parallel straight lines H_1, and the secondary field due to the tree by the concentric circles H_2. If the two fields are in phase the resultant will be as in (*b*), the distortion closely resembling that which occurs in the neighbourhood of a wire carrying a current in a uniform magnetic field. The resultant field can be mapped out by a portable direction finder. This was done for several trees, bearings on the apparent direction of 2LO being taken in a number of positions on a circle of approximately 10 feet radius round the tree. A curve can be drawn showing the relation between the angular departure from true bearing and the direction of the line joining the set and the tree with respect to the transmitter. A field distortion of 10 degrees was given by a very large oak tree.

An expression is derived by which the power absorbed by a tree can be evaluated by measuring the error produced on a direction-finding set at a distance *d* from the tree, in terms of the height of the tree, the distance *d* and the error in field distortion produced.

The author then quotes Sommerfeld and Bouthillon as showing that a wave must not be regarded as travelling parallel to the surface but

Since there is no reflected wave the incident wave must be regarded as passing completely into the earth at this critical angle θ, and it becomes possible to state the rate at which the earth is absorbing energy. It is the amount of energy

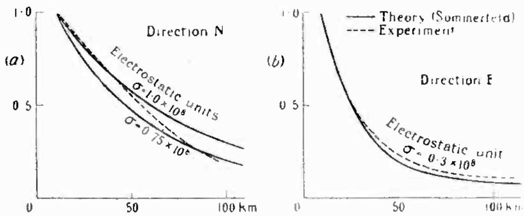


Fig. 10.

carried by a wave through a surface inclined at an angle (90 deg.—θ) to the direction of propagation, and is shown to be

$$P_0 = \frac{E^2 \times c}{8\pi} \mid \cos \theta \mid \times 10^{10}$$

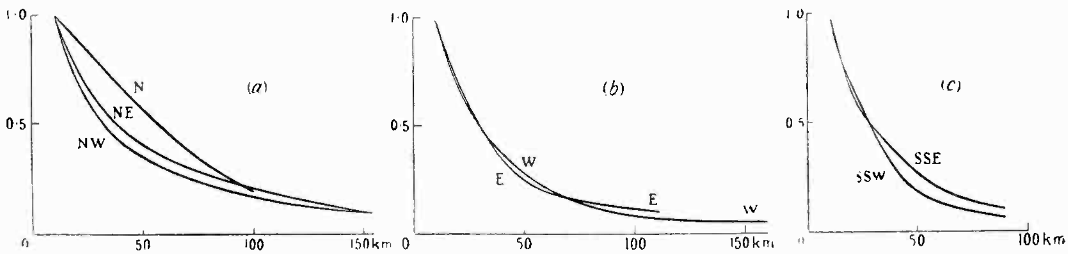


Fig. 8.

rather as incident to the surface at the critical angle of incidence for which the reflected wave vanishes. This is shown in Fig. 14, where the angle θ—corresponding to Brewster's angle in optics—is determined by the frequency and the electrical constants of the earth.

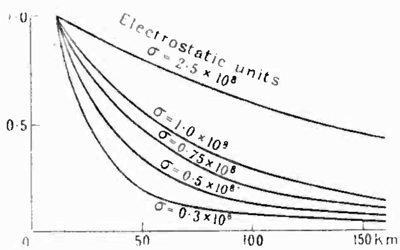


Fig. 9.

For the particular experimental conditions here dealt with, the angle is given by

$$\tan \theta = \left(\sqrt{\frac{2j\sigma}{f}}\right)$$

where σ is the conductivity of the earth in electrostatic units, f is the frequency of the waves, and $j = \sqrt{(-1)}$.

where P_0 = power absorbed by earth per km.²,

E = field strength of waves, and

$c = 3 \times 10^{10}$ cm. per sec.

From this, an expression is derived showing the number of trees per unit area required to absorb an amount of power equal to that absorbed by the earth, from which expression it is concluded that about 1,600 trees per km.² will have an attenuating effect equal to that of the earth for the particular experimental conditions given.

The equivalent bare surface is that surface devoid of trees, etc., which would absorb the same amount of energy as the surface under consideration, and the author proceeds to derive values of the conductivity of the equivalent surface. The results are shown in Table IV, which shows the effect of trees on the apparent conductivity of the surface for the wavelength under consideration.

Actual counts of the trees in the various districts have been made, showing that the number varies from about 500 per km.² in the least-wooded districts (N. of London) to the 4,000 per km.² in the most densely-wooded parts (S. of London).

It is concluded that the effect of trees may go a long way towards explaining the different apparent conductivities observed in the different directions, and also in causing all the values to be considerably below that of the conductivity as found by other methods. No doubt hedges, other vegetation, houses and other erections contribute to the absorption produced, but it seems probable that trees alone caused the greatly preponderating effect in these particular experiments.

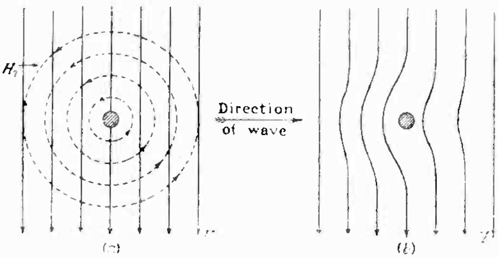


Fig. 11.

Opportunity was taken when it presented itself of making measurements on other wavelengths. Observations were taken on the Birmingham B.B.C. transmitter (475 m.) at a few positions, and

TABLE IV.

EFFECT OF TREES ON APPARENT SURFACE CONDUCTIVITY.

Number (N) of trees per km.^{2}	σ_1, in E.S.U. (approx.)
0	2.5×10^8*
200	2.0×10^8
500	1.5×10^8
1,000	1.0×10^8
2,000	0.5×10^8
4,000	0.2×10^8
6,000	0.1×10^8

on transmissions from the N.P.L., Teddington, on 720 m. The results obtained confirm those of the main experiments.

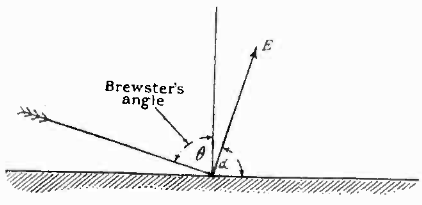


Fig. 14.

The work described was carried out for the Radio Research Board, under the Department of Scientific and Industrial Research.

* Normal value.

DISCUSSION.

A lengthy discussion followed the reading of the paper.

The discussion was opened by **Dr. R. L. Smith-Rose** who thought that the paper was a very progressive step towards knowledge of attenuation, a subject which had been neglected for twenty years. Since the early work of Duddell and Taylor, increase in the power of the transmitter and in the sensitiveness of the receiver had diverted attention from it. Its significance had been neglected up to the time of broadcasting, a reliable service of which depended on the surface waves. The paper confirmed the theoretical work of Sommerfeld. Considering the discrepancy of conditions theory, as corrected, agreed with experiment. In his Chairman's address, Col. Lee had referred to the tilt in Scotland being greater than that measured in England. This might be because the ground in Scotland was of lower conductivity and he suggested experiments around a Scottish broadcasting station. He illustrated slides of other contour maps, one around New York district, an air map and contours of New York City showing the local absorption by steel-framed buildings, and a third of the field around the Melbourne (3LO) broadcasting station.

Prof. E. V. Appleton said that the paper was so complete that little criticism was possible. He thought the effect of trees might vary with season, due to variation of the condition of the trees. Had the author calculated the effective resistance of the tree and its reactance as a condenser—that is, compared R with $1/C_p$? Such capacity effect might lead to a process of scattering, which could be judged by whether the minimum was sharp or not.

Mr. R. A. Wilmotte, referring to the contour map of Fig. 7, noted that at certain forests in the south, the curves seemed to be closer in front and farther apart behind the forests. This might be due to reflection or similar effects at the forests. He also discussed the possibility of reflection from the sea coast, quoting the differences shown between Birmingham and the Wash. He suggested investigation of the attenuation due to towns, measurements being made just before and beyond, especially of towns with not many aerials tuned to 2LO.

Mr. Warren said that the paper added considerably to knowledge of the factors governing attenuation. As regards the use of the word itself, attenuation included spreading, diversion, absorption, etc.; the author had dealt with absorption only. Although a value of σ had been found which fitted Sommerfeld's theory, there might be other causes of absorption. He discussed the possibilities of differences of the earth's conductivity at the surface and deeper down. The measurement for tilt was probably different to that for absorption due to this cause. Referring to the use of 10 kms. as a standard (Fig. 8), he thought that differences along separate radial lines up to 10 km. might cause inaccuracy in the ratios employed for the remainder of the line.

Mr. J. E. Taylor thought it expedient to use discretion in making deductions. As to correction for the curvature of the earth's surface, what was the nature of the correction and the ranges to which it was applied? Regarding the effect of trees as compared with hills, why should one excrescence have a greater effect than another? Energy passing into the ground was presumably dissipated as an i^2R loss, and the current in the ground would give an external field effectively equivalent to a re-radiation. He also referred to the fact that certain regions had been described as "dead spots" for broadcast reception.

Capt. P. R. Eckersley considered the work interesting to the B.B.C. since broadcasting work depended on the direct ray. A field strength map in Sweden, with a forest on one side and a lake on the other, showed absorption from the forest. Dr. Meissner in Germany considered that the half wavelength aerial gave rise to less attenuation. There were effects in mountainous districts and the shielding effect in valleys was well known. Much difficulty on this account was experienced in the region served by the Cardiff station. The assymetry of radiation from 5GB was apparently due to large masts. The attenuation of 5GB was equal all round, and there were no large forests.

Lt.-Col. H. R. T. Lefroy said that the paper gave confirmation of early military experiences before the war. Taking cover in woods working with portable receivers led to loss of reception. He suggested that the effect of trees was implicit in Dr. Smith-Rose's previous figures for earth conductivity. As regards depth of penetration, this might be important in different conditions of weather.

Lt.-Col. Aston pointed out that in Fig. 7, contours 2 and 3 were close at Gravesend, where the Thames was opening out, and were wider apart between Windsor and Reading where there were certainly more trees than between Chatham and Gravesend.

Lt.-Col. Angwin said that the author excluded all factors save that dealt with in the paper. The New York contour lines in the slide shown (by Dr. Smith-Rose) were less regular and had great differences of gradient. Espenschied attributed this to the density of building. He suggested that different attenuation gradients might be due to the aggregation of houses, aerials, frame structures, etc.

Mr. Barfield briefly replied to several of the points raised in the discussion, leaving more detailed points to be answered in writing.

On the motion of the Chairman (**Lt.-Col. A. G. Lee**) the author was cordially thanked for his paper.

Fire Damage at Ditton Park Research Station.

A serious fire occurred at the Radio Research Station, Ditton Park, near Slough, on 1st December. A 200-foot lattice mast was wrecked and a laboratory building (erected round the mast) and all the apparatus in it were totally destroyed. The damage is estimated at several thousands of pounds. The photograph shows the scene after the fire.

Abstracts and References.

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PROPAGATION OF WAVES.

FURTHER MEASUREMENTS ON WIRELESS WAVES RECEIVED FROM THE UPPER ATMOSPHERE.—R. L. Smith-Rose and R. H. Barfield. (*Proc. Roy. Soc.*, 116A, pp. 682-693, November, 1927.)

The paper describes a continuation of work on the analysis of the electromagnetic field of radio waves arriving at a receiving station from the upper atmosphere. The results previously published (*Proc. Roy. Soc.*, A, 107, 587, 1925, and 110, 580, 1926) were confined to measurements on waves received from the Bournemouth transmitting station. In the present paper the investigation is extended to transmissions from three other stations, viz., Birmingham, London and Newcastle.

Measurements are made of the mean angle of incidence of the downcoming waves, and from these the effective height of the ionised layer is calculated. By making use of a knowledge of the attenuation of the surface-wave over land, it has been possible to arrive at values for the coefficient of reflection of the ionised layer for the various cases dealt with.

SUITE D'UNE ETUDE SUR LA PROPAGATION DES ONDES COURTES (Continuation of an investigation on the propagation of short waves).—M. Lardry. (*L'Onde Electrique*, 6, 70, October, 1927, pp. 465-481.)

Account of a new chapter in the investigation carried on daily since January, 1924, some results of which have already appeared in *L'Onde Electrique* (3, 1924, pp. 254, 449 and 502; and 4, 1925, pp. 355 and 401). The method has been kept the same all through, the intention being to measure, every day at the same time, the signal strength of a transmitter working regularly under the same conditions, and thus to study the anomalies of propagation with the distance constant. The transmission chosen was the daily meteorological bulletin from Casablanca on 51 metres. Advantage was also taken of the voyages of the *Jacques Cartier* (31 metres) across the Atlantic to obtain a general view of the anomalies of propagation as a function of the distance. Very simple apparatus, consisting of a detector with reaction and one low frequency stage, was employed, the aim being to secure stability rather than sensitivity. The observations recorded are shown graphically and discussed. The large variations found in the daily averages are attributed to the lower atmosphere, and the superimposed extremely rapid fluctuations to quite local meteorological phenomena, while it is thought that the long-period variations from year to year, showing perhaps a migratory character, might find their explanation in the upper atmosphere. The "new chapter" refers to the very anomalous reception disclosed last winter, when the Casablanca transmission, instead of increasing in intensity from the autumn onwards as in previous years, had very great difficulty in getting through at all, also markedly abnormal signal strength from the *Jacques Cartier* and other sources was observed. It is hoped that this unanticipated fact will help to throw light on long-period variations extending over one or more years.

OBSERVATIONS PENDANT L'ECLIPSE DU 29 JUIN (Observations during the eclipse of 29th June).—A. Nodon. (*L'Onde Electrique*, 6, 69, p. 460.)

Radio observations were carried out during the partial eclipse at Sauveterre de Béarn (Low Pyrenees), but nothing abnormal was recorded.

DIAGRAMME DES CHAMPS ELECTRIQUES MESURÉS À MEUDON PENDANT LE DÉBUT DE L'ANNÉE 1926 (Graphs of electric fields measured at Meudon during the first part of 1926).—(*L'Onde Electrique*, 6, 70, October, 1927, pp. 509-511.)

The graphs are reproduced of the U.R.S.I. observations made at Meudon of the fields of Bordeaux, Nantes, Rome and Leafield, for the first five months of 1926. The measurements were carried out by the method described in the first number of *L'Onde Electrique* (January, 1922).

WAVE PROPAGATION AND THE WEATHER.—F. Charman. (*E.W. & W.E.*, 4, 51, pp. 735-742, December, 1927.)

ON THE REFRACTION OF ELECTRO-MAGNETIC WAVES IN A SPHERICALLY STRATIFIED MEDIUM.—T. Y. Baker. (*Phil. Mag.*, 4, 24, pp. 955-980, November, 1927.)

Various considerations are enumerated, all of which make the investigation of the paths of light and wireless waves very complicated, and it is only in hypothetical cases where some of the governing factors are omitted that rigorous mathematical treatment is possible. Such a course is followed in this paper. Nothing but straightforward refraction is considered, that is to say, the waves are supposed to move everywhere at right angles to themselves with velocities inversely proportional to the infractive index, also all diffraction, absorption and surface reflection effects, whether at the earth's surface or possibly at the Heaviside layer, are left out of account. While the investigation aims at showing what kind of physical effects in the reception of wireless signals will be found in this hypothetical atmosphere, no attempt is made to discuss the physical conditions such as density degree of ionisation, etc., at any point that produce the particular refractive index at that point, except that it is assumed that refractive index is a function of wavelength. With these limitations, mathematical investigation is made of the nature of the distribution of refractive index that will allow of a transmission of energy completely round the earth and give rise to wireless phenomena such as the skip distance.

DU MILIEU ETHÉRÉ (On the ether medium).—L. Garrigue. (*QST Français et Radio Electricité*, 8; 40, 42, 43, 44; pp. 37, 31, 30 and 4 respectively.)

Continuation of the philosophical discussion begun in the June number of *QST Français* (these Abstracts, October, 1927, p. 635). In the July number (40) the author expresses the opinion that the manner of working of the simple toy gyroscope is sufficient proof of the existence of an ether in motion. In the September and two following numbers the article changes its title to "De l'Onde Hertzienne et de sa Propagation" and the Hertzian wave is explained as the result of the impressions of the electron's gyratory movement upon the ether wave.

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY.

LA RÉSONANCE ET LES ATMOSPHÉRIQUES (Resonance and atmospherics).—H. de Bellescize. (*L'Onde Electrique*, 6, 68 and 69, pp. 333-356 and 427-444 respectively.)

The author collects together the views scattered in certain of his previous publications. He regards the different aspects which atmospherics assume as various manifestations of a single phenomenon, namely, the re-establishment of electrical equilibrium in the layers of the atmosphere. The phenomenon is always taking place and is in no sense localised. When it is said that there are no atmospherics, it means simply that at that time their level is momentarily dominated by the signal. The practically continuous discharges, that may or may not be accompanied by luminous manifestation, with multiple nuances due to chance, present a continuous or subdivided appearance according to their amplitude and the distance at which they are observed, the density of the successive shocks varies inversely as their amplitudes and a sufficient increase of the sensitivity of the receiver always leads to recovering the level of the disturbances. This point of view is supported by the experiment consisting of listening to signals, subject to fading, with a receiver provided with a device automatically varying the sensitivity inversely as the signal intensity, when complete calm and more or less violent disturbance alternate with one another at the caprice of the fading. A bibliography is appended.

SYSTÈME ANTIPARASITE MARREC (The Marrec system for eliminating atmospherics).—Y. Marrec. (*L'Onde Electrique*, 6, 70, October, 1927, pp. 501-508.)

Paper read before a meeting of the S.A.T.S.F., 10th May 1927. After recalling the principal means that have been employed to protect radio communications from atmospheric disturbances: resonance effects, beats, high and low frequency differential systems, limitation of amplitude; the author examines the action of atmospherics on these different systems, and gives his opinion as to the reasons for their failure. He then describes the Marrec filter, with experimental demonstrations of its effectiveness. The discussion after the reading of the paper is reproduced.

ATMOSPHERICS AND TRANSATLANTIC TELEPHONY.—A. G. Lee. (*Electrician*, 11th November, 1927, pp. 588-590.)

Extracts from the inaugural address to the Wireless Section of the I.E.E., delivered on 2nd November.

An abstract of the address is also to be found in *E.W. & W.E.* for December, pp. 757-759.

THE ELECTROSTATICS OF THE THUNDERSTORM.—A. W. Simon. (*Journ. Franklin Inst.*, 204, 5, pp. 617-647.

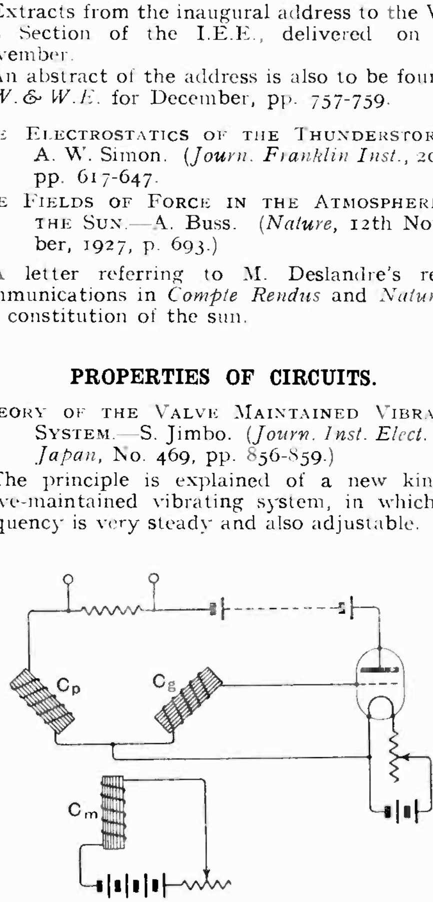
THE FIELDS OF FORCE IN THE ATMOSPHERE OF THE SUN.—A. Buss. (*Nature*, 12th November, 1927, p. 693.)

A letter referring to M. Deslandre's recent communications in *Compte Rendus* and *Nature* on the constitution of the sun.

PROPERTIES OF CIRCUITS.

THEORY OF THE VALVE MAINTAINED VIBRATING SYSTEM.—S. Jimbo. (*Journ. Inst. Elect. Eng. Japan*, No. 469, pp. 856-859.)

The principle is explained of a new kind of valve-maintained vibrating system, in which the frequency is very steady and also adjustable. The

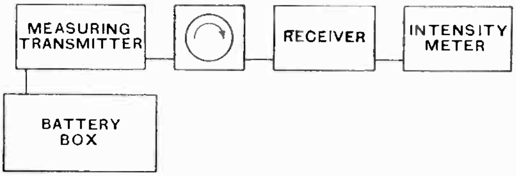


device is the combination of a valve and a mechanically vibrating system which is electro-magnetically coupled with the valve circuit and an inductive coil excited by D.C., as shown below.

EIN BEITRAG ZUR QUANTITATIVEN MESSUNG VON EMPFÄNGERN (Contribution to the quantitative measurement of receivers).—E. Klotz. (*Telefunken-Zeitung*, 8, 45/46, pp. 54-64.)

Description of apparatus developed and employed in the Telefunken laboratories for testing wireless receivers. In the arrangement the distant transmitter is replaced by an auxiliary transmitter, close to the receiver, connected through a calibrated coupling adjustment, the outgoing currents being measured with a special instrument, as shown below.

The transmitter furnishes alternating tension that can be varied in its effective value from 1—3,000,000, where the smallest value to which it can be adjusted is .005 microvolt. The tension can be altered between 3.10^6 and 15.10^{-3} periods and in addition is modulated by note frequency.



The degree of modulation can be chosen between 0 and 100 per cent. The indicating intensity meter shows tensions between .02 and 100V. Its calibration is frequency-constant and, within wide limits, independent of the running conditions. The use of the apparatus is shown by means of an example.

On Frequency Variations of the Triode Oscillator.—D. Martyn. (*Phil. Mag.*, 4, 24, pp. 922-942, November, 1927.)

Frequency variations due to changes in filament current, plate voltage, and coupling are investigated experimentally. Variations as great as two octaves or more are described. The most important cause of frequency variations is found to be the flow of grid current. The conditions for maximum and for minimum frequency change are worked out. The experimental results are then explained in detail by means of the theory.

On the Values and the Effects of Stray Capacities in Resistance-coupled Amplifiers.—M. von Ardenne and W. Stoff. (*Proc. Inst. Radio Engineers*, 15, 11, pp. 895-901.)

The general theory of stray capacities is first developed with due consideration of the phase conditions, and then the values and effects of stray capacities are discussed for a three-stage amplifier of practical dimensions.

The Short Wave Limit of Vacuum Tube Oscillators.—C. R. Englund. (*Proc. Inst. Radio Engineers*, 15, 11, pp. 914-927.)

An investigation of the short wave limit of valve oscillators of the normal type, where regeneration builds up oscillations in a resonant circuit, indicates that the physical limits for ordinary commercial valves lie between 3.5 and 1.5 metres, depending on the type of valve used. By means of a small special valve a wavelength of 1.05 metres was reached. No frequency control was left at this wavelength. With a small power valve not deviating greatly from ordinary vacuum construction, it was possible to operate at 3.5 metres with adequate frequency control, and it is concluded that the 3.5—5 metre range is available for technical purposes. Apparatus for measuring wavelength is discussed together with its application to the measurement of capacity and inductance. A bibliography of short wave valve oscillator work is attached.

The Suppression of Parasitic Oscillations in Valve Circuits.—M. Reed. (*E.W. & W.E.*, 4, 51, pp. 725-732, December, 1927.)

A Graphical Method of Amplifier Coupling Design.—M. G. Scroggie. (*E.W. & W.E.*, 4, 51, pp. 733-734, December, 1927.)

Voltage Detection Coefficient.—E. L. Chaffee. (*Proc. Inst. Radio Engineers*, 15, 11, pp. 946-957.)

The advantages of the use of voltage detection coefficient as a means of expressing the sensitivity of a detector and for the comparison of detectors are discussed. An experimental method is given for the measurement of the fictitious equivalent audio voltage which, if acting in the plate circuit of a detector, would give the demodulated audio plate current. Some experimental results are given for both plate-circuit detection and grid-circuit detection. The experimental results show that a high-μ tube is usually more sensitive as a detector than a low-μ tube.

Resonant Circuits with Reactive Coupling.—R. T. Beatty. (*Phil. Mag.*, 4, 25, pp. 1081-1098, November, 1927.)

A mathematical paper considering linear fundamental equations with constant coefficients, so that the discussion is limited to the subject of amplification over a linear region of the characteristic curve and under conditions where the grid current is negligible: that is, the amplification is without distortion. The problem is simplified without using approximations by the introduction of equivalent circuits, and a representation by means of curves derived from a parabola is given, by help of which the behaviour of the circuits can be ascertained by inspection.

The geometry of the parabola is used to facilitate the discussion of amplification and resonance curves, and an attempt is made to give a quantitative basis for the treatment of selectivity by the introduction of two new terms—"tolerance" and "activity."

The results so far obtained are summarised in a table. With regard to the reception of broadcasting, it is found that selectivity is best achieved with symmetrical circuits and no reaction, provided that sufficient amplification can be obtained.

Making Normal Co-ordinates Coincide with the Meshes of an Electrical Network.—E. A. Guillemin. (*Proc. Inst. Radio Engineers*, 15, 11, pp. 935-945.)

The theory of normal co-ordinates in oscillatory systems is briefly reviewed, and their significance in connection with the electrical network pointed out. The relation which must hold between the circuit constants in order that normal co-ordinates may be made to coincide with certain meshes is derived. The effect of having made a certain

C

mesh a normal co-ordinate of the system is then shown for the transient state, first, to confine the corresponding normal frequency to that mesh; secondly, to cause its amplitude to be independent of the other circuit constants; and thirdly, to cause that normal frequency to remain inactive unless the actuating E.M.F. is impressed in that mesh. The effect so far as the steady state is concerned, is to confine resonance with the normal frequency in question to the normal mesh, and in general to present a means for eliminating or localising resonance peaks in more complicated networks.

QUELQUES EXPÉRIENCES AVEC DES TRIODES ET LES OSCILLATIONS DE RELAXATION (Some experiments with valves and relaxation oscillations).—B. van der Pol and J. van der Mark. (*L'Onde Electrique*, 6, 69, pp. 461-464.)

AU SUJET D'UNE MÉTHODE SIMPLE DE CALCUL DE L'INDUCTANCE DE MODULATION (On the subject of a simple method of calculating the modulation inductance.)—C. Krulisz. (*L'Onde Electrique*, 6, 69, p. 464.)

Referring to his article of this title in *L'Onde Electrique* for June, 1927, pp. 255-262, Commandant Krulisz writes that the internal resistance ρm of the generating valve was there taken as equal to the "static" resistance of the valve, just in order to simplify the problem, but he here points out that this is only correct when the valve works on the straight part of its characteristic curve, which is not the case in the majority of practical applications. Actually, the "dynamic" resistance of a generating valve working with good efficiency is smaller, but this fact does not introduce any alteration in the aspect of the calculations. From a quantitative point of view, greater values for the inductance are demanded for a given problem.

The value of the "dynamic" resistance is being thoroughly investigated by M. J. Groszkowski at Warsaw.

CONTRIBUTION À L'ETUDE DE LA BASSE FRÉQUENCE (Contribution to the study of low frequency). —M. Dupont. (*QST Français et Radio Electricité Réunis*, 8, 44, pp. 13-18.)

An article in two parts dealing firstly with the characteristics of valves and applications, and secondly with connecting transformers.

SUPERS ET M.F. (Superheterodynes and Medium Frequency).—J. Vivié. (*QST Français et Radio Electricité*, 8, 42, pp. 17-25.)

First instalment of a serial article on superheterodynes and intermediate frequency amplification.

LES NEUTRODYNES.—S. Lwoff. (*QST Français et Radio Electricité*, 8, 44, pp. 56-62, November, 1927.)

Concluding instalment of a serial article on neutrodyne theory and practice begun in the September number of last year.

TRANSMISSION.

THE NEW YORK-LONDON TELEPHONE CIRCUIT.—S. B. Wright and H. C. Silent. (*Bell System Technical Journal*, 6, 4, October, 1927, pp. 736-749.)

Discussion of the special provisions in use on the transatlantic telephone to compensate for the variability of the wire and ether paths, for the radio noise, and for the fact that two-way transmission is effected upon a single wavelength. So-called technical operators are in attendance at each end of the radio path and are equipped to adjust the magnitude of the speech currents entering the radio transmitters to such a value as to load these transmitters to capacity. The amplification introduced at the radio receivers can also be adjusted to compensate for changes in the transmission efficiency of the radio paths. Finally, voice-operated relays together with suitable delay circuits are provided which so control the apparatus that at any given time it can transmit in but one direction. By this arrangement, a speaker's voice upon leaving his transmitting station cannot operate his own receiver although this is tuned to the transmitting wavelength.

LES ANTENNES D'EMISSION (Transmitting antennæ) —M. A. Cremailh. (*QST Français et Radio Electricité Réunis*, 8; 38, 41 and 43; pp. 21, 45 and 60 respectively.)

A theoretical and experimental study of the construction, operation, and means of obtaining optimum radiation, of the majority of possible antenna types.

EIN RÖHRENGENERATOR ZUR ERZEUGUNG VON MODULIERTER HOCHFREQUENZ FÜR LABORATORIUMSZWECKE (A valve transmitter for the production of modulated high frequency for laboratory purposes). — F. Gabriel. (*Elekt. Nachr. Technik.*, 4, 10, October, 1927, pp. 426-434.)

Description of a three-valve generator containing one control valve, one transmitting and one

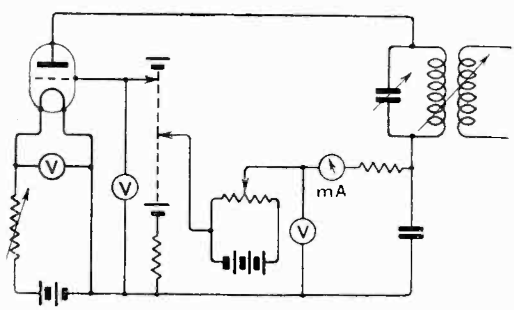


Fig. 1.

modulating. For the control valve's self-exciting circuit, the dynatron arrangement is chosen as being the simplest means of obtaining perfectly sinusoidal oscillations and freedom from reaction. The principle is shown in Fig. 1.

The transmitting and modulating valves are connected up in a circle, as represented in Fig. 2, the arrangement being very convenient for observing the degree of modulation. To high frequency

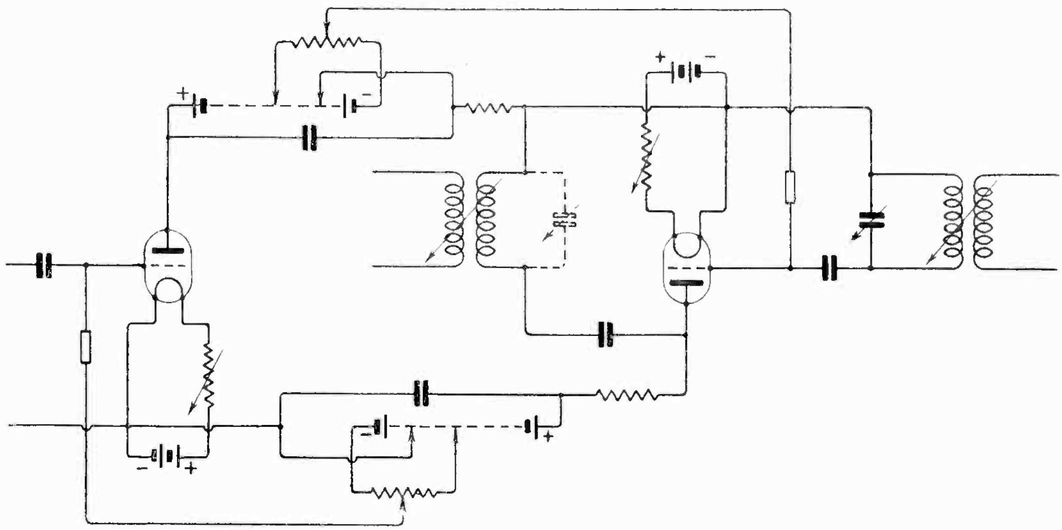


Fig. 2.

the circle is barred by means of choke coils and a special circuit opened which is inaccessible to low frequency.

SOME EXPERIMENTS WITH SIDE-BAND TELEPHONY ON SHORT WAVELENGTHS.—E. Howard Robinson. (*E.W. & W.E.*, 4, 51, pp. 715-721, December, 1927.)

CALCUL DES CONSTANTES ELECTRIQUES ET MÉCANIQUES DES ANTENNES PSEUDO-SYMÉTRIQUES AVEC APPLICATION AUX ANTENNES GENRE FL (Calculation of the electrical and mechanical constants of pseudo-symmetrical antennæ, with application to antennæ of the FL type.)—M. Stern. (*L'Onde Electrique*, 6, 70, October, 1927, pp. 482-500.)

Concluding part of an article begun in *L'Onde Electrique* for July, of which a brief summary was given in these Abstracts for November, p. 695.

RECEPTION.

THE PROBLEM OF SELECTIVITY.—A. Castellain. (*Wireless World*, 9th November, 1927, pp. 649-651.)

An article intended to show as simply as possible on what factors selectivity of tuning depends and how it is connected with the problem of good quality reproduction.

AUTOMATIC VOLUME CONTROL.—(*Wireless World*, 23rd November, 1927, pp. 719-720.)

Abstract of a paper by Mr. Harold A. Wheeler, read before the Institute of Radio Engineers on 2nd November, 1927, constituting an important contribution to the technique of broadcast reception. Compensation for changes of signal strength due to fading is obtained with negligible time lag and without making use of relays or moving parts.

A PLEA FOR CHOKE-COUPLING.—A. L. Sowerby. (*Wireless World*, 9th November, 1927, pp. 641-642.)

MAUVAISE RÉCEPTION EN RADIOPHONIE (Faulty broadcast reception).—R. Braillard. (*QST Français et Radio Electricité Réunis*, 8, 40, pp. 48-53.)

A lecture given to the Société Belge des Electriciens, at Brussels, 26th February, 1927, discussing the causes and remedies for poor broadcast reception.

SUR LES CONTACTS IMPARFAITS (On imperfect contacts).—H. Pélabon. (*L'Onde Electrique*, 6, 69, pp. 401-426.)

The author describes the apparatus he has employed to vary automatically the distance between the two parts of a detector, or the pressure they exert on one another, in a continuous manner. He first studies the system galena-steel with both direct and alternating current and as a detector, and finds that two kinds of rectification (interior and exterior) exist for all contacts formed by a metal and a semi-conductor, and is led to insist on the part played by thermoelectric phenomena and coherence. Purely metallic contacts, for which there is only a single rectification, are then considered, including the system steel-steel, the article terminating with a brief discussion of the theory of the two contact resistances (*cf.* these Abstracts June, November and December, 1926, pp. 386, 703 and 770 respectively, and June, 1927, p. 372).

VALVES AND THERMIONICS.

THE VALVE FILAMENT AT CONSTANT VOLTAGE.—E. H. Banner. (*Journ. Sci. Instr.*, 4, 10 and 11, 1927, pp. 317 and 349 respectively.)

Description of experimental work continuing that done at Birmingham in 1924 (*Proc. I.R.E.*, 14, 325). The primary object of the work was an experimental investigation of the term "constant filament current" or voltage, for standard tests.

When the filament of a thermionic valve emits and a thermionic current flows from the filament to the anode and through an external circuit back to the filament, the filament current is necessarily different at all points along the filament. An ammeter in each filament lead and a voltmeter across them will all read differently when the valve emits, the actual deviations depending on the electronic emission and the circuit used. The only exceptions are the case of a filament connected directly to a source of P.D. with no intermediate rheostat, when the voltage will be maintained constant by the supply, but the currents will vary in any case. The other exception is that of the valve with the separately heated cathode, the potential of which is uniform.

The variations of the reading of the filament voltmeter and ammeters have been investigated experimentally, and a circuit has been devised in which there is no change of reading of the voltmeter or either ammeter when the anode current is switched on and off. The current read is the filament battery current, and with this circuit tests may be repeated on valves with the certainty of the filament conditions being constant for different tests.

An investigation was also made of the validity of the practice of readjusting the filament voltage after switching on the anode potential, and it was found that this practice is not correct as regards maintaining the filament under constant conditions, except for those valves intended to be run without a rheostat.

NEW USES FOR VALVES.—A. Dinsdale. (*Wireless World*, 9th November, 1927, pp. 643-645.)

Account of the employment of valves in power stations to control A.C. and D.C. generators.

THE NEW COSMOS A.C. VALVE.—*Wireless World*, 23rd November, 1927, pp. 713-714.)

Brief account of this power output valve of excellent characteristics with indirectly heated cathode, the necessary emission being obtained from a long, fine nickel tube coated with a mixture of barium and strontium oxides, enclosing the heater in the form of a hairpin filament, and insulated from it by a layer of porcelain. The consumption is one ampere at four volts.

A NOTE ON THE THERMIONIC WORK FUNCTION OF TUNGSTEN.—C. Davisson and L. Germer. (*Physical Review*, 30, 5, pp. 634-638, November, 1927.)

The authors correct their measurements upon the thermionic work function of tungsten (*Phys. Rev.*, 20, 300, 1922) for the "Schottky effect"—that is, for the reduction of the work function by the external electric field at the surface of the filament; and also they take occasion to discuss the interpretation of their work function measurements rather more fully than in the original paper.

DIRECTIONAL WIRELESS.

DIRECTIONAL WIRELESS AS AN AID TO NAVIGATION.—R. L. Smith-Rose. (*Nature*, 26th November, 1927, pp. 774-776.)

A survey of the subject, which may be divided into two parts, according as the directive characteristic is applied at the transmitting or the receiving end of the wireless link. The latter case is considered first and the directional receiver or direction-finder is discussed, with its accuracy, position (whether on shore or board ship), and the conditions for freedom from night errors; and a brief account is given of fixed beacon stations. The second part on directional transmission is divided into three sections, dealing respectively with the beam system as installed at Inchkeith and South Foreland, rotating loops, and course setters.

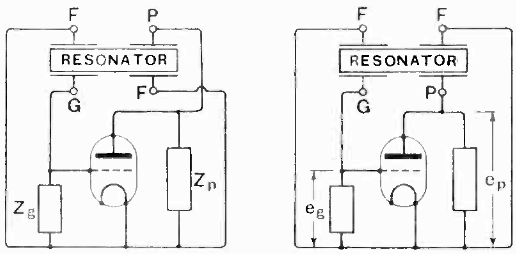
DIRECTIONAL RADIATION WITH HORIZONTAL ANTENNAS.—A. Meissner. (*Proc. Inst. Radio Engineers*, 15, 11, pp. 928-934.)

A translation into English of the paper appearing in *Zeitschrift für Hochfrequenz.*, 30, 3, 77-79, September, 1927 (these Abstracts, December, 1927, p. 766).

MEASUREMENTS AND STANDARDS.

PIEZO-ELECTRIC OSCILLATORS AND PIEZO-ELECTRIC FREQUENCY STABILIZERS.—Y. Watanabe. (*Journ. Inst. Elect. Eng. Japan*, No. 469, August, 1927, pp. 835-855.)

From the point of view of self-oscillating action, piezo-electric oscillators may be divided into three



(a) (b)

classes: when the regenerative coupling between plate and grid of the valve is due to the

(1) coupling action given by the piezo-electric coupler as in Fig. 1.

(2) regenerative coupling by means of the piezo-electric resonator, and as in Fig. 2.

(3) and simply to the "pulling into step" characteristics of the valve amplifier.

Each class of oscillator is considered, particularly with regard to the conditions for building up oscillation, and some experimental results are given for verification.

The frequency stabilising action of the valve oscillator by means of the piezo-electric resonator may be explained by the well-known characteristics of "Zieherscheinungen" which take place in the coupled circuit valve oscillator. Although the natural frequency of the electrical oscillation circuit of the oscillator may be pretty widely changed, the frequency of the oscillation can be stabilised at a nearly constant value by means of the piezo-electric resonator, which behaves as the statically coupled secondary oscillation circuit, the natural frequency of which is constant. This coupled circuit, including the resonator, may be easily represented in the form of an equivalent electrically coupled circuit by taking into consideration the motional admittance of the resonator. Consequently the observation of the frequency characteristic near the resonance point enables us to determine the equivalent electric constants of the piezo-electric resonator. The great effectiveness of the stabilising action of the resonator is shown by some experimental results and compared with the electric method for obtaining constant frequency.

MOUNTING QUARTZ OSCILLATOR CRYSTALS.—R. C. Hitchcock. (*Proc. Inst. Radio Engineers*, 15, 11, pp. 902-913.)

Various types of mountings are described for quartz oscillator crystals having frequencies in the vicinity of one million cycles per second. For low power work a spaced upper electrode is recommended, mounted in a neon-filled tube. For radiating up to 50 watts from the crystal-controlled tube, a similar mounting placed in a copper-based tube is advised. This latter tube can be cooled by immersion in an oil bath. Accurate temperature control of the oil bath keeps the radio frequency within narrow limits.

ON THE USE OF THE ELECTROMAGNETIC RECEIVER IN ACOUSTICAL MEASUREMENTS.—T. S. Littler. (*Journ. Sci. Instr.*, 4, 11, pp. 337-341)

The advantages of the electromagnetic receiver as a microphone in sound measurements are discussed. It is pointed out that the sensitiveness of the moving-coil receiver is much more constant than that of the moving-iron variety, reasons for which are given. A modification of the usual type of receiver is described, the instrument being rendered sensitive and selective by the use of a tuned electrical circuit, and an arrangement is also given by means of which errors, due to stray electromagnetic disturbances, can be eliminated.

A RADIO SIGNAL-INTENSITY RECORDER.—B. Saltmarsh. (*E.W. & W.E.*, 4, 51, pp. 743-745, December, 1927.)

DESCRIPTION OF A VALVE WAVEMETER WITH RANGE OF 10 METRES TO 20,000 METRES.—F. M. Colebrook. (*E.W. & W.E.*, 4, 51, pp. 722-724, December, 1927.)

Description of a valve oscillator wavemeter which is an improvement on the previous design described in the *Wireless World* of 6th October, 1926.

NOTES ON THE ACCURACY OF VARIABLE AIR CONDENSERS FOR WAVEMETERS.—W. H. Griffiths. (*E.W. & W.E.*, 4, 51, pp. 754-757, December, 1927.)

L'ETALONNAGE ABSOLU DES ONDEMÈTRES (Absolute calibration of wavemeters).—P. Olivet. (*QST Francais et Radio Electricité Réunis*, 8, 42, pp. 6-13.)

The author reviews in succession three methods of calibration employed in practice: multivibrator, quartz plate, and Lecher wires, dealing more in detail with the last method.

SUBSIDIARY APPARATUS.

A VACUUM TUBE POTENTIOMETER.—A. L. Fitch. (*Journ. Opt. Soc. Amer. and Rev. Sci. Instr.*, 14, 4, pp. 348-353.)

In his book "The Thermionic Vacuum Tube" Van der Bijl discusses a circuit which with suitable modifications becomes one of the most versatile of electrical measuring circuits. He uses it to measure the amplifying power of valves under varying conditions. As modified, it is essentially a valve voltmeter circuit and may be used wherever electrical quantities can be measured by equating potential drops. The circuit is shown below:—

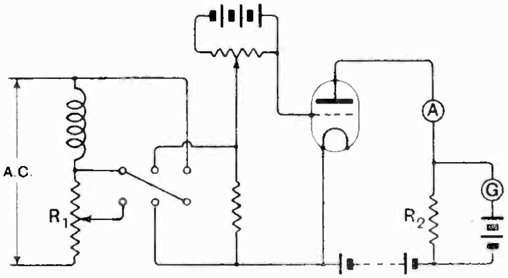


Fig. 1.

A second form of the circuit with two valves has been devised, which does away with the necessity of throwing a switch to and fro. This paper discusses the circuits and the uses to which they may be put in an electrical measurements laboratory.

EXPONENTIAL LOUD-SPEAKER HORNS.—A. Dinsdale. (*Wireless World*, 16th and 23rd November, 1927, pp. 564 and 705 respectively.)

AN APPLICATION OF THE VACUUM TUBE OSCILLATOR.—C. B. Crofutt. (*Journ. Opt. Soc. Amer. and Rev. Sci. Instr.*, 14, 5, pp. 431-432.)

Account of the use of the valve oscillator to obtain a sustained source of sound, frequently desirable in lecture or laboratory experiments.

METAL RECTIFIERS. (*Electrician*, 18th November, 1927, p. 626.)

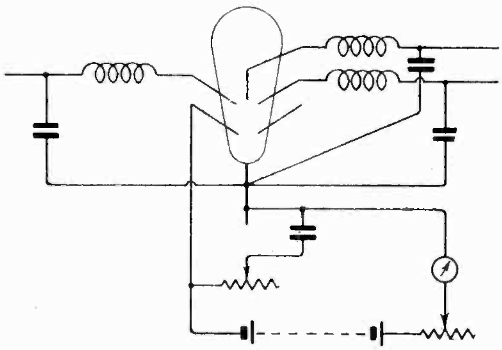
Description of a new rectifier depending for its operation on electronic action at a permanent junction between a copper disc and a layer of cuprous oxide formed upon one face of it. The rectifying effect depends on the fact that the ratio of the resistance from the copper to the oxide coating is very high compared with the resistance from the oxide coating to the copper. Many applications of the device are suggested.

There is also an account of this rectifier and its applications in the *Electrical Review* of 11th November, 1927, pp. 833-834.

The principle on which the rectifier operates is the same as that described by Prof. Sheldon in the *Scientific American* of September, 1926 (these Abstracts, December, 1926, p. 771).

ÜBER DIE BESEITUNGEN DER HOCHFREQUENZSTÖRUNGEN, HERVORGERUFEN DURCH EINEN QUECKSILBERDAMPF-GLEICHRICHTER (On the elimination of the high-frequency disturbances produced by a mercury vapour rectifier).—G. Leithäuser. (*Elekt. Nachr. Technik*, 4, 10, October, 1927, pp. 434-435.)

A mercury vapour rectifier was obtained for the high power station at Norddeich for charging an amplifier battery the charging tension of which amounted to about 650 volts. After the rectifier had been constructed and installed it was found that the disturbances were far greater than had



been expected and reception was absolutely impossible. A systematic investigation to do away with the disturbances had, therefore, to be undertaken, which is described here. Freedom from disturbance was finally obtained by a judicious insertion of condensers, as shown in the diagram below of the circuit-arrangement ultimately developed.

GENERAL PHYSICAL ARTICLES.

DER SELBSTTÖNENDE KRISTALL ALS THERMISCHER EFFEKT (The spontaneously singing crystal as a thermal effect).—F. Seidl. (*Annalen der Physik*, 84, 19, pp. 384-394.)

A paper referring to that of K. Lichtenecker (*Zeits. f. techn. Physik*, 8, 4, pp. 161-163) in which he opposes the views expressed by the writer in a previous paper (*Phys. Zeitschr.*, 27, 64 and 816) and attributes the phenomenon of the spontaneously singing crystal not to the electromagnetic oscillations but to the steep temperature gradient occurring at the metal point. The writer here gives evidence for believing that both electromagnetic and acoustical oscillations originate in the layer of gas at the point of contact, the many resemblances between the spontaneously singing crystal and the spontaneously singing arc suggesting the possibility that the crystal phenomenon is due to a microscopically small arc or other discharge. The writer intends making further experiments which, it is hoped, will give a final answer to the question.

THE DETERMINATION OF THE ELASTIC MODULI OF THE PIEZO-ELECTRIÇ CRYSTAL ROCHELLE SALT BY A STATICAL METHOD.—W. Mandell. (*Proc. Roy. Soc.*, A, 116, pp. 623-636, November, 1927.)

Rochelle salt, which is a double tartrate of sodium and potassium, having the formula $NaKC_4H_4O_6$, $4H_2O$, possesses far larger piezo-electric properties than any other known substance. Whereas the greater of the two piezo-electric moduli of quartz is 0.0677 E.S.U. per kilogram, a usual cuuve for Rochelle salt is 10 E.S.U., and this can be increased to 200 E.S.U. per kilogram for crystals grown in a special manner so as to develop a composite structure. Since this piezo-electric effect is associated only with crystals having an asymmetric structure and occurs when the crystal is submitted to mechanical stresses, it is likely that the phenomenon may be closely related to its elastic properties, and experiments were devised to measure the elastic moduli, the theory and results of which are given here. A further experiment was made to find the variation in elasticity with change of temperature, but no discontinuity was found near the critical temperature of 23° C., when the piezo-electric effect almost abruptly disappears.

THE TEMPERATURE VARIATION OF THE ELASTICITY OF ROCHELLE SALT.—E. P. Harrison. (*Nature*, 26th November, 1927, p. 770.)

A letter referring to that of Mr. Morgan Davies on this subject in *Nature* of 3rd September, p. 332 (these Abstracts, November, 1927, p. 701), stating that it recalls the analogy between piezo-electric phenomena and the reciprocal relations between strain and magnetic properties shown by ferromagnetic metals, in particular the stationary value in Young's modulus-temperature curve for nickel at about 400° C., the Curie point for that material. The writer adds that a close examination of the temperature variation of the thermal expansion of a piezo-electric crystal would be expected to reveal a discontinuity at the temperature of abrupt change in the piezo-electric modulus which, if present, would be analogous to that found by him in the thermal expansion of nickel.

PHOTO-ELECTRIC CONDUCTION IN SELENIUM.—R. J. Piersol. (*Physical Review*, 30, 5, pp. 664-672.)

Description of experiments leading to the conclusion that the photo-conduction in selenium is due to a photo-electric liberation of electrons rather than to an allotropic change from an insulating to a conducting form of selenium, and that the mechanism of the current conduction under dark conditions is entirely different from that of the photo-conduction.

PHOTO-ELECTRIC EFFECT AND SURFACE STRUCTURE IN ZINC SINGLE CRYSTALS.—E. Linder. (*Physical Review*, 30, 5, pp. 649-655.)

A paper dealing with an experiment in which the photo-electric current from different parts of the surface of a single crystal of zinc was measured. From the results it appears that photo-electric emission depends upon the orientation of the crystal lattice in the emitting surface. Maximum current was obtained when the hexagonal axis was normal to the illuminated surface and minimum when it was parallel, the ratio being about 2 : 1.

THE RELATION BETWEEN REFRACTIVE INDEX AND DENSITY.—D. Burnett. (*Camb. Phil. Soc. Proc.*, 28, 8, pp. 907-911, October, 1927.)

IONISATION BY COLLISION.—L. G. Huxley. (*Phil. Mag.*, 4, 24, pp. 899-902, November, 1927.)

In this Journal for September, p. 505, J. Taylor gives a reply to the author's remarks on his "Photoelectric Theory of Sparking" in the author's communication entitled "Ionisation by Collision" (*Phil. Mag.* for May), and, in addition, he also raises objections to the Theory of Sparking formulated by Townsend. The intention of the present paper is to consider these objections and comment on the replies.

A DIFFERENTIAL RETARDING POTENTIAL METHOD FOR THE STUDY OF THE ENERGY DISTRIBUTION OF SLOW ELECTRIC EMISSIONS.—C. F. Sharman. (*Camb. Phil. Soc. Proc.*, 28, 8, pp. 922-929, October, 1927.)

INTEGRAPH SOLUTION OF DIFFERENTIAL EQUATIONS.—V. Bush and H. Hazen. (*Journ. Franklin Institute*, 204, 5, pp. 575-615, November, 1927.)

In a previous paper (this Journal, January, 1927) a continuously recording integraph was described, by means of which differential equations, involving only one integration, could be solved. The present paper describes a revision of this machine such that an equation involving two successive integrations, corresponding to practically any second-order total differential equation, with all terminal conditions included, can be solved.

ON MAXWELL'S STRESS, AND ITS TIME RATE OF VARIATION.—S. R. Milner. (*Phil. Mag.*, 4, 24, pp. 943-949, November, 1927.)

ON ELECTRIC PHENOMENA IN GRAVITATIONAL FIELDS.—E. T. Whittaker. (*Proc. Roy. Soc.*, A, 116, pp. 720-735, November, 1927.)

CONTEMPORARY ADVANCES IN PHYSICS. XIV.—INTRODUCTION TO WAVE-MECHANICS.—K. Darrow. (*Bell System Technical Journal*, 6, 4, October, 1927, pp. 653-701.)

DYNAMICAL AND ELECTRICAL PROBLEMS WHOSE SOLUTIONS SATISFY SCHRÖDINGER'S WAVE EQUATION.—A. Bramley. (*Journ. Franklin Inst.*, 204, 5, pp. 561-574, November, 1927.)

UNIDIRECTIONAL QUANTA IN WAVE MECHANICS.—G. Breit. (*Journ. Opt. Soc. Amer. and Rev. Sci. Instr.*, 14, 5, pp. 374-380.)

The problem of emission by an atom is treated according to Schrödinger's rules. The translational motion of the atom as a whole is taken into account. The charge-current density vector is shown to be propagating with the velocity of light in the direction of the emitted quantum. Only unidirectional quanta can be emitted according to the theory. The reason is that the charge-current wave radiates infinitely more intensely if it travels with light velocity than otherwise.

MISCELLANEOUS.

RADIO VISION.—C. Francis Jenkins. (*Proc. Inst. Radio Engineers*, 15, 11, pp. 958-964.)

The writer outlines his method of radio vision and states that, while seeing by radio what is actually happening at a distant place is now an accomplished scientific attainment, the mechanism is not yet a merchandising development, though he confidently believes the completion of a radio vision receiver acceptable to the public is the work of but a few months more.

TELEVISION.—H. E. Ives. (*Bell System Technical Journal*, 6, 4, October, 1927, pp. 551-559.)

Discussion of the chief problems presented in the accomplishment of television, namely: the resolution of the scene into a series of electrical signals of adequate intensity for transmission, the provision of a transmission channel capable of transmitting a wide band of frequencies without distortion, means for utilising the transmitted signals to re-create the image in a form suitable for viewing by one or more observers, and arrangements for the accurate synchronisation of the apparatus at the two ends of the transmission channel.

THE PRODUCTION AND UTILISATION OF TELEVISION SIGNALS.—F. Gray, J. Horton and R. Mathes. (*Bell System Technical Journal*, 6, 4, October, 1927, pp. 560-603.)

A well-illustrated article in three sections, dealing respectively with the apparatus for the analysis and synthesis of the image, the television signal wave, and the terminal circuits for sending and receiving television signals.

SYNCHRONISATION OF TELEVISION.—H. M. Stoller and E. R. Morton. (*Bell System Technical Journal*, 6, 4, October, 1927, pp. 604-615.)

RADIO TRANSMISSION SYSTEM FOR TELEVISION.—E. L. Nelson. (*Bell System Technical Journal*, 6, 4, October, 1927, pp. 633-652.)

Starting from the general requirements imposed on the transmitting medium, this paper discusses the engineering of a radio system for television purposes and describes the radio facilities actually employed for the recent Bell System demonstration. The tests to which the system was submitted to determine its suitability are outlined and the measured frequency-response characteristics shown. An interesting phenomenon due to multi-path transmission, the production of positive and negative secondary images, is reported. A brief series of experiments concerned with the transmission of both voice and image "on a single wavelength" is also described.

VALVE AMPLIFIERS FOR SUBMARINE CABLES.—A. M. Curtis. (*Electrician*, 18th November, 1927, pp. 620-621.)

A paper intended to point out the requirements of cable amplifiers, particularly those used on high-speed loaded cables, and to describe how these requirements have been met in the present signal-shaping amplifier of the Western Electric Co.

RADIO—AN AID TO IMPROVING SERVICE.—L. Beckwith. (*Electrical World*, 15th October, 1927, p. 595.)

Radio aids in improving electric service by indicating the location of faulty equipment. Experience has shown that a radio-frequency disturbance invariably exists in the vicinity of a piece of electrical equipment for sometime previous to its complete failure ; this condition is particularly noticeable on equipment used with distribution voltages, where radio-frequency disturbances have been known to precede the failure of a piece of equipment for as long a period as several months.

LEAGUE OF NATIONS.—*Electrical Review*, 11th November, 1927, p. 820.)

In view of the need felt by the League of Nations for the possession of further communication facilities, it is announced that the Board of the Swiss Marconi Company has decided to install a new high-speed radio-telegraph transmitter with an anode power of 50 kilowatts. The range of the installation will be over 3,000 kilometres, so that the station will be capable at any moment of linking-up the headquarters of the League with any place in Europe, the Far East, and North Africa. The present transmitters will be reinforced, so that by next summer the League will have at its disposal four high-power transmitting sets, and it will be possible to receive simultaneously from twelve foreign stations. D. E. H.

Esperanto Section.

Abstracts of the Technical Articles in our last Issue.

Esperanto-Sekcio.

Resumoj de la Teknikaj Artikoloj en nia lasta Numero.

PROPAGADO DE ONDOJ.

ONDA PROPAGADO KAJ LA VETERO. F. Charman.

Oni priskribas preparajn provojn kunrilatigi long-distancajn signalojn (je 30 ĝis 45 metroj), kun barometra premado.

Signaloj el Nova Zelando, Aŭstralio, Brazilio, kaj Usono estis sisteme observitaj, kaj al ili oni donis fortecojn laŭ la Kodo "R." Rezultaj kurvoj montrantaj signalfortecajn variadojn kun barometraj variadoj estas donitaj kaj diskutitaj longe.

Le aŭtoro poste turnis sin al ĝenerala diskutado pri l'efektoj de la supra tavolo, montrante la efektojn de neunuforma medio kaj de konkava kaj konveksa tavolo. La ĝeneralaj meteorologaj ĉirkaŭaĵoj de la Britaj Insuloj estas poste diskutitaj, kun speciala aludo al la signalaj variadoj observitaj, dum la efekto de signalo vojaĝanta tra ciklono aŭ kontraŭciklono estas ankaŭ montrita.

Oni diras, ke la esplorado estas etendota al aliaj ondogrupoj, kaj ke oni estas ricevinta indikojn, ke la fenomenoj pritraktitaj estas ankaŭ komunaj kun la brodkasta ondogrupo.

ATMOSFERAĴOJ.

ATMOSFERAĴOJ KAJ TRANSATLANTIKA TELEFONIO.

Raporto pri la malferma kunveno, por la 1927-1928a kunvenaro, de la Senfadena Sekcio de la Instituto de Elektraj Inĝenieroj, kun la inaŭgura parolado de la Presidento, Leŭt.-Kol. A. G. Lee, M.C., B.Sc.

La parolado traktis pri l'atmosferaĵoj aparte rilate al la Transatlantika Telefona Servado. Laboradon pri la formo de atmosferaĵoj, direkton de alveno, k.t.p., oni diskutis, kaj oni donis detalojn pri la preparaj mezuradoj, kiuj efektivigis la lokigon de la Brita riceva stacio ĉe Cupar Fifeshire.

Post diskutado pri la kvanto da elimino ebla per selektiva agordado, kaj post priskribo pri la cirkvitoj uzitaj ĉe Cupar, la parolinto turnis sin al la utiligo de direkteblaj antenaj sistemoj. Polusaj kurvoj de kelkaj malsimilaj antenaroj estas montritaj, inkluzive unu uzanta rotaciantan kadron kaj vertikalan antenon tiel kombinitan por doni polusan kurvon en la formo de mallarĝa folio.

PROPRECOJ DE CIRKVITOJ.

LA SUBPREMO DE PARAZITAJ OSCILADOJ EN VALVAJ CIRKVITOJ. M. Reed.

La artikolo traktas ĝenerale pri la temo de Parazitaj Osciladoj. Post mallonga enkonduko, oni montras, ke estas, ĝenerale, tri eblaj oscilaj cirkvitoj, (1) Hartley'a cirkvito, (2) agorditanoda cirkvito, (3) agorditkrada cirkvito. Ĉiu el ĉi tiuj tri ekzemploj estas konsiderita detale, kaj metodoj por elimini la maldeziritan efekton estas diskutitaj. Vektoraj diagramoj estas donitaj pri la kurentoj kaj voltkvantoj necesaj en diversaj okazoj.

Tre utila resumo de la metodoj uzitaj en la artikolo estas donita en tabelo ĉe la fino, kaj du mallongaj matematikaj aldonoj estas ankaŭ donitaj.

GRAFIKA METODO DE AMPLIFIKATORA KUPLA DESEGNADO. Marcus G. Scroggie.

Ĉi tiu artikolo traktas pri rezisteca kapacita kuplado je aŭdeblaj frekvencoj, traktante aparte pri la tempo-konstanto de malŝarĝo de la kupla kondensatoro. Oni ricevis esprimon montrantan la efekton de tempo-konstanto, kaj serio de grafikaĵoj ilustras la efekton de diversaj valoroj de tuta tempo-konstanto je la plimalaltaj aŭdeblaj frekvencoj.

SENDADO.

KELKAJ EKSPERIMENTOJ PER FLANKONDARA TELEFONIO JE MALLONGOJ ONDOLONGOJ. E. Howard Robinson.

Post enkonduka diskutado pri portantaj subpremaj sistemoj, kaj la utiligo sole de flankaroj, la aŭtoro ilustras "mem-rektifan" modulatoron, unue laŭ ĝia eksperimenta aranĝo kaj poste laŭ ĝia fina formo, kie ĝi evoluigas ambaŭ flankajn arojn sen portanta ondo. Oni donas longe praktikajn detalojn pri eksperimentoj pri la evoluigo de l'aparato, kun kompleta cirkvita diagramo de la sendilo kaj detaloj pri la cirkvitaj konstantoj. La ricevilo uzita en la eksperimentoj estas ankaŭ priskribita kaj ilustrita, kaj la efektoj observitaj je la funkciado de la sistemo trans longa distanco estas diskutitaj.

Aldonaĵo donas mallongan matematikan diskutadon pri la relativa utileco (laŭ la vidpunkto de ŝparado de potenco) de unuoblaj flankaraj kaj duoblaj flankaraj sendadoj.

RICEVADO.

REGISTRILO DE RADIO-SIGNALA INTENSECO. B. Saltmarsh.

Post mallonga diskuto pri la teorio de velkado kaj pri fruaj provoj kaj esploroj pri la temo, la aŭtoro pritraktis metodojn por registri.

Li poste priskribis registrilon desegnitan por elimini la disvolviĝan prokraston kiu apartenas al fotografaj registraj metodoj. Post sufiĉa amplifado je radio-frekvenco, la signalo estas rektifita per stabila kristalo kaj la rektifita kurento pasigita tra reflektanta galvanometro. La lumo el la galvanometro trapasas optikan kojnon kaj kondensilon por aktivigi fotoelektran ĉelon, kies elmeto, post kelkaj ŝtupoj de malaltfrekvenca amplifado, aktivigas plumon funkciigitan elektromagnete, kiu skribas sur cilindro, 15 colojn (38 c.m.) ĉirkaŭe, rotacianta unufojon ĉiuhore.

Specimena registraĵo estas montrita, kun diagramoj de la optika aranĝo, k.t.p.

HELPA APARATO.

PRISKRIBO PRI VALVA ONDOMETRO KUN SKALO DE 10 METROJ ĜIS 20,000 METROJ. F. M. Colebrook.

La ondometro estas plibonigaĵo de antaŭa desegno priskribita en *Wireless World*, 6a de Oktobro, 1926a. Valvo, oscilanta je aŭdebla frekvenco, estas enkorpigita por apliki moduladon laŭdezire al la radio-frekvenca oscilatoro. La onda skalo estas provizita pere de serio de enŝtopaj bobenoj. La cirkvito estas modifita oscilatoro Hartley'a, kaj oni pretendas al konstanteco de normigado ĝis unu parto en milo, rilate al ŝanĝoj ĉe anodaj kaj filamentaj voltkvantoj. La baterioj bezonitaj estas enkorpigitaj en la instrumentujo.

Oni donas fotografaĵon kaj cirkvitan diagramon montrantan la diversajn elektrajn konstantojn, kaj diskutas la ĝeneralajn detalojn de l'instrumento.

LA VIBRADOJ DE LAŬTPAROLILAJ DIAFRAGMOJ.

Redakcia noto, citanta rezultojn obtenitajn dum eksperimentoj ĉe "Kone" Laŭtparolilo. Sablaj figuroj estas montritaj, ilustrantaj la manierojn de vibrado de la diafragmo je diversaj frekvencoj, kaj la rezultoj estas diskutitaj mallonge. Je 150 cikloj la diafragmo vibras laŭ sektoroj, kiuj plinombriĝas ĝis frekvenco de 800 cikloj, super kio la diafragmo vibras laŭ nombro da ringoj.

DIVERSAĴOJ.

RESUMOJ KAJ ALUDOJ.

Kompilita de la *Radio Research Board* (Radio-Esplorada Komitato), kaj publikigita laŭ aranĝo kun la Brita Registara Fako de Scienca kaj Industria Esplorado.

MATEMATIKO POR SENFADENAJ AMATOROJ. F. M. Colebrook.

Daŭrigita el antaŭaj numeroj. La nuna parto traktas pri Kombinoj de Impedancoj, Grafika Prezentado de Impedancoj en Paralelo (kun diversaj valoroj de Faza Angulo), Kuplitaj Cirkvitoj (kun indukta aŭ kapacita kuplado), Amortizaj Oscilatoroj, Potenco je Alternkurentaj Cirkvitoj, k.t.p.

PROCESADO PRI RADIO-PATENTOJ EN USONO. A. H. Morse.

Mallonga noto pri la nuna pozicio de leĝa antaŭeco en Usono rilate al patentoj traktantaj regeneradon.

LIBRO-RECENZOJ.

Recenzoj de Prof. G. W. O. Howe estas donitaj pri la jenaj germanaj verkoj :—

Transformatoraj Amplifikatoroj, de Müller kaj von Ardenne.

Poŝlibro de Senfadena Telegrafio kaj Telefonio, redakciita de Dro. F. Banneitz.

Termionaj Valvoj, de Forstmann kaj Schramm.

Correspondence.

Letters of interest to experimenters are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

Amplification of Small Currents.

To the Editor, E.W. & W.E.

SIR,—I am reluctant to trespass again upon your space after the prominence you were kind enough to give my letter in your November issue. Dr. Taylor, however, after giving the sufficient reason that he was unaware of what had gone before, goes on to dismiss my method, of which he can therefore have had no experience, as less satisfactory and so unworthy of mention.

The definition given in his article of a "Thermo relay," although I disagree with the term, fits my instrument as well as it does that of Moll and Burger. It becomes a question then as to whether the latter instrument is really an advance at all. I maintain that it is not.

It cannot be held that enclosure in a vacuum is an advance over previous knowledge. This obvious refinement was embodied in several of my early designs and is mentioned in my patents, besides being well known long before that. On the remaining point of small heat capacity, thermo-couples made by my methods have frequently been exhibited, possessing much smaller mass and heat capacity than any I have seen described by Moll and Burger.

Further, the wide choice of metals available and the ease with which many junctions can be arranged in series, with suitable mounting and enclosure, provide sufficient sensibility for most purposes without the necessity of a vacuum; thus avoiding sacrifice of what the original authors term "quickness."

W. H. WILSON.

The Performance of Valves in Parallel.

To the Editor, E.W. & W.E.

SIR,—Your issue for November contains an article by Mr. R. P. G. Denman on the performance of valves in parallel.

I venture to point out that the whole treatment is based on a fallacy, and that the results obtained are, therefore, incorrect.

The fallacy lies in the assumption that the valve itself is a source of E.M.F., an assumption which is convenient and legitimate in certain cases, but which is inadmissible in the present instance.

The actual fact is that the H.T. battery or generator is the only source of E.M.F., and the valves are merely variable resistances. The fall of potential across any valve at any particular instant is exactly the same as the fall of potential across every other valve, and the flow of current in the various valves depends simply on their resistances at the instant in question.

Let r_1, r_2, . . . denote the resistances at any instant of the various valves, and let i_1, i_2, . . . denote the currents flowing through them. Let r be the combined resistance and i the total current, then

$$\frac{1}{r} = \frac{1}{r_1} + \frac{1}{r_2} + \dots \frac{1}{rn} \text{ and } i_x/i = r/r_x$$

Taking the matter a step farther it may be assumed that r_1, r_2, . . . represent the mean resistances over a complete cycle, and that i_1, i_2, . . . are the mean currents. Subject to suitable definitions of mean resistances and mean currents the above equations would hold good when applied to mean values taken over a complete cycle.

It follows at once that the suggestion that the current in one valve can be 180 degrees out of phase with the currents in the other valves is impossible, and in fact the whole of the algebraical and numerical results in the paper are erroneous.

The correct values of the mean resistances r_1, r_2, . . . are easily determined in the case of an amplifier with a small input, for the resistances are the anode A.C. resistances of the valves. The problem in the case of an oscillator is a much more difficult one and the writer does not feel disposed to invite criticism by putting forward numerical estimates.

It is clear, however, that the variations in current between different valves working in parallel are much less than the figures given by Mr. Denman.

In large sets it is no doubt desirable that each individual valve should be operated under the conditions which will give minimum cost for a given output, but for receiving amplifiers and small transmitters the advantages to be gained by individual control would be more than counterbalanced by the disadvantages of extra complication.

K. E. EDGEWORTH.

Khartoum, Sudan.

To the Editor, E.W. & W.E.

SIR,—My article on "The Performance of Valves in Parallel" is not based on a fallacy, as announced by Col. Edgeworth in his letter.

The fact that the alternators depicted in Fig. 2 do not enjoy a physical existence in no way invalidates the assumption that the valves behave as such, in this as in other cases.

The assumption is a convenient one because it enables us to substitute for the rather awkward conception of a periodically varying resistance, the more usual idea of a fixed anode A.C. resistance to which an alternating E.M.F. is applied; but with proper treatment the two methods would inevitably lead to the same results. I say "with proper treatment" because Col. Edgeworth, having stated the equation

$$\frac{i_x}{i} = \frac{r}{r_x}$$

subsequently defines the quantities r_1, r_2 "in the case of an amplifier with small input" as the anode A.C. resistances of the valves. Having thus so far totally ignored a fundamental parameter of the triode, namely the mutual conductance, I am unable to see what "suitable definitions" Col. Edgeworth could assign to the "mean values" of the "mean currents" in his equation.

The statement that one current can be 180 degrees out of phase with the others is entirely correct, and if, after further consideration, Col. Edgeworth should require a second proof of this I can give it to him in a very simple form.

Since Col. Edgeworth has exposed no fallacy in my article, very little importance can be attached to his final statements, unsupported as they are by any kind of acceptable evidence. In my own work I came to no such positive conclusions. The present position is that the matter is being investigated experimentally by authorities on Modulation, while as regards Power Amplifiers it may be pointed out that the figures given as representing the variations of μ and r among low impedance valves were extremely conservative, for in actual practice these values cannot economically be held within closer limits than a maximum deviation of ± 25 per cent. from the nominal characteristics.

In one respect, at least, Col. Edgeworth's remarkable contribution to the subject of my article may be said to have borne good fruit, for it has led me to discover a genuine error in the work, and this I now hasten to correct.

In the discussion of Figs. 4 and 6 it was assumed that the slopes of the dynamic characteristics were constant for a given load, and would not be affected by the application of separate alternating grid voltages. But reference to the equations from which these slope conductances were derived will disclose the fact that the apparent load on each valve is partly determined by such values. The proper treatment is, as it happens, much more interesting and leads to very satisfactory results. It is briefly as follows :—

The dynamic characteristics of all parallel-connected valves should first be drawn in such a way that the excursions of grid as well as of anode potential are equal, while the algebraic sum of the current changes must be such as will give rise to the necessary change of anode potential. If now the load resistance is artificially increased until it approaches the critical value where one current reduces to zero, it will be seen that the dynamic characteristic for that valve gradually assumes a horizontal position. Subsequently its slope is reversed, showing the 180 degree phase shift already dealt with.

Now, let matters be so arranged that separate excursions are possible for the grid voltages, and we find that, merely by altering the relative values of these voltages, the slopes of the dynamic characteristics may be varied at will, the sole condition to be observed being that the product of the load resistance and the total changes of current shall be equal to the common change of anode potential.

Bearing this in mind, a brief consideration of the limiting conditions leads to a remarkably simple rule, strictly applicable only to cases where grid current is permissible, but apparently giving a sufficiently close approximation for most other purposes. This rule is as follows :—

For maximum output with ***a*** *given load, the alternating grid voltages to be applied should be such as will give rise to equal current changes in all parallel-connected valves.*

The adjustment is obviously one which can be effected with great simplicity, and it is particularly interesting to note that, provided the ratio μ/r is constant, any number of valves n may by this method be caused to yield the same output as a single valve of n-fold rating. Finally, since μ/r is the mutual conductance, a quantity which does remain reasonably constant in any given series of valves, I am inclined to think that the above result should prove to be of definite practical value in high-power work.

R. P. G. DENMAN.

Science Museum,
S.W.10.

The Theory of the Flat Projector.

To the Editor, E.W. & W.E.

SIR,—I want to clarify some points which arise from the answer which Professor Fleming gave in the November issue of *E.W. & W.E.* about my remarks on his article.

For instance, Professor Fleming finds in his article that the E.M.F. induced in the reflector wire is $\pi/2$ out of phase with the aerial current; but in his answer Professor Fleming states that this E.M.F. is in phase with the aerial current. Further, he finds in his answer that the flat projector produces, in the beam direction, with its aerials and reflector wires respectively, two fields which are $\pi/2$ out of phase, at the same place. This is in contradiction to the performance of a reflector system, which must give a wave in phase with the direct wave.

All these incompatibilities are due to the fact that the electromagnetic field's propagation, near the aerial wire, is not a simple one; it has neither an infinite velocity in the first quarter wavelength round the oscillator, nor the velocity of light near the aerial, with a starting phase, at the oscillator, coinciding with the aerial current phase.

The propagation of the electromagnetic field near an aerial and its effect on a reflector wire was studied experimentally by W. Tatarinoff in *Zeitschrift für Hochfrequenztechnik*, October, 1926, pp. 117-120. The results are interesting. The author considers these two wires, half a wave-length in length, one being the oscillator, the other the reflector. The reflector behaves as *a pure resistance*, and its induced current lags behind the aerial current by an angle—

$$\phi = \psi + 2\pi r/\lambda$$

where r is the distance between the aerial and reflector and ψ actually a function of r.

If it is supposed that the electromagnetic field, due to the aerial, has an infinite velocity in the first quarter wavelength round the aerial, and that the true radiation begins after this quarter wave-length, then—

$$\phi = \pi \quad r < \lambda/4$$

$$\phi = \frac{\pi}{2} + 2\pi\frac{r}{\lambda} \quad r > \lambda/4$$

If, on the other hand, it is supposed that near the aerial the propagation of the electromagnetic field has the velocity of light and that it starts at the oscillator in phase with the aerial current, then

$$\phi = 2\pi \frac{r}{\lambda} (\psi = 0)$$

(near the oscillator).

But, actually, Tatarinoff finds experimentally that the function W of r varies in the following way:—

r	0	$\lambda/4$	$\lambda/2$	$3\lambda/4$	λ
ψ	180°	156°	135°	120°	103°
ϕ—360°	—180°	—114°	—45°	+30°	+103°

If r is increased ψ tends to $\pi/2$.

He finds, from these experimental results, the following values for r, for which the aerial and reflector fields are in phase in the beam direction:

0.285λ 0.845λ 1.372λ 1.875λ 2.375λ, etc. . . .

Therefore, in a flat projector which uses tuned aerial and reflector wires, the spacing between the aerials and reflectors must be 0.285λ and not 0.25λ. But if the spacing is kept 0.25λ, the same result can be obtained by detuning the reflector wires.

N.W.I. TUDOR A. TANASESCU.

To the Editor, E.W. & W.E.

SIR,—With reference to the article by Dr. Fleming on the theory of the projector, and the criticism by Mr. Tanasescu, may I be allowed to join issue in support of the latter?

1. Dr. Fleming, in the first paragraph of his reply to Mr. Tanasescu, begs the question, for there is no suggestion that the fields due to aerial and reflector of a Franklin grid do not cancel out behind the system, and add in front. What is criticised is the method of getting the result; and the chief point at issue is the definite statement by Dr. Fleming that the current in the reflector wire is in phase (or antiphase, it does not matter much which) with the current in the aerial spaced one-quarter wavelength in front.

In other words, Dr. Fleming asks us to believe that the polar diagram of two tuned aerials quarter wavelength apart, fed from a *centrally* placed transmitter (or two receiving aerials feeding a central receiver) will be a cardioid; whereas we know most definitely that the diagram will be a figure of eight. We know also that to get a cardioid from such a system we must get a misphase of currents equivalent to the spacing (90°), and one way of doing this would be to move the location of the transmitter (or receiver) to a point coincident with one aerial, which brings us back to the case of an aerial and its reflector.

Dr. Fleming will probably suggest that this is not a fair commentary, as the example above is for two driven aerials whereas the case in point is for one aerial driving another. But, however the aerials are energised, the fact still remains that for the resulting diagram to have a shadow at the back and addition in front, the phase of currents in two tuned aerials spaced quarter wavelength apart must differ by that spacing—namely, 90°, and not 180° (or 0°).

Whether in practice a half-wave aerial and a half-wave reflector driven from it will give a perfect shadow is another matter, and it may be necessary to fake the length of the reflector to bring about the desired result.

2. Dr. Fleming dismisses Mr. Tanasescu's remarks somewhat summarily by observing that he has forgotten that true radiation does not begin until quarter wavelength away. But this is most unconvincing, for if it is so for radiation from an aerial, it will be so for radiation from a reflector, and thus we are forced back to the real point at issue, the phase of currents in aerial and reflector.

3. I do not understand how a half-wave wire can be said to have a low resistance, and to be wholly inductive. Surely it has a very high resistance (radiation), and it will act as a non-inductive load to any applied E.M.F. of its natural frequency.

4. In conclusion, I would like to point out that Mr. Tanasescu makes a small mistake in stating that the spacing distance of adjacent aerials is $\lambda/4$ apart. The theoretical maximum spacing is $\lambda/2$ and, in practice, the spacing is a little less than this.

London, S.W.7. M. C. M. BHISEK.

To the Editor, E.W. & W.E.

SIR.—The article in *E.W. & W.E.* by Dr. J. A. Fleming on the Theory of the Reflector in your July issue, and subsequent letter by Mr. Tanasescu and reply by Dr. Fleming, are very interesting; but neither Mr. Tanasescu's letter nor Dr. Fleming's reply seem to clear the point completely.

Mr. Tanasescu apparently seeks to point out that as the reflector wire is considered not greater than ¼ wavelength behind the active aerial wire it is still in the direct magnetic field of the latter. Therefore the phase of the E.M.F. induced into it with respect to the current in the active aerial producing that magnetic field is 90 degrees in advance. This is analogous to the E.M.F. induced into the secondary winding of a transformer by a magnetising current in the primary.

The current in the reflector wire, if it is in resonance, will be in phase with the induced E.M.F., and will therefore be leading by 90 degrees on the current in the active aerial. The field due to the reflector wire current will therefore be leading by 90 degrees on the field due to the active aerial.

As the reflector wire is 90 degrees behind the active aerial in space, the two fields will add directly in the direction of right angles to the plane of the aerial in front of the aerial system, and will subtract directly in a direction at right angles to the plane of the aerial system behind.

If, as stated in Dr. Fleming's letter, the reflector is removed to a distance of $\frac{3}{4}\lambda$ instead of $\frac{1}{4}\lambda$, we have an additional 360 degrees phase angle coming in, due to the additional time taken for the original wave to reach the reflector wire, *i.e.*,

$$\tfrac{3}{4}\lambda - \tfrac{1}{4}\lambda = \tfrac{1}{2} = 180 \text{ degrees.}$$

and a further 180 degrees change for the reflected wave to come back.

B.B.C., London. H. L. KIRKE.

Some Recent Patents.

The following abstracts are prepared, with the permission of the Controller of H.M. Stationery Office, from Specifications obtainable at the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1/- each

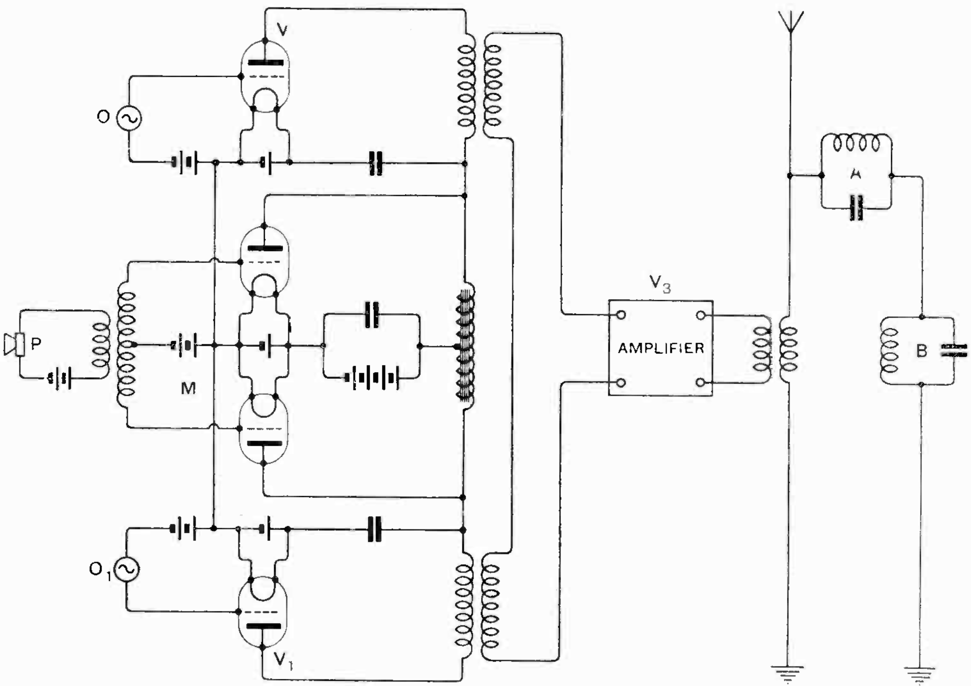
PREVENTING FADING.

(*Application date, 17th June, 1926. No. 277426.*)

In the case of short-wave radiation of the order of 4,500,000 cycles it has been found that a comparatively small difference in frequency amounting, say, to ten or fifteen thousand cycles, exercises a marked effect upon the incidence of fading. For instance, the periods of maximum and minimum intensity of a signal imposed upon carrier waves differing in frequency by the stated amount do not coincide. Any fluctuations which do occur appear to take place quite independently, and without having any perceptible relation to each other. It is, therefore, probable that the combined effect of two such signals at any particular station will always ensure a satisfactory degree of signal strength.

In the short-wave transmitting system shown in the figure, two independent H.F. sources O, O_1 are adjusted to have a frequency-difference of a few thousand cycles. After independent amplification in the tubes V, V_1, and simultaneous modulation by a push-pull combination M from a common microphone P, in which the signal components are impressed upon the carrier wave in phase opposition, the combined output is fed through a power amplifier V_3 to the radiating aerial. Impedance elements A, B, tuned to the two carrier waves, are inserted in the aerial so that the latter oscillates with two degrees of freedom, radiating both carrier waves equally. At the receiving end both signals are detected separately and, after passing through a phase-adjuster, are fed in parallel to the same pair of telephones.

Patent issued to Standard Telephones and Cables, Ltd.

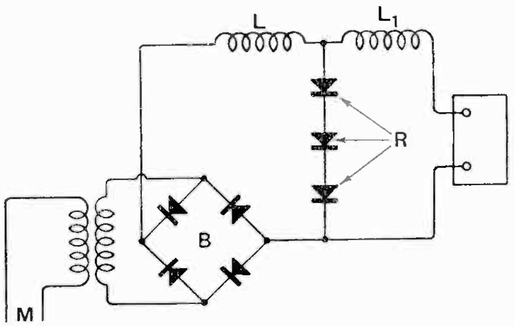


SMOOTHING CIRCUITS.

(*Convention date (U.S.A.), 7th October, 1925. No. 259,537.*)

A full-wave rectifying bridge B, comprising four solid unidirectional elements, arranged as shown, is fed with alternating current from the mains M and passes the rectified pulsations into a smoothing circuit. The latter comprises reactances L, L_1 shunted by a bridge R consisting of galena or crystalline selenium elements, or of metallic elements similar to those used in the rectifier B.

The bridge R has a falling resistance characteristic, so that as the voltage applied to the inductance L rises, owing to the fluctuating output from the rectifier, the resistance of R falls. Similarly as the voltage falls the resistance of the shunt increases.



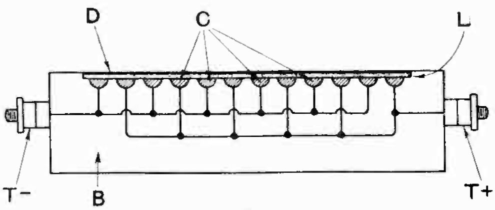
This serves to smooth-out pulsations with a minimum waste of power.

Patent issued to Westinghouse Brake and Saxby Signal Co.

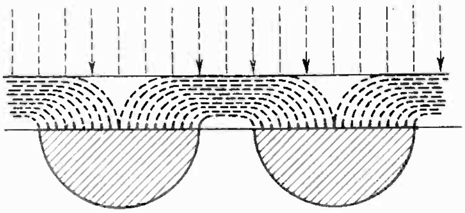
MICROPHONES.

(*Application date*, 8*th July*, 1926. *No.* 278,443.)

A series of carbon-rod electrodes C are set flush with the surface of a wooden holder B, and are connected alternately to the positive and negative terminals $T+$, $T-$ of the instrument. A thin layer L of carbon powder is sprinkled over the rods, and the whole is then closed in by a diaphragm D. The result is that current changes resulting from the impact of a sound-wave take place in substantially the direction of travel of the wave, as



A



B

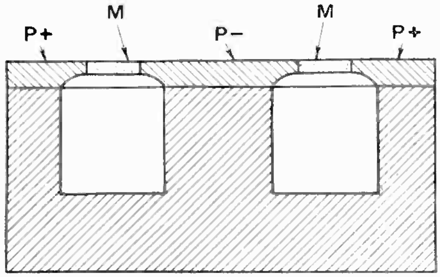
shown in Fig. B, where the dotted line arrows represent the received sound and the thicker dotted lines the current flow across the electrodes. In the ordinary type of microphone with transverse electrodes, the current variations take place at right angles to the direction of the sound-wave.

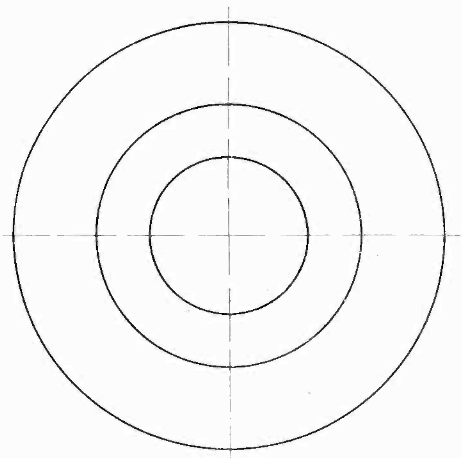
Patent issued to H. J. Round.

MICROPHONES.

(*Application date*, 23*rd July*, 1926. *No.* 278,470.)

In this instance the sensitive material consists of a conducting or non-conducting powder arranged to form a thin layer M or dielectric between the opposite poles $P+$ and $P-$ of an electrostatic circuit. These are connected in series with a high resistance (not shown) across the terminals of a high-tension battery. Under the influence of the applied voltage, the powder will cohere in position, but thin upper and lower diaphragms of rubber may be provided to retain it in place when the battery is disconnected.





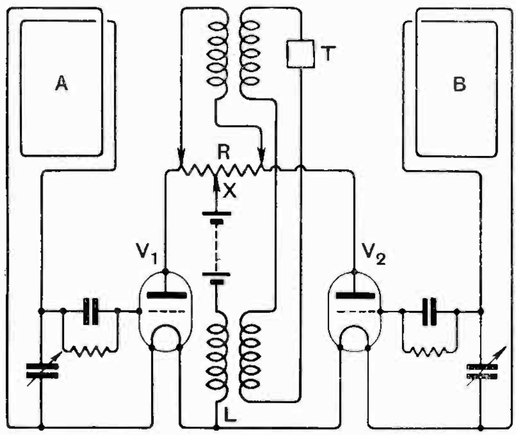
The impact of a sound-wave will cause the powder particles to vibrate in a direction at right angles to the electrostatic field, so that there is practically no constraint to their motion in this direction. The system is, therefore, highly aperiodic. Vibratory motion, due to the sound-waves, sets up capacity changes across the poles $P+$, $P-$ and corresponding potential fluctuations across the series high-resistance. These may be applied directly to a suitable amplifier or may be dealt with in any suitable known manner.

Patent issued to A. G. D. West and the British Broadcasting Co.

BALANCING OUT INTERFERENCE.

(*Application date, 13th August*, 1926. *No.* 278,479.)

Relates to a method of eliminating interference, due either to atmospherics or undesired tuned signals, which depends upon the use of two or more different carrier-waves for transmitting the desired signal, and a corresponding number of tuned



circuits at the receiving end. In the case of tuned interference, in particular, the receiving circuits can be so arranged that only one is affected by the unwanted signal. After rectification the pure-signal low-frequency component is opposed to the mixed-signal component, so that the resultant current represents the interfering signal only.

By combining the pure and mixed components additively, instead of in opposition, the resultant current will contain a double-strength pure signal component together with a component of interference. By opposing the result of the first and second operation, the final output will be a double-strength pure signal free from any trace of interference.

As shown in the figure, the two different carriers are received independently upon the aerials *A*, *B* and, after suitable amplification, the outputs from the detectors V_1, V_2 are opposed across the reactance *R*, and are added across the reactance *L*. The two effects are then combined in the desired sense in a third circuit containing the receiver *T*. By adjusting the tapping *X*, it is possible to find a point at which disturbances due to atmospherics as well as tuned interference can be eliminated.

Patent issued to J. Robinson.

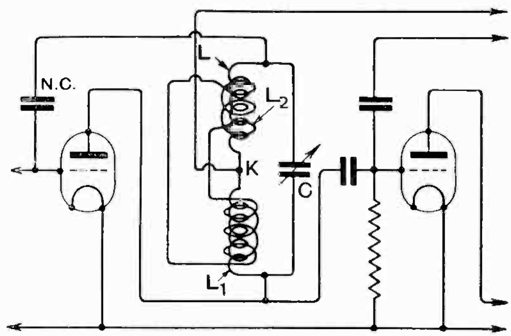
PARASITIC H.F. OSCILLATIONS.

(*Application date, 17th July*, 1926. *No.* 278,812.)

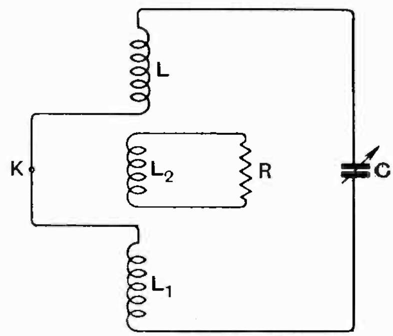
A standard method of neutralising the inter-electrode capacity of an amplifying-valve consists in connecting one end of the tuned output circuit to the anode and the other through a neutralising-condenser to the grid, the middle point of the output coil being joined to a point of steady high-frequency potential such as the H.T. battery. It is found that such an arrangement is liable to set up powerful parasitic oscillations having a frequency much higher than that of the natural tuning of the output circuit as a whole. These disturbances are due to the inherent self-resonance of the parts of the anode inductance lying on each side of the central tapping point.

It can be shown, however, that when a parasitic oscillation is built up in the half coil *L*, the main tuning condenser *C* forms a tight capacity-coupling with the other half L_1 of the same coil. The parasitic currents in the two halves of the inductance will therefore be in phase at the outer terminals of the coil. In other words the currents in *L* and L_1 will, at any given moment, be both flowing towards or away from the centre point *K*. On the other hand, the current due to the received signal frequency will flow continuously from one end to the other of the coil as a whole.

Advantage is taken of this difference in phase between the parasitic and signal currents to provide means for damping-out the former. With this object in view an additional coil L_2 is closely coupled to the main inductance, as shown either in Figs. A or B, and the direction of the windings is so chosen that the voltages induced in this



(A)



(B)

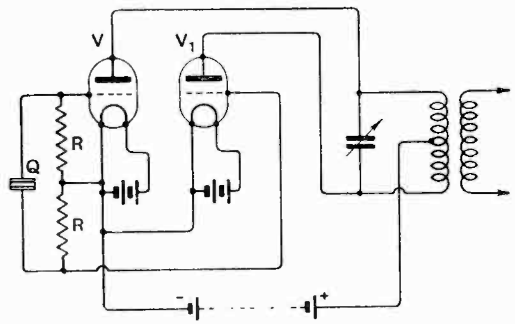
winding by the signal currents are mutually opposed, so that there is no resultant current. Voltages due to the parasitic currents are, however, added together, and the resultant current is dissipated in the closed circuit formed by the coil L_2 and a series resistance *R*. The additional winding, though serving to eliminate parasitic disturbances, is stated to produce no appreciable damping effect upon the desired signal.

Patent issued to N. P. Hinton, H. G. Glover, and the Metropolitan Vickers Co.

PIEZO-CONTROLLED OSCILLATORS.

(*Convention date* (*U.S.A.*), *1st September*, 1926. *No.* 277,008.)

In order to avoid disturbance in the operation of a quartz oscillator *Q*, due to the shunt capacity



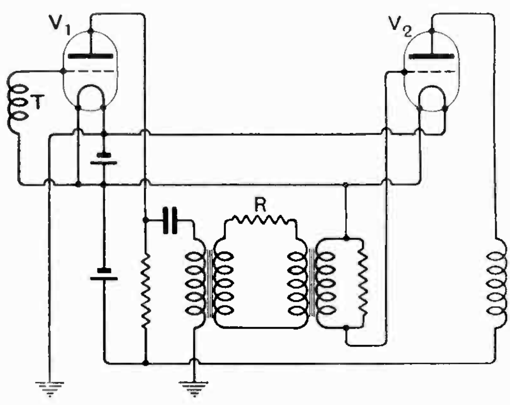
of the valve electrodes, two valves *V*, V_1 are arranged in series as shown with the crystal connected across the grids, in shunt with suitable impedances *R*. The cathode and grid capacity of both valves *V* and V_1 are now interposed in series across the crystal so that the total shunt capacity is reduced to less than one-half that of the ordinary single-valve arrangement.

Patent issued to British Thomson Houston Co.

PREVENTING L.F. DISTORTION.

(*Convention date* (*France*), *22nd July*, 1925. *No.* 255,875.)

Relates to means for providing an automatic



gain-control regulation in the low-frequency amplifiers interposed between the studio microphone and the power modulator. Such control is usually carried out by an operator or supervisor who, at best, can only remedy any defect in reproduction after it has first made its appearance. In the arrangement shown in the Figure, reliance is placed upon a resistance element *R* inserted in the coupling transformer between the first and second L.F. stages V_1, V_2, the former being fed from an input coil T_1 coupled to the microphone.

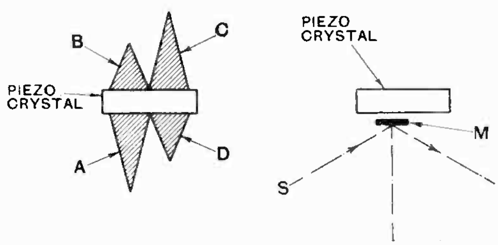
The element *R* is of the type in which the ohmic resistance increases with intensity of current. In actual practice the metal filament of an incandescent lamp will serve the purpose. The elasticity of the arrangement is such that the amplifying power of the whole apparatus may be ten times greater for small amplitudes than for large. Owing to the calorific inertia of the element *R*, the resistance-variations are not instantaneous, so that wave deformation is avoided. At the same time the regulation is far more prompt than can be ensured by any form of manual control.

Patent issued to Société Française Radio Electrique.

UTILIZING PIEZO-ELECTRIC VIBRATIONS.

(*Convention date* (*Germany*), *25th March*, 1926. *No.* 268,367.)

The invention consists broadly in a method of utilising piezo oscillations to give a visual indication



(A) (B)

of the existence and character of high-frequency currents.

It has been found that when a quartz crystal is set into mechanical oscillation at its natural or inherent frequency, powerful air currents are set up at certain points along the surface of the crystal. This effect can be demonstrated by strewing a light powder, such as lycopodium, over the oscillating crystal, when it will be observed to be blown away at parts corresponding to the shaded areas *A*, *B*, *C*, *D* of Fig. A. For example, when the crystal is impulsed by a high-frequency oscillating current, the resulting air-currents can be directed against a fluid jet or siphon recorder to give a corresponding marking or indication on a moving strip of paper. Or, as shown in Fig. B, a small mirror *M* is pivoted close to the crystal, and is oscillated by the air-currents to deflect a light-ray coming from a source *S* and focused upon a sensitised film.

Patent issued to the Telefunken Co.